Assessment of Available Micronutrients Status in the Soils of Melur Block, Madurai District, Tamil Nadu, Using GIS and GPS Techniques

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

A soil resource inventory was conducted at village level in the Melur block of Madurai district, Tamil Nadu to assess the micronutrients status in the soils and to prepare fertility maps depicting the extent of soil micronutrient deficiency/sufficiency using GIS and GPS techniques. Soil samples were collected at revenue village wise along with geo coordinates and analysed for available micronutrients such as Zn, Fe, Cu and Mn by adopting standard procedures. Based on the nutrient status, the soils were grouped as deficient or sufficient using the critical limits. Per cent deficiency of micronutrients in Melur block was worked out and the thematic maps showing status of different available micronutrients were generated. The results indicated that, Fe and Zn deficiency is most prevalent in the soils of Melur block in Madurai district to an extent of more than 35 per cent, followed by Cu (1.1%) and Mn (10%).

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1. INTRODUCTION

Sound knowledge about soil fertility status is very much relevant for identifying constraints in crop husbandry for attaining sustained productivity and facilitating agro-technology transfer programme. Soil fertility is one of the important factors controlling yields of crops [1]. Soil survey and testing are the proven practical methods for evaluating the soil fertility status and to prescribe balanced fertilizer management strategies to improve crop productivity and to sustain the soil health [2]. Micronutrient deficiencies in soils drastically affect the growth, metabolism and reproductive processes in plants, animal and human beings. Particularly, Zinc and boron deficiency in soils and plants is a global micronutrient disorder reported widely in many countries (> 30 percent) [3].

Generally, quantity and distribution of micro nutrients in soils depends upon the parent materials, organic matter, pH, mineralogy, soil forming processes, drainage, vegetation, anthropogenic and natural processes [4]. Micronutrient status of Tamil Nadu is generally poor as a result of intensive cropping without proper substitution of deficient nutrients and lesser recycling of organic manures. The micronutrient deficiency in Tamil Nadu was 58 % deficiency in znic, 19 % deficiency in Iron and 6 % deficiency in Copper and manganese. Hence the present investigation was carried out in Melur block Madurai district. Spatial variability analysis of nutrients is one of the key factors for precision agricultural management and helps in rational of soil resources management to ensure sustainability of agricultural productivity. The soil nutrient concentrations reported as index values, can be used to predict soil fertility levels which provides a common scale for judging nutrient supply and balance in soil [5]. The Global Positioning System (GPS) has wide adaptability in Agriculture for preparing thematic maps to describe various land uses, land cover and soil fertility [6]. A soil resource inventory was made in Melur block of Madurai district, Tamil Nadu, India for assessing the micronutrients availability in soils using GPS geo coordinates to prepare the fertility maps at village level.

2. MATERIALS AND METHODS

The study area of Melur block, Madurai District is having an area of 3057 ha is located between 10° 03' 36" N latitude and 78° 33' 58" E longitude. Madurai District of Tamil Nadu, India. The average elevation of the Madurai District, Melur block is 101 mean see level. The length of growing period (LGP) is greater than 120 days [7]. The climate is semi-arid with a mean annual average rainfall of 857.63 mm. About 70% of the workforce is dependent on agriculture and allied activities. Granites, quartz/silica, apatite, sand, kaolinite clay and corundum iron are the common minerals present in the soils. The block has 14 revenue villages and it compressing 49 villages.

A detailed soil survey of the study area was carried out on a grid map prepared using ArcGIS software. A total of 280 soil samples were collected with soil auger from a depth of 0-20 cm in fourteen revenue villages and each village collected 20 soil samples. The exact sample locations (latitude and longitude) were recorded with the help of a hand held GPS device. The collected soil samples were processed and stored for further soil analysis. The stored samples were then analysed for pH, electrical conductivity by standard procedure and soil available micro nutrients as estimated by Diethylene Triamine Penta Acetic acid (DTPA)extractable method [8]. Based on the below critical limits the soil samples were groped as low, moderate and high. The extent of micro nutrient deficiency of Melur block was computed and expressed in per cent and thematic maps for micro nutrient status were generated by using Arc GIS.

2.1 Geostatistical Analysis

This study was carried out through geostatistics, geostatistical studies consists of variography and kriging steps [9]. In the variography stage the spatial structure of each soil particles were characterized by experimental semi variogram γ(h) using the following equation:

$$\gamma(h) = \left(\frac{1}{2N(h)}\right) \sum_{i=1}^{N(h)} * \{Z(x_\alpha + h) - Z(x_\alpha)\}^2$$

where, N(h)= no.of pairs separated by distance interval h

γ(h) = variogram for a distance (lag) h between observations Z (xα) and (xα +h).

A preliminary variogram surface analysis was performed to check whether there existed any zonal affect or trend in either direction. The omni

directional experimental variogram for each property were then constructed. Theoretical models were fitted to these. The best fit model for both analysed properties was a spherical model using the equation:

$$\gamma(h) = C_0 + C_1\{1.5\left(\frac{h}{a}\right) - 0.5\left(\frac{h}{a}\right)^3\} \quad h \leq a$$

$$\gamma(h) = C_0 + C_1 \quad\quad\quad h \leq a$$

Here, a is the range, C_0 the nugget semivariance, and $C_0 + C_1$ the sill or the total semi variance.

In order to see the relative contribution of nugget to total variance, we calculated the relative nugget effect (RNE) according to:

$$\text{RNE} = \left(\frac{C_0}{C_0 + C_1}\right) * 100$$

The variogram parameters extracted for each fitted model were used to interpolate the value at unsampled location by means of Ordinary kriging. The ordinary kriging is an exact interpolation technique which assumes the local stationary of the mean. Ordinary kriging uses a linear combination of observations within a predefined neighbourhood around x_0 [10]. The Ordinary kriging estimator Z^* (x_0) with the associated variance σ^2 ok (x_0) can be represented as

$$Z^*\text{ok}(x_0) = \sum_{\alpha=1}^{n(x_0)} \lambda_\alpha Z(x_\alpha)$$

$$\sigma^2\text{ok}(x_0) = \sum_{\alpha=1}^{n(x_0)} [\lambda_\alpha\gamma(x_\alpha - x_0)] + \psi$$

Here, $\lambda\alpha$ is the weight assigned to n observations, Z ($x\alpha$) and ψ is the L arrange multiplier.

3. RESULTS AND DISCUSSION

3.1 Soil Fertility Status of Study Area

The analytical results of physic-chemical parameters of the soil samples from the study area are presented in Table 1. The available micro nutrient status and percent distribution micro nutrient status are presented in Table 2 and 3.

3.2 Soil Physico-chemical Properties of Melur block

The solubility of most nutrients varies in response to pH. The overall soil reaction (pH) of Melur block of Madurai district ranged from 6.8 to 8.1 with a mean of 7.3, indicating that the soils are slightly acidic to alkaline in nature (Table 1). The highest alkaline soil pH value of 8.1 was noticed in Kilaiyur and the lowest value of 6.8 was noticed in kottakudi. According to Amara Denis et al. [11] Brady and Weil [12], alkalinity problem in soils is due to the indigenous calcareous parent material with typical low organic matter content.

Table 1. Percent distribution of pH and electrical conductivity of soils in Melur block of Madurai district, India

Revenue village	pH				Electrical conductivity (dS m^{-1})			
	Mean	Acid (<6.0)	Neutral (6.0-8.5)	Alkaline (>8.5)	Mean	Safe (<1)	Critical (1-2)	>2
Surakundu	7.5	9.1	90.9	0.0	0.48	100.0	0.0	0.0
Therkkutheru	7.6	0.0	100.0	0.0	0.41	100.0	0.0	0.0
Kidaripatti	6.9	0.0	100.0	0.0	0.43	100.0	0.0	0.0
Melur	7.9	0.0	100.0	0.0	0.15	100.0	0.0	0.0
Kilaiyur	8.1	0.0	100.0	0.0	0.14	100.0	0.0	0.0
Thiruvathavur	7.5	0.0	100.0	0.0	0.35	100.0	0.0	0.0
Uranganpatti	7.1	12.5	87.5	0.0	0.17	100.0	0.0	0.0
Manikkampatti	7.6	0.0	100.0	0.0	1.90	100.0	0.0	0.0
Kottakudi	6.8	0.0	100.0	0.0	0.20	100.0	0.0	0.0
Veppadappu	7.4	0.0	100.0	0.0	0.30	100.0	0.0	0.0
Poonjuthi	7.6	0.0	100.0	0.0	0.17	100.0	0.0	0.0
Arittapatti	7.2	0.0	100.0	0.0	0.36	100.0	0.0	0.0
Ambalakaranpatti	7.3	0.0	100.0	0.0	0.34	100.0	0.0	0.0
Vellalapatti	7.4	8.5	89.4	2.1	0.30	97.9	0.0	2.1
Mean	**7.3**	**2.15**	**97.7**	**0.15**	**0.40**	**99.8**	**0**	**0.2**

The electrical conductivity (EC) is the measure of the soluble salts present in the soil and is affected by cropping sequence, irrigation, land use and application of fertilizers, manure, and compost [13]. The electrical conductivity (EC) of the soils varied from 0.14 to 1.90 dS m^{-1} with a mean of 0.40 dSm^{-1}. The highest mean EC value of 1.90 dSm^{-1} was registered in Manikkampatti and Kilaiyur was registered the lowest EC of 0.14 dSm^{-1} Melur block . Most of the samples were reported to contain low salt status with a mean EC of < 0.40 dS m^{-1}. The low salt status of the soils may be due to leaching of salts to lower horizons due to coarser texture of soil. Similar results were also reported by Awanish Kumar et al. [14] in the soils of Kabeerdham district of Chhattishgarh.

3.3 Micronutrient's Availability

Soil available micronutrients status mg kg^{-1} in different villages in Melur block of Madurai district is furnished in Table 2. The available Fe content in the soils of Melur block ranged from 1.19 to 5.54 mg kg^{-1} with a mean of 3.57 mg kg^{-1}. The highest DTPA-Fe was observed in the village of Melur (5.55 mg kg^{-1}) followed by Poonjuthi (4.62 mg kg^{-1}) and Uranganpatti (2.43 mg kg^{-1}) village while the lowest available Fe was registered in the soils of Melur block. The Fe sufficiency in soils might be ascribed to non-calcareousness to slightly calcareous nature of the soils of region and coarse texture of the soils, which was in accordance with the findings of Katyal and Rattan [15]. Lowest available Fe was registered in the soils might be due calcareous

nature of the soil. Similar findings were reported by Karpagam and Grish Chander [16] in the soils of Virudhunagar district.

The DTPA-Mn content in the soils of Melur block of Madurai district ranged from 1.82 to 8.48 mg kg^{-1} with a mean of 5.14 mg kg^{-1}. The highest Mn availability was recorded in Kilaiyur (9.58 mg kg^{-1}) followed by Arritapatti (8.31 mg kg^{-1}) and Kottakudi (6.06 mg kg^{-1}) in Melur blocks. The lowest mean DTPA-Mn was observed in the soils of Vellapatti (1.83 mg kg^{-1}). Higher Fe and Mn content in the soils of Melur block may be due the occurrence of Fe- Mn rich rocks containing minerals such as granites, quartz/silica, apatite, kaolinite clay and corundum iron. Higher Mn status in the surface soils may also be attributed to the lower oxidation and acidic nature of soils. Similar findings were reported by Sharma and Chaudhary [17].

The DTPA-extractable Zn status of the soils ranged from 0.93 to 2.74 mg kg^{-1} with a mean of 1.86 mg kg^{-1}. The available Zn status was the highest in Kottakudi (3.72 mg kg^{-1}) followed by Surakundu (3.01 mg kg^{-1}) and Poonjuthi (2.94mg kg^{-1}). The lowest mean available Zn content was observed in the soils of Melur (0.97mg kg^{-1}) which might be apparently due to continuous cropping especially with rice based cropping system with intensive application of major nutrient fertilizers without adequate supply of micronutrients and organic manures. Increasing cropping intensity in marginal lands and lower use of micronutrients in district has enhanced the magnitude of zinc deficiency [18].

Table 2. Range and mean values of soil available micronutrients status (mg kg^{-1}) in soils of Melur block of Madurai district, India.

Revenue village	DTPA - Fe		DTPA - Mn		DTPA - Zn		DTPA - Cu	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Surakundu	1.92 - 7.28	**4.60**	0.76 - 9.78	**5.36**	1.22- 4.80	**3.01**	1.80-2.26	**2.03**
Therkkutheru	1.30 - 4.65	**2.97**	1.54- 8.51	**5.02**	0.95-1.32	**1.36**	0.97-1.37	**1.17**
Kidaripatti	2.07 - 6.95	**4.51**	1.22- 9.50	**5.36**	0.32-1.84	**1.08**	0.51-2.02	**1.26**
Melur	3.34 -7.76	**5.55**	3.54-5.21	**4.37**	0.83-1.11	**0.97**	0.38-1.48	**0.93**
Kilaiyur	1.41- 6.07	**3.74**	3.06-16.10	**9.58**	0.42-3.21	**1.85**	0.89-1.48	**1.18**
Thiruvathavur	1.54 - 5.52	**3.53**	1.32-5.54	**3.43**	0.56-3.14	**1.84**	1.50-3.50	**2.50**
Uranganpatti	1.74 - 3.02	**2.43**	3.96- 6.78	**5.37**	0.86-1.94	**1.40**	0.88-1.50	**1.19**
Manikkampatti	1.56 - 3.76	**2.66**	1.32- 4.37	**2.84**	0.91-2.10	**1.50**	0.54-1.93	**1.24**
Kottakudi	2.17- 6.68	**4.43**	2.03- 10.1	**6.06**	1.88-5.56	**3.72**	1.16-2.31	**1.68**
Veppadappu	2.28- 6.36	**4.32**	0.4 - 7.80	**4.1**	0.82-3.16	**1.99**	0.42-1.81	**1.11**
Poonjuthi	1.82- 7.43	**4.62**	1.96 - 8.74	**5.34**	1.34-4.54	**2.94**	1.80-2.01	**1.91**
Arittapatti	1.98 - 5.37	**3.67**	1.45-15.17	**8.31**	0.92-1.91	**1.41**	0.74-1.50	**1.12**
Ambalakaranpatti	1.70- 3.64	**2.69**	1.42- 9.09	**5.21**	0.88-1.28	**1.08**	1.28-2.31	**1.79**
Vellalapatti	1.93 - 3.79	**2.83**	1.52- 2.14	**1.83**	1.35-2.45	**1.92**	0.97-2.17	**1.57**
Mean	**1.91-5.54**	**3.57**	**1.82-8.48**	**5.14**	**0.93-2.74**	**1.86**	**0.98-1.98**	**1.47**

Table 3. Percent sample micro nutrients deficiencies (Fe, Mn, Zn, Cu) in the soils of Melur block of Madurai district, India

Revenue village	DTPA - Fe			DTPA - Mn			DTPA - Zn			DTPA - Cu		
	D	M	H	D	M	H	D	M	H	D	M	H
Surakundu	26	44	30	15	46	39	0	55	45	0	66	34
Therkkutheru	30	47	23	13	56	31	47	45	8	0	75	25
Kidaripatti	36	51	13	0	75	25	60	26	14	0	54	56
Melur	28	41	31	0	67	33	59	31	10	15	45	40
Kilaiyur	30	50	20	0	45	55	51	24	25	0	61	29
Thiruvathavur	34	51	15	12	45	43	62	24	14	0	72	28
Uranganpatti	70	30	0	0	70	30	45	36	19	0	45	55
Manikkampatti	45	45	10	17	61	22	60	25	15	0	87	13
Kottakudi	43	45	12	0	69	31	0	46	54	0	59	41
Veppadappu	46	30	24	20	65	15	56	25	19	0	66	33
Poonjuthi	60	26	14	15	48	37	0	49	51	0	71	29
Arittapatti	19	48	23	18	63	19	42	40	18	0	65	35
Ambalakaranpatti	20	45	25	16	67	17	44	40	16	0	68	32
Vellalapatti	18	70	12	21	60	19	0	56	44	0	71	29
Mean	**36**	**44**	**18**	**10**	**59**	**31**	**37**	**37**	**25**	**1.1**	**64**	**34**

Note: D: deficient(low), M: moderate(medium), and H: sufficient(high)

The DTPA-extractable Cu status of the soils of Melur block ranged from 0.98 to 1.98 mg kg^{-1} with a mean of 1.47 mg kg^{-1}. The highest available Cu status was recorded in the soils of Thiruvathavur (2.50 mg kg^{-1}) followed by Surakundu (2.03 mg kg^{-1}) and Poonjuthi (1.91 mg kg^{-1}) in Melur block. The lowest mean available Cu content was observed in the soils of Melur (0.93 mg kg^{-1}).

Based on the micronutrient availability, the soils of different Villages in Melur block of Madurai district is grouped in to deficient (low), moderate (medium), and sufficient (high) categories using the respective critical limit and per cent of each category in Melur block is depicted in Table 3. Analysis of surface soil samples collected from various villages of Melur block revealed that, more than 18 per cent of the soils were sufficient, 36 per cent were deficient and 44 per cent samples were moderate in DTPA Fe status. Among the fourteen villages, the soils of Uranganpatti showed higher Fe deficiency (70 %) and highest Fe sufficiency was observed in the soils of Surakundu (30 %).

The DTPA-extractable Mn content in the soils of Melur block revealed that about 31 per cent of the soils were sufficient, 10 per cent were deficient and 59 per cent samples were moderate in DTPA Mn status. Among the villages, the soils of Veppadappu showed higher Mn deficiency (20 %) and highest Mn sufficiency was observed in the soils of Kilaiyur (55 %). High Fe and Mn in the soils might be due to inherent parent materials like gneiss and granitic rocks which was in accordance with the results of Nahak Truptimayee et al. [6].

The DTPA-extractable Zn status in the soils showed, 37, 37 and 25 per cent of low, medium and higher category, respectively. Among the villages the extent of Zn deficiency was the highest in Thiruvathavur (62 %) followed by Kidaripatti and Melur. In medium category, higher percentage of samples was found in Vellapatti (56 %) followed by Surakundu (23.3 %) in Melur block. The soil samples collected from Kottakudi (54 %) had higher Zn status and sufficient for better crop productivity.

The Cu deficiency in the soil samples of Melur block were found to be low predominantly (1.1 per cent), while 64 and 34 per cent of samples were found to be medium and high category, respectively. The highest percentage of samples with high Cu content was observed in Kidaripatti (56 %) followed by Uranganpatti (55 %) and Melur (40 %). The highest percentage of medium category samples was noticed in the soils of Manikkampatti (87 %) and Therkkutheru (75 %) in Melur blocks.

3.4 Mapping of Micronutrients Status

The spatial variability maps for available micro nutrients *viz*, Fe, Mn, Zn and Cu were prepared by constructing linear directional semivariogram in spatial dependent models by plotting the semi-variance, which is a function of log between neighbouring observations. Inverse distance

weighted model was fitted to semivarogram in order to create continuous surface for the estimated soil properties by using model fitting interface. Based on the percentage of nugget, spatial dependence classes were categorized in to spatial variability map as low, medium and high nutrient status (Figs. 1 to 4).

The fertility status of micronutrients at block level revealed that, almost all the soils in various villages were deficient in Fe, Mn and Zn. However the Cu was soils of Melur block had marginal in status. Similar attempt was made and reported by Prabhavati et al. [19] for the Agro-climatic zones of Belaum district, Karnataka. The Zn status in the soils varied widely from marginal to highly deficient in all the villages of the Melur block except few blocks like Kottakudi, Poonjuthi and Surakundu. The soils of most of villages in Melur blocks had medium copper availability status.
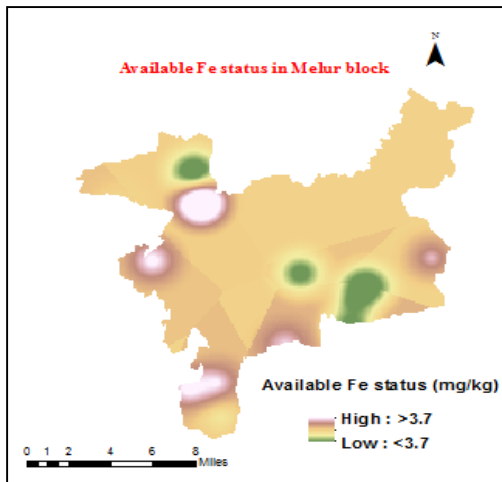
Fig. 1. Available Fe status in Melur block
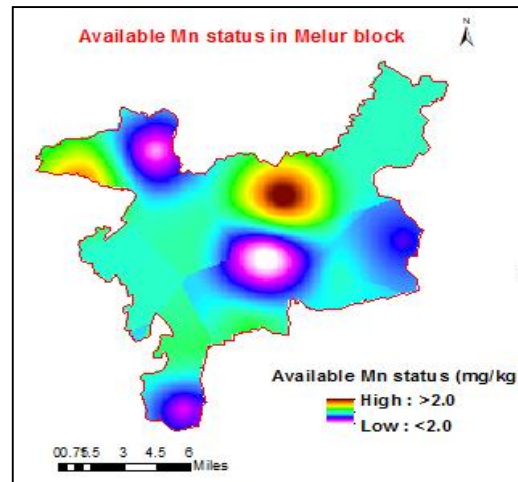
Fig. 2. Available Mn status in Melur block
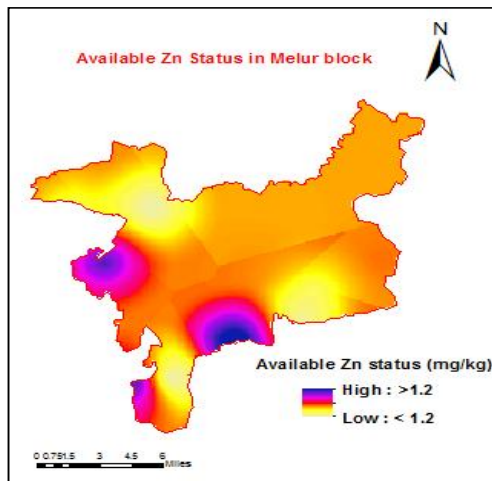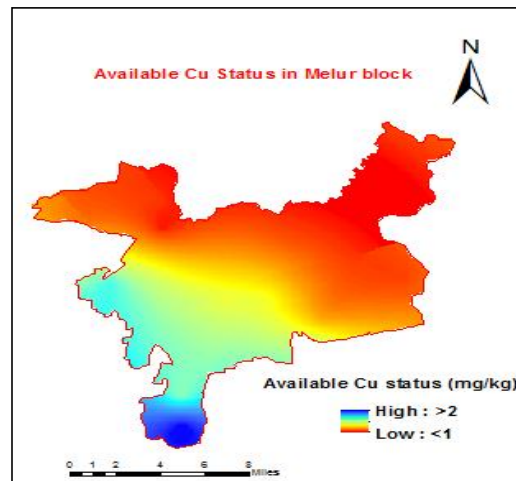

Fig. 3. Available Zn status in Melur block

Fig. 4. Available Cu status in Melur block

Table 4. Descriptive statistics of available micro nutrient

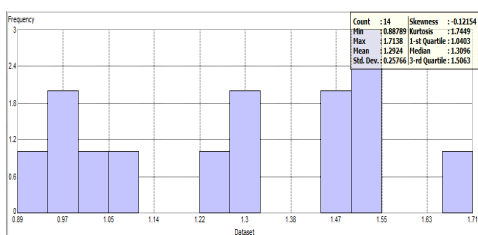| S.No	Property	Number	Min.	Max.	Mean	Std.dev.	Skewness	Kurtosis
1	Fe	280	0.889	1.713	1.292	0.257	0.121	1.74
2	Mn	280	0.604	2.597	1.565	0.415	0.615	3.53
3	Zn	280	0.030	1.313	0.541	0.407	0.448	2.24
4	Cu	280	0.072	0.916	0.350	0.285	0.490	2.16

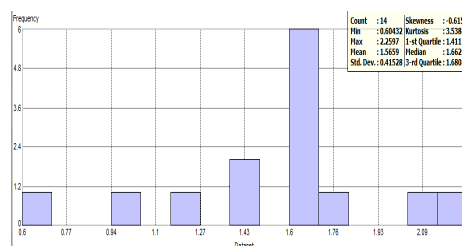**Fig. 5. Histograms of available Fe status**

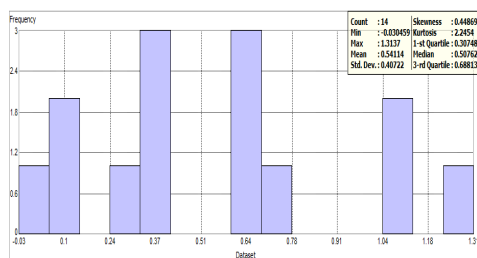

Fig. 6. Histograms of available Fe status

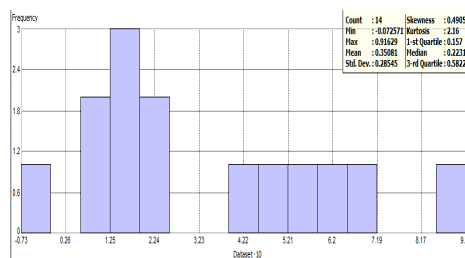**Fig. 7. Histograms of available Fe status**

Fig. 8. Histograms of available Fe status

3.5 Variogram Construction and Analysis

The experimental variogram of micro nutrient, together with the fitted spherical models shows the Table 4 and Fig. 5 to 8. Micro nutrient displayed a well-defined spatial structure with their characteristics sill and range indicated by Frogbrook et al. [20] such variogram that the properties vary in a patchy way resulting in areas with small values and other areas with larger values. The range of spatial correlation of the variogram provides average extent of these patches. The average standard error for sand and clay are 0.25 to 0.41 respectively.

Our results are comparable with other studies that applied GIS tools for the special distribution of environmental attributes, as demonstrated by Olivares et al. [21,22]. The GIS allowed the entry, editing, storage, selection, transformation, analysis, display or visualization and printing of spatial data. In this study, the GIS was indispensable tools for the analysis and presentation of maps in land evaluation, to establish regionalization, zoning and subdivision methodologies for strategic crops in Melur block, Madurai District, Tamil Nadu, facilitating storage and analysis. of a wide range of spatial data in agriculture, similar to the use and result obtained in the studies carried out by Olivares et al. [23], Olivares et al. [24]; Olivares and López [25].

In summary, for the search for improvements in the crops productivity in tropical regions and the selection of really suitable areas for their optimal development, it is essential to carry out studies that include soil characterization, soil quality studies such as the one carried out in this research, in terms of important properties or attributes within the agro ecosystem, as reported by the advances of Olivares [26], through the establishment of models of soil properties that affect the productivity of crops [4] and its relationship with the economic and social characteristics and sustainability of these areas [27] [28].

4. CONCLUSION

Micronutrients are required in small quantities for the plant but found to be most important in the plant system to increase the yield. Crop growth and yield, particularly quality gets affected, if any of the essential micronutrient is deficient in the soil. In recent times, micronutrient deficiencies become deficient invariably in all the soils under intensive cropping system of majority of the agriculturally progressive states of India. From the soil resource inventory made in Melur block for the micronutrients assessment, it was concluded that, Fe deficiency is predominant in the soils (36 %) followed by Mn (10%), Zn (37%) and Cu (1.1 %). The soil micronutrient status will be highly useful for planning and organizing soil fertility improvement programs. Fertility maps will be helpful to plan for balanced nutrient management to get more yield and net returns by avoiding the yield loss due to nutritional deficiency especially with to micronutrients.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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