



## Quantifying and Mapping of Major, Secondary and Micronutrient Status of Tomato Growing Soils in Kolar District, Karnataka Using GIS and GPS Approach

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors PNSP and CTS designed the study, performed the statistical analysis, wrote the protocol. Author PNSP wrote the first draft of the manuscript. Authors PNSP and CTS managed the analyses of the study. Authors VR and AS managed the literature searches. All authors read and approved the final manuscript.*

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### **ABSTRACT**

Assessment of land use-induced changes in soil properties is essential for addressing issues of spatial variability in soil fertility and sustainable land productivity. In view of this, a study was conducted to assess the impact of spatial variability on physicochemical properties, macro and micro nutrient status of 75 farmers fields of tomato growing areas of Kolar district, Karnataka. Arc Map with spatial analyst function of Arc GIS software was used to prepare soil fertility maps, which would act as an important tool for soil as well as nutrient management for sustainable crop production by using Global Positioning System coordinates. The results revealed that the soils under investigation were acidic to alkaline in reaction (pH 4.41 to 8.13), mostly non saline and low to high in organic carbon status (0.53 to 1.95%). Available nitrogen, phosphorus, potassium and sulphur content varied from 150.53-348.10, 6.4 - 111.44, 147.18 - 916.61 and 12.29 - 103.8 kg ha<sup>-1</sup>. Exchangeable Ca, Mg are in the range of 2.5 – 14.2 and 1.2 – 6.6 C mol (p+) kg. The GIS-aided

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thematic maps with respect to available zinc, 6.67 (low), 21.33 (medium) and 72 (high) per cent samples were categorized, based on the existing critical limits. All the studied samples i.e., 100 per cent were high in copper content, 65.33, 30.67 and 4 per cent samples of Mn, 25.33, 32 and 42.67 per cent samples of Fe, were categorized as low, medium and high in nutrient status respectively. With respect to available boron 16.67 per cent was under low, 38.09 per cent was under medium and 45.24 per cent was under high nutrient status. The nutrient index (NI) of tomato growing areas of Kolar district revealed that N (1.19), manganese (1.39) and iron (1.29) were categorized as low, available boron (2.17) as medium and P (2.65), K (2.71), S (2.65) zinc (2.75), copper (3.0) as high nutrient index category.

*Keywords: Fertility status; GIS; GPS; Arc GIS; nutrient index; major; secondary and micronutrients.*

## 1. INTRODUCTION

Soil testing is often used to determine the nutrient status of crops and it also helps in develop the cost effective nutrient management practices to recommend to the farmers. After achieving food security it is being increasingly felt that India needs to achieve nutritional security for betterment of its population. In achieving nutritional security fruits and vegetables play an important role [1]. To fulfill the needs of nutritional requirements, tremendous effort will have to be done to increase the production of fruits and vegetables through a rational and balanced use of production inputs, specially with the fertilizers. Macronutrients (N, P, K, S) and micronutrients (Zn, Fe, Cu, Mn and B) are important soil elements that control its fertility. Soil fertility is one of the important factors controlling yields of the crops and soil characterization in relation to evaluation of soil fertility of an area or region which is an important aspect in context of sustainable production.

Soil fertility plays an important role in sustaining crop productivity of an area, particularly in situations where input of nutrients application differs and the information on the nutritional status can go a long way to develop economically viable alternatives for management of deficient nutrients in the soil. The modern geospatial technologies such as Remote Sensing (RS), Geographical Information System (GIS), Global Positioning System (GPS) and Information Technology (IT) offer immense potential for soil and water resources development and management. Collection of soil samples by using Global Positioning System (GPS) is very important for preparing the GPS and GIS based thematic soil fertility maps [2]. The improper nutrient management has, led to emergence of multinutrient deficiencies in the Indian soils [3]. Composite soil samples are collected by GPS instrument to know latitude and

longitude of that particular location. It has got great significance in agriculture for future monitoring of soil nutrient status of different locations / villages. However detailed characterization and generation of soil fertility maps for the tomato growing areas are predominant and agriculturally significant Kolar district of Karnataka is virtually lacking and hence present investigation was carried out.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The survey was carried out in kolar district covering four taluks viz., Kolar, Maluru, Bangarupeta and Srinivasapura. The district is situated in Eastern dry Zone (Zone 5) of Karnataka between N 12 45' 54" to 13 35' 47"N latitude and 77°57' 29 to 78 35 18 East longitude and at an elevation of 700 m above mean sea level. Total rainfall received from July to November in 2016 is 267.1 mm with 30 rainy days against the normal rainfall of 434.6 mm. Mean maximum temperature varies from 29.7°C to 30.6°C and minimum temperature varies from 15.6°C to 19.9°C respectively during 2016.

### 2.2 Soil Analysis

The soils were collected at a depth of 0-15 cm using soil auger. The Geo- coordinates at each sampling site were recorded using hand held global positioning system (Oregon 550, Garmin Ltd.). The collected surface soil samples were air dried in shade, ground and screened through 2 mm sieve and used for laboratory analysis. The sieved samples were further passed through 0.5 mm sieve for organic carbon estimation. After processing, the representative soil samples were stored in a labelled bag for analysis. The soil samples were analyzed for pH (1:2.5), EC (1:2.5), organic carbon [4], available nitrogen

(alkaline permanganate method) [5], available phosphorus [6], available potassium (neutral normal ammonium acetate method), and available (0.15%  $\text{CaCl}_2$ ) sulphur [7]. The available zinc (Zn), iron (Fe), copper (Cu) and manganese (Mn) in soil samples were estimated by atomic absorption spectrophotometer (AA-230D) following DTPA extraction method [8] and for hot water soluble boron (HWS-B) method [9] is used and details of soil test rating are presented in Table 1. Nutrients index (NI) was enumerated for surface soil samples as described by Motsara et al. [10] as  $[(1 \times \text{no. of samples in low categories}) + (2 \times \text{no. of samples in medium categories}) + (3 \times \text{no. of samples in high categories})] / \text{Total number of samples}$ . Further, on the basis of NI, soil fertility level in respect of different nutrients was categorized as low (<1.67), medium (1.67-2.33), or high (>2.33).

### 2.3 Geostatistical Analysis

Collection of soil samples by using Global Positioning System (GPS) is very important for preparing the GPS and GIS based thematic soil fertility maps [2]. The Kolar district soil map (1 : 2,50,000) published by NBSS and LUP was utilized for selection of sample sites. The Kolar district map was vectorised by using Raster to Vector software (ERDAS software), and then it was exported into ARC GIS Software. The thematic maps on distribution of the micro and macronutrients has been generated by geostatistical software (ARC GIS 10.4) was used to analyze the spatial attributes of the analytical data of respective parameters such as pH, EC, O.C, available nutrient status for major,

secondary and micro nutrients with the coordinates (GPS points while sampling) using ordinary kriging method [11] in order to define the semivariograms. From semivariograms, differences in Nugget/Sill ratio and range were examined for fertility status of the studied soils. The semivariogram, the main component of kriging, is an effective tool for evaluating spatial variability. The variogram provides a clear description of the spatial structure of variables and provides some insight into possible processes affecting data distribution [12]. The best fit model (spherical) was applied to kriging interpolation. Ordinary kriging was chosen to create the spatial distribution maps of fertility status. Maps for soil sampling sites were generated based on x, y coordinates recorded in the field using Arc-GIS. The fertility maps showing nutrient status was generated using the analytical data of individual nutrient. The point data collected using GPS was then transformed into polygon data using kriging interpolation technique in Arc GIS software. Maps showing the spatial distribution of deficient and sufficient area for individual nutrients were also generated and digitized using the same GIS package.

### 2.4 Statistical Analysis

Representative values (mean and median) of soil physical and chemical parameters were calculated with the help of descriptive statistics. The simple correlation analysis of data was computed in relation to available major and micronutrient content with different physico-chemical properties of the experimental soils [13].

**Table 1. Soil test rating of primary, secondary and cationic micronutrients**

Nutrients	Units	Soil testing rating		
		Low	Medium	High
Organic Carbon	percent	0.5	0.5-0.75	>0.75
Available N	kg ha <sup>-1</sup>	<280	280-560	>560
Available P <sub>2</sub> O <sub>5</sub>		< 23	23-56	> 56
Available K <sub>2</sub> O		< 140	140-330	> 330
Available S		< 22.4	22.4 - 44.8	> 44.8
Exchangeable Ca	m.eq 100 g <sup>-1</sup>	< 1.5		> 1.5
Exchangeable Mg		< 1		> 1
DTPA-extractable Fe	mg kg <sup>-1</sup>	<5.5	5.5-9.5	>9.5
DTPA-extractable Cu		<0.4	0.4-0.8	>0.8
DTPA-extractable Mn		<4.0	4.0-8.0	>8.0
DTPA-extractable Zn		<0.6	0.6-1.2	>1.2
Available boron		< 0.5	0.5- 1	> 1

### 3. RESULTS AND DISCUSSION

#### 3.1 Physico - Chemical Properties of Studied Soils

Soil texture of Kolar district samples ranges from sandy loam to sandy clay loam. The sand per cent ranges from 67-79.12 with a mean of 75.02 and a median of 75.12 per cent with a standard deviation 2.59. The silt per cent ranges from 0.36-12.48 with a mean of 5.05 and median of 3.36 per cent with standard deviation of 3.31 whereas clay per cent ranges from 14-24.52 with a mean of 19.93 and median of 20.52 per cent of a standard deviation 2.55. Out of 75 samples 41.33 per cent samples are sandy loam and 58.67 samples are sandy clay loam. The details statistics of studied soils are presented in Table 2.

The pH of soil samples analyzed in the district ranged from 4.41 - 8.13 with a mean and median of 6.91 and 6.92 respectively with 0.58 as standard deviation. Thus, the soils of the district was categorized into acidic, neutral and alkaline. It was found that about 20 per cent of district soils were acidic in nature, 56 per cent were found to be neutral and 24 percent soils are alkaline in nature. The lowest values of pH under the cultivated land may be due to the depletion of basic cations in crop harvest and drainage to streams in runoff generated from accelerated erosions as reported by Foth and Ellis [14]. This may also because of formation of

these soils from acidic parent material rich in basic cations as reported by Mali and Raut [15].

The electrical conductivity of Kolar district observed to be between 0.06 and 1.67 dS m<sup>-1</sup> with a mean and median of 0.42 dS m<sup>-1</sup> with standard deviation of 0.24. It was observed that only 1.34 % are saline soils. The remaining soils were found to be register electrical conductivity less than critical value. Thus, it is inferred that the soils of cultivated fields of Kolar district do not suffer from any salt problem as of now. The district has neither major rivers of perennial nature nor any irrigation canals to influence the soluble salt content of the soils in general. The normal EC may be ascribed to leaching of salts to lower horizons due the light textured nature of the soils.

The organic carbon content was found to be 0.53 to 1.95 per cent. The mean and median of organic carbon content in the studied soils was 0.98 and 0.98 per cent, respectively, with standard deviation of 0.42. Among studied soil samples of the district, 16 % were found to be low in organic carbon, 17.33 % were medium whereas most of the soils *i.e.*, 66.67 % were found to be high in organic matter content. The low organic carbon in the soils of Kolar district may be due to low input of organics and also rapid rate of decomposition because of high soil temperature prevailing in the district. The high content of organic carbon reported in the studied area might be due to addition of organic matter

**Table 2. Descriptive statistics of analytical results of soils in tomato growing areas of Kolar district**

S. No	Parameter	Units	Max.	Min.	Mean	Media n	Standard deviation
1	pH		8.13	4.41	6.91	6.92	0.58
2	E.C	dS m <sup>-1</sup>	1.67	0.06	0.42	0.24	0.36
3	O.C	%	1.95	0.23	0.98	0.98	0.42
4	Sand		79.12	67	75.02	75.12	2.59
5	Silt		12.48	0.36	5.05	3.36	3.31
6	Clay		24.52	14	19.93	20.52	2.55
7	Available Nitrogen	kg ha <sup>-1</sup>	348.1	150.53	250.17	257.15	35.36
8	Available Phosphorus		111.44	6.4	62.93	64.52	24.15
9	Available Potassium		916.61	149.18	434.11	431.42	155.16
10	Available Sulphur		103.80	12.29	57.49	56	22.81
11	Exchangeable Calcium	c mol (p <sup>+</sup> )	14.2	2.5	7.53	8.1	2.25
12	Exchangeable Magnesium	kg <sup>-1</sup>	6.6	1.2	3.99	4	1.27
13	Available Zinc	mg kg <sup>-1</sup>	6.98	0.25	2.5	1.91	1.66
14	Available Manganese		21.72	0.66	3.94	3.22	3.32
15	Available Copper		2.35	0.77	1.29	1.25	0.36
16	Available Iron		15.67	0.9	4.84	4.27	2.57
17	Available Boron		2.92	0.28	1.1	0.92	0.75

and its subsequent decomposition. High temperature and good aeration in the soil increased the rate of oxidation of organic matter resulting reduction of organic carbon content. The high temperature prevailing in the area was responsible for the rapid burning of organic matter, thus resulting in medium organic carbon content of these soils. These results are in confirmatory with results reported by Sathish et al. [16] and Prasad et al. [17].

### 3.2 Major and Secondary Nutrient Status

The available nitrogen content ranged from 150.53 to 348.10 kg ha<sup>-1</sup> with a mean and median of 250.17 and 257.15 kg ha<sup>-1</sup>, respectively with standard deviation of 35.36. The soils contained low to medium nitrogen content in the soils. The low available nitrogen in most of the soils might be due to the higher temperature in semi arid climate of Kolar as a result more volatilization which resulted in low status of available nitrogen. Similar results were also reported by Rajeshwar et al. [18] in the soils of Krishna district, Andhra Pradesh and Kumar et al. [19] in Dumka and Lachinpur series of Jharkhand.

The available phosphorus content ranged from 6.4 to 111.44 kg ha<sup>-1</sup> with a mean and median of 62.93 and 64.52 kg ha<sup>-1</sup>, respectively and standard deviation of 24.15. The soils contained low to high phosphorus content in the soils. Phosphorus is present in soil as solid phase with varying degree of solubility. When water soluble P is added to the soil, it is converted very quickly to insoluble solid phase by reacting with soil constituents. These reactions affect the availability of P and as a result of these reactions, a very small amount of total P is present in soil solution at any time reflected by soil testing. High and continuous application of phosphatic fertilizers might have resulted in occurrence of high phosphorus soils in the district. Such build up in available phosphorus was also noticed in the soils of Amritsar district of Punjab, Haveri district of Karnataka and Coimbatore of Tamil Nadu during fertility mapping by Sharma et al. [20] and Padmavathi et al. [21], respectively.

The available potassium ranges from 149.18 to 916.61 kg ha<sup>-1</sup> with mean and median of 434.11 and 431.42 kg ha<sup>-1</sup>, respectively with a standard deviation of 155.16. The potassium status in the studied area ranges from low to high. These results confirmed the finding as reported by Jatav [22] in the soils of Inceptisols group of Baloda

block of Janjgir-Champa district of Chhattisgarh and Shukla [23] in the Inceptisols, Alfisols and Vertisols orders of Pamgarh block in Janjgir-Champa district (C.G.). Adequate available K in these soils may be attributed to the prevalence of potassium-rich minerals like Illite and Feldspars [20] and also the variation in available potassium across the soils of different districts was noticed by several workers [24,20] and was attributed to variation in mineralogical compositions.

The available sulphur ranges from 12.29 to 103.80 kg ha<sup>-1</sup> with mean and median of 57.49 and 56 kg ha<sup>-1</sup>, respectively with a standard deviation of 22.81. The sulphur content in the studied areas ranges from low to high. The exchangeable calcium ranges from 2.5 to 14.2 c mol (p<sup>+</sup>) kg<sup>-1</sup> with mean and median of 7.53 and 8.1 c mol (p<sup>+</sup>) kg<sup>-1</sup> soil with a standard deviation of 2.25. The calcium in the studied area was recorded sufficient. The similar trend were also recorded by Nayak et al. [25] in swell and shrink soils of Vertisol order in Vidarbha region. The exchangeable magnesium ranges from 1.2 to 6.6 with mean and median of 3.99 and 4 c mol (p<sup>+</sup>) kg<sup>-1</sup> soil with a standard deviation of 1.27. The magnesium in the studied area was recorded sufficient. The similar results were observed by Nayak et al. [25] in swell and shrink soils of Vertisol order in Vidarbha region. All the soils were in the sufficiency range of Mg may be due to its genesis in the semiarid area.

### 3.3 Availability of Micro Nutrients

The DTPA extractable Zn, Fe, Mn, Cu, and hot water extractable boron were analysed and Zn content in soils of Kolar district ranged from 0.25 to 6.98 mg kg<sup>-1</sup> with mean and median 2.5 and 1.91 mg kg<sup>-1</sup>, respectively with standard deviation of 1.66. The studied soils of the district were low to high in zinc category. The results are in conformity with the finding of Shukla [23] in soils of Pamgarh block in Janjgir-Champa district (C.G.). Similar findings were also reported by Prasad et al. [17] in tomato growing soils of Chikkaballapura district of Karnataka.

The Fe content ranges from 0.9 to 15.67 mg kg<sup>-1</sup> with mean and median of 4.84 and 4.27 mg kg<sup>-1</sup>, respectively with standard deviation of 2.57. The studied soils of the district were low to high iron category. Available Fe content in soils of Kolar might be due to its topography and amount of iron required by crops is being released by iron bearing minerals. Similar trend of Fe was reported by Prasad et al. [17] in soils of Chikkaballapura district of Karnataka.

The Mn status of district ranged from 0.66 to 21.72 mg kg<sup>-1</sup>, respectively with mean and median of 3.94 and 3.22 mg kg<sup>-1</sup> with standard deviation of 3.32. The Mn content in the studied soils were recorded as low to high in nutrient status. The sufficiency of available Mn might be due to high organic matter content under optimum soil reaction. Similar observations were also reported by [26] in soils of Vidarbha region.

The Cu status ranged from 0.77 to 2.35 mg kg<sup>-1</sup> with mean and median 1.29 and 1.25 mg kg<sup>-1</sup>, respectively with standard deviation of 0.36. The studied soils of the district were low to high in copper status. The data indicated the sufficiency in Cu status of soil. It might be due to interactive effect of soil properties like pH, EC and OC which have managing role in the availability of Cu. Majority of the soil samples recorded high level of available Cu content with a model class of >0.4 mg kg<sup>-1</sup> DTPA-extractable copper.

The boron status of district ranged from 0.28 to 2.92 mg kg<sup>-1</sup> with mean and median of 1.1 and 0.92 mg kg<sup>-1</sup> with standard deviation of 0.75. The studied soils of the district were low to high in boron status. Availability of B might have increased due to increased soil organic matter. The results confirmed the findings, as reported by Kumar and Babel [27].

### 3.4 Gis Aided Mapping of Soil Characteristics of Kolar District

Soil characteristics data obtained for different soil mapping units were mapped using Arc GIS 10.4. software. The soil maps for pH, EC, organic carbon, major, secondary and micro nutrients viz., N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B were prepared and presented in Fig. 1, Fig. 2 and Fig. 3 and percent distribution of soil parameters are presented in Table 3. The category in which nutrients were present in Kolar district were shown in legend. As per categorization of soil chemical characteristics and availability of nutrients, the status covered under each category shown by different colour legends.

The pH range in the district is divided into 5 categories for mapping. First category is strongly acidic (5-5.5), followed by moderately acidic (5.5-6.0), slightly acidic (6.0-6.5), neutral (6.5-7.3) and slightly alkaline (7.3-7.8). Overall it was found that about 20 per cent of district soils were acidic in nature, 56 per cent were found to be neutral and 24 per cent soils were alkaline in nature. The electrical conductivity of soil is a measure of salt content. Soils having EC less than 0.8 dS m-

1 are denoted as non saline. Out of surveyed samples 81.33 per cent are normal and remaining are medium in salt content, indicated non saline soils. Similar findings were made by Mishra et al. [2].

Sixteen per cent samples are low in available carbon, 17.33 per cent in medium and 66.67 per cent under high organic carbon content. The available nitrogen content in Kolar district falls under two categories only *i.e.*, low and medium. The percent distribution of available N was 81.33 per cent was under low and 18.67 per cent was medium. There is only 6.67 per cent samples are low in available P<sub>2</sub>O<sub>5</sub>, where as 13.33 per cent as medium and 80 per cent samples are high in available P<sub>2</sub>O<sub>5</sub>. Thus, there is an indication of build up of phosphorus in the soils of Kolar under intensively cultivated tomato growing soils. Only 29.33 per cent samples are medium and remaining 70.67 per cent are high in K status. These results are in conformity with the findings of Mishra et al. [2] and Mandal et al. [28].

The studied soils are 100 per cent sufficient in calcium and magnesium. Out of 75 samples, 72 per cent samples are high in sulphur, 21.33 per cent samples are medium and 6.67 per cent samples are low in available sulphur. Out of 75 samples collected from various soil mapping units 6.67, 21.33 and 72 per cent were categorized as low, medium and high zinc status respectively. All the studied samples *i.e.*, 100 percent are high in copper content. Out of studied samples 65.33 per cent samples were in low, 30.67 per cent samples in medium and 4 per cent samples in high Mn content. Out of studied soils 25.33 per cent soils were low, 32 percent soils were medium and 42.67 samples high in available Fe status respectively. Among them 16.67 per cent was under low, 38.09 per cent was under medium and 45.24 per cent soils were under high category.

### 3.5 Nutrient Index of the Studied Soils

Considering the concept of soil nutrient index the soils of the studied area were grouped into three categories as low, medium and high index values for studied area and details are presented in Table 4. The nutrient index (NI) of tomato growing areas of Kolar district reveals that available nitrogen (1.19), manganese (1.39) and iron (1.29) were categorized as low, available boron (2.17) as medium and organic carbon (2.51), available phosphorus (2.65), potassium (2.71), sulphur (2.65), zinc (2.75), copper (3.0), exchangeable calcium (3.0), magnesium (3.0)

was under high nutrient index category. For macronutrients these results are in conformity with the findings of Verma et al. [29] for soils of Punjab. For micronutrients the results are in conformity with the findings of Kumar et al. [30] and Prasad et al. [17] at Jhabua district of

Madhya Pradesh and Chikkaballapura district of Karnataka. Verma et al. [29] reported that there is low nutrient index for N and Zn, high nutrient index for P, Cu, Fe and Mn and medium availability for K in major sugar cane growing soils of Punjab.

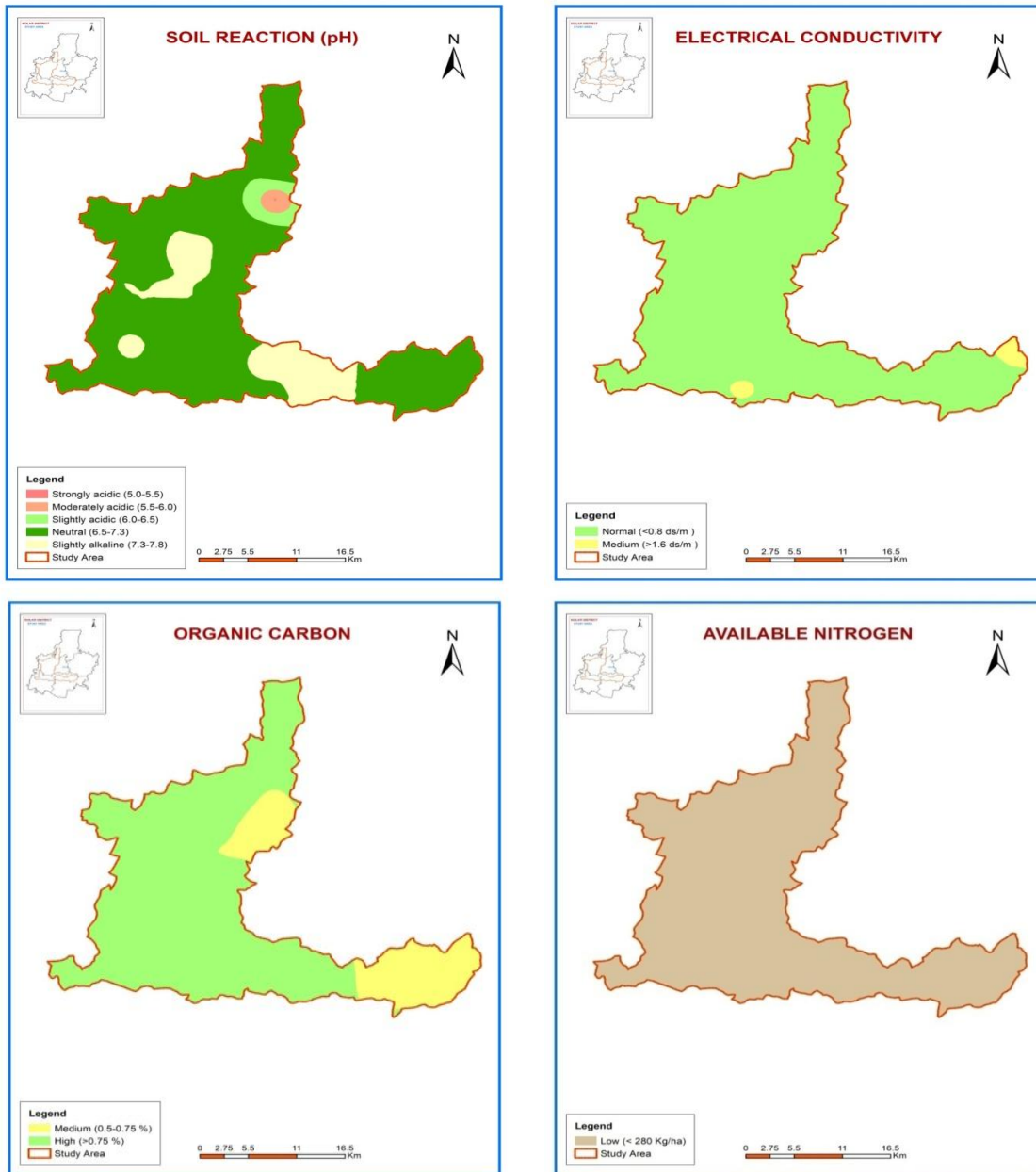


Fig. 1. GIS and GPS aided Mapping of pH, Electrical Conductivity, Organic Carbon and Available N

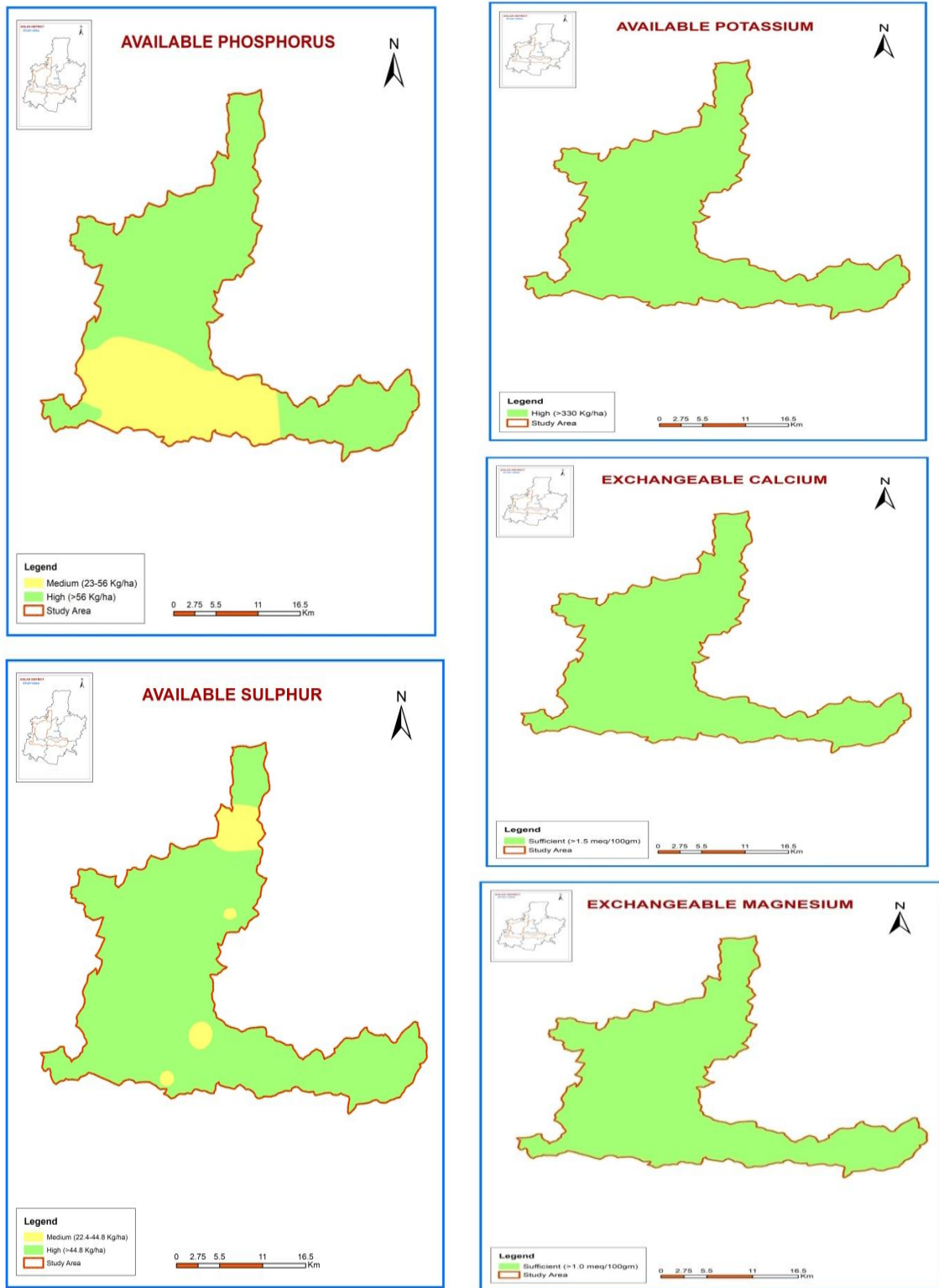


Fig. 2. GIS and GPS aided Mapping of major and secondary nutrients



**Table 3. Percent distribution of soil parameters in tomato growing areas of Kolar district**

S. No	Parameter	Low (%)	Medium (%)	High (%)
1	pH	20 (Acidic)	56 (Neutral)	24 (Alkaline)
2	E.C	81.33 (Normal)	17.33 (Medium)	1.34 (Saline)
3	O.C	16.00	17.33	66.67
4	Available Nitrogen	81.33	18.67	0
5	Available Phosphorus	6.66	21.33	72
6	Available Potassium	0	29.33	70.67
7	Exchangeable Calcium	0	0	100
8	Exchangeable Magnesium	0	0	100
9	Available Sulphur	6.67	21.33	72
10	Available Zinc	5.33	14.67	80
11	Available Manganese	65.33	30.67	4
12	Available Copper	0	0	100
13	Available Iron	76.00	18.67	5.33
14	Available Boron	25.33	32.00	42.67

### 3.6 Correlation (R) of the Major and Micronutrients with Other Physico Chemical Properties

Among the soil properties, soil pH and organic carbon has been comprehensively identified as the most important soil factor controlling the availability of micronutrients in soil.

Soil pH is negatively correlated with the micronutrients viz., Zn, Mn, Cu, Fe and B for Kolar district soils. For Kolar soils Mn (-0.315\*\*) and Fe (-0.350\*\*) are significantly negatively correlated with pH. EC is positively correlated with all the micronutrients Zn, Mn, Cu, Fe and B for Kolar soils and details are presented in Table 5. In Kolar soils, EC was significantly positively correlated with Zn (0.241\*\*) and Mn (0.363\*\*). The mean available Zn, Cu, Fe and Mn contents decreased with increase in pH and increased with increase in organic carbon content of the soil. Similar trend was also observed by Reza et al. [24] and Ravi et al. [31] reported that soil properties exercise greatest influence in controlling the micronutrient status of soils.

Available Cu was negatively correlated (-0.339) with pH. Negatively significant correlations of available Mn with pH (-0.315\*\*) in Kolar soils was observed. Similar results are reported in Lachimipur series of Jharkhand [32] which may be due to the formation of insoluble higher valent oxides of Mn. Copper showed positive correlation with N, P, K and S in Kolar. The increased availability of  $\text{Cu}^{+2}$  may be due to the fact that DTPA being chelating agent extracts micronutrient cations from different pools and the

higher amount of organic carbon coupled with low pH values is further likely to increase. This was in conformity with the findings of Kumar et al. [33]. For Kolar soils organic carbon is positively correlated with Zn, Mn and Fe and significantly positively correlated with Cu (0.237\*\*), whereas with boron negatively correlated. Similar results were also reported by Rajeshwar et al. [18] in soils of Garikapadu of Krishna district of Andhra Pradesh.

The availability of micronutrients increased with organic matter content might be ascribed to greater availability of chelating agents through organic matter. Diethylene Triamine Penta Acetic acid, being chelating agent, extracts micronutrient cations from different pools [8] and the higher amount of organic carbon coupled with low pH values is further likely to increase the solubility of micronutrient cations. This might be the reason for positive correlation with micronutrients. Similar findings have also been reported by Kumar et al. [19]. Available zinc was negatively correlated with clay due to fixation or adsorption by tightly held minerals. It showed non significant relation with both sand and silt. Available boron was negatively correlated.

Positive correlation of Zn, Cu, Fe, Mn and B was observed with silt. It has been reported that adsorbed metal ions (Zn, Cu, Fe, Mn) are in equilibrium with the soil solution. Thus, a soil having greater surface is expected to adsorb greater amount of these ions and vice versa. Increase in the finer surface area for ion exchange and hence can contribute to greater DTPA-extractable forms of metal ions. Similar results were reported by Bhanwaria et al. [34].

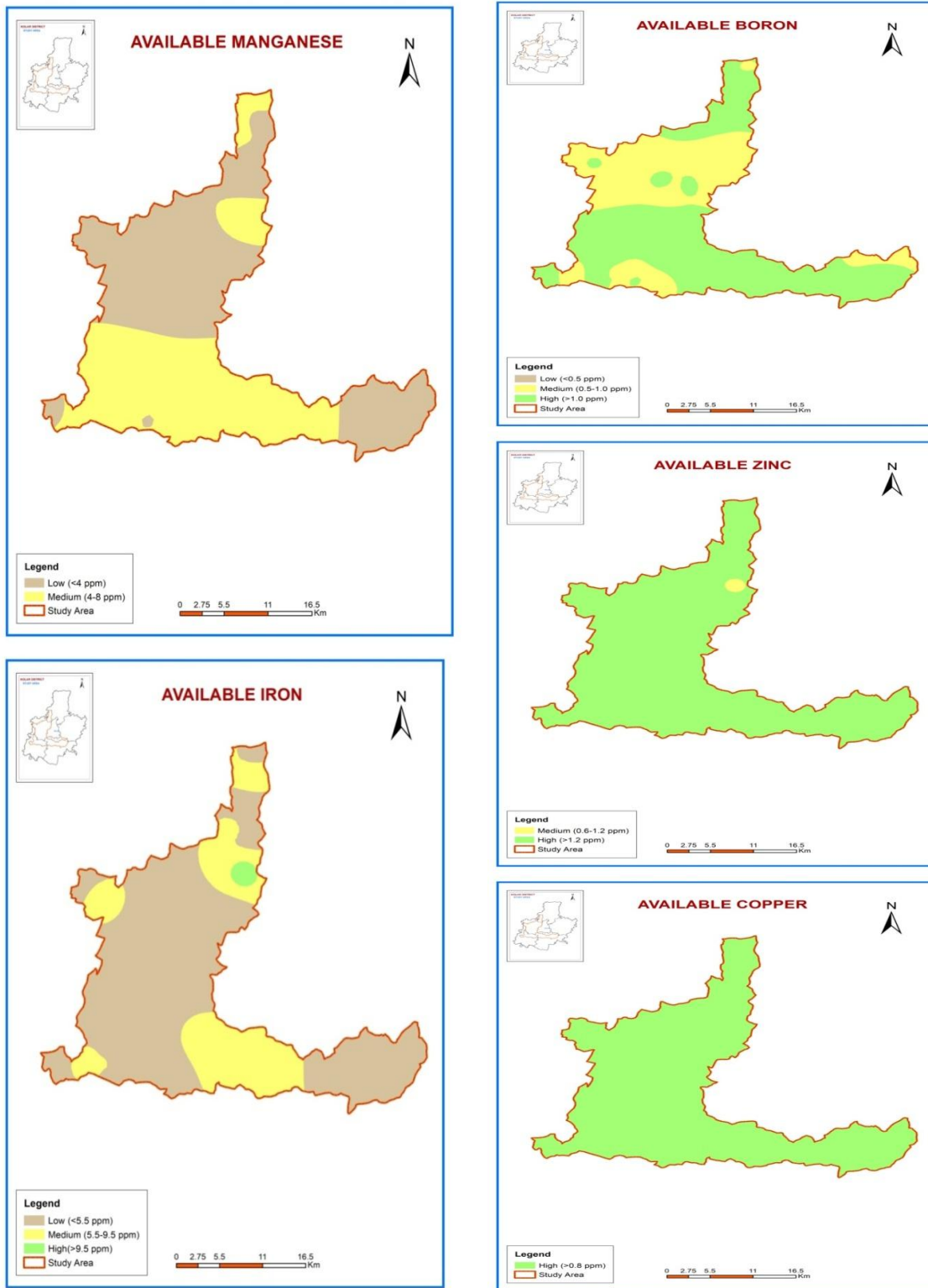


Fig. 3. GIS and GPS aided Mapping of micronutrients

**Table 4. Nutrient index (n.i) of tomato growing areas of kolar district**

S. No	Parameter	Low	Medium	High	N.I	N.I. Class
1	Organic Carbon	12	13	50	2.51	High
2	Available Nitrogen	61	14	0	1.19	Low
3	Available Phosphorous	5	16	54	2.65	High
4	Available Potassium	0	22	53	2.71	High
5	Exchangeable Calcium	0	0	75	3.00	High
6	Exchangeable Magnesium	0	0	75	3.00	High
7	Available Sulphur	5	16	54	2.65	High
8	Available Zinc	4	11	60	2.75	High
9	Available Manganese	49	23	3	1.39	Low
10	Available Copper	0	0	75	3.00	High
11	Available Iron	57	14	4	1.29	Low
12	Available Boron	19	24	32	2.17	Medium

**Table 5. Correlation (r) between soil physico chemical properties with micronutrients of tomato growing areas of Kolar district**

	pH	EC	O.C	Sand	Clay	Silt
Available Zinc	-0.163	0.241**	0.004	0.056	-0.124	0.139
Available Manganese	-0.315**	0.363**	0.138	-0.105	-0.319**	0.327**
Available Copper	-0.200	0.214	0.237*	-0.195	-0.039	0.183
Available Iron	-0.350**	0.107	0.175	-0.048	-0.157	0.159
Available Boron	-0.044	0.133	-0.043	-0.014	-0.092	0.082

\*\* Significant at 0.01 level

\* Significant at 0.05 level

**Table 6. Correlation (r) between major and secondary nutrients with micronutrients in tomato growing areas of Kolar district**

	Available nitrogen	Available P <sub>2</sub> O <sub>5</sub>	Available K <sub>2</sub> O	Available sulphur	Exchangeable calcium	Exchangeable Mg
Available Zinc	0.020	-0.022	-0.062	0.068	-0.172	0.104
Available Manganese	0.091	-0.124	0.009	0.025	-0.232*	0.063
Available Copper	-0.071	0.137	-0.180	-0.041	-0.123	-0.107
Available Iron	0.177	-0.012	-0.215	-0.090	-0.223	-0.101
Available Boron	-0.162	0.185	-0.054	0.084	-0.157	0.032

\*\* Significant at 0.01 level

\* Significant at 0.05 level

Zinc was positively correlated with nitrogen in Kolar, which shows that there exists a synergetic relationship between zinc and nitrogen, where as zinc was negatively correlated with phosphorus in soils of Kolar and details are presented in Table 6, which clearly shows there exists an antagonistic relationship. Available zinc was negatively correlated with potassium. Zinc was positively correlated with nitrogen and sulphur which shows synergetic relationship in Kolar

district soils. Similar results were recorded by Mahendra kumar [35] in Mysore district, Karnataka.

#### 4. CONCLUSION

The nutrient index (NI) of tomato growing areas of Kolar district revealed that N (1.19), manganese (1.39) and iron (1.29) were categorized as low, available boron (2.17) as

medium and P (2.65), K (2.71), S (2.65), zinc (2.75), copper (3.0) as high nutrient index category. Based on the status of nutrients, fertilizer recommendations were made which has resulted in enhancing the yield and reducing the cost of fertilizers in addition to providing balanced nutrients so as to improve availability of nutrients to crop for better growth and yield. These results call for urgent need to adopt soil test based balanced nutrient management for better soil health, enhanced tomato production and productivity as well as profitability in a sustainable manner.

## DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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