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Geospatial Distribution of Iron in Major Sugarcane Growing Soils of Sivagangai, Tamil Nadu, India

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Authors' contributions

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

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ABSTRACT

The present study was undertaken to assess the available DTPA iron status in the major sugarcane growing soils of Southern Sivangai district, Tamil Nadu, India. A total of 500 geo referenced surface (0-30 cm) were collected from five blocks *viz.,* Kalaiyarkovil, Padamathur, Sivagangai, Thiruppachetty and Thiruppuvanam and analyzed for basic soil properties and available DTPA iron. Simple correlation was worked out to ascertain the degree of relationship between soil properties and available DTPA iron content of soil study area. The available DTPA iron in the entire sugarcane growing soils ranged from 2.95 to 5.79 mg kg^{-1}, 2.11 to 4.31 mg kg^{-1}, 3.49 to 5.59 mg kg^{-1}, 1.99 to 5.66 mg kg^{-1} and 3.94 to 6.39 mg kg^{-1} in soil samples of Kalaiyarkovil, Padamathur, Sivagangai, Thiruppachetty and Thiruppuvanam respectively. In the soil samples

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from Kalaiyarkovil, Padamathur, Sivagangai, Thiruppachetty, and Thiruppuvanam, the results revealed that 52, 59, 55, 53, and 51 % of the soils were deficient in available iron and 33, 29, 35, 30 and 32 % of the soils were moderate in available iron, and 15, 12, 10,5 and 17 % of the soils were sufficient in available iron. As per the nutrient index study, the soils of study area recorded very low to low fertility rating for available iron and the mean nutrient index value (NIV) ranged from 1.42 to 1.64 in the soil of the study area. SOC and CEC were found to have a beneficial impact on iron availability, whereas EC and $CaCO_3$ levels had a negative impact on DTPA iron availability.

Keywords: Sugarcane; DTPA-Fe; pH; EC; CaCO3; CEC; SOC and simple correlation; GPS and GIS.

1. INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a crop that acts as a natural renewable agricultural resource and provides sugar, bio-fuel, fiber and manure besides many by products. The crop is grown mainly for sugar production and for making jaggery and desi sugar [1]. It is one of the important commercial sugar crops in the world (Anon., 2005).

In India, sugarcane is grown under diverse agro-climatic conditions covering an area of 5.06 million ha with an annual production of 405.41 million tonnes and an average productivity of 80.10 t ha^{-1} (India agristat, 2018-2019). In Tamil Nadu, sugarcane is cultivated to the extent of 1.664 million hectares with the production of 171.40 million tonnes of cane and an average productivity of 103 t ha^{-1} [2]. Among the cane growing states, Tamil Nadu stands third in area and production, and first in productivity, which is about 35% higher than national productivity. In Sivagangai, sugarcane is cultivated to the extent of 1480 ha [3].

Micronutrients play a vital role in crop growth, crop productivity, soil fertility and human nutrition. Among the micronutrients, Iron is required for the creation of chlorophyll and proteins, photosynthesis, electron transfer, nitrate and sulphate oxidation and reduction, and other enzyme functions [4]. Iron deficiency causes interveinal chlorosis in newly emerging young leaves due to reduced chlorophyll synthesis resulting in poor growth and loss in yield and sucrose content up to 74 and 42%, respectively [5].

Micronutrient deficiency in soil is one of the yield limiting factors [6]. Intensive cultivation, monocropping without proper crop rotation, introduction of high yielding varieties, use of high analysis fertilizers devoid of micronutrients and unavailability of organic manures resulted in micronutrient deficiencies and soil organic matter depletion [7]. Soil constraints like alkalinity, calcareousness, excess of carbonate and bicarbonate ions, ionic imbalances and pollution further aggravated this. In Indian soils, iron is the limiting micronutrient next only to zinc.

Micronutrient content of Indian soils was Zn (44%),B (33%), Fe (15%), Mo (13%), Cu (8%) and Mn (6%) respectively [8].

Several authors have indicated that the availability of micronutrients in soils depends on soil pH, organic matter content, adsorptive surfaces and other physical, chemical and biological conditions [9].

Evaluation of available DTPA iron status of soils has become very vital in making role and recommendations for sustainable agricultural development; Sivagangai is a southern region where lands are put into different uses especially for agricultural purposes and unfortunately, these agricultural lands are re-evaluated to determine the status of available DTPA iron in the soil. Therefore, the objective of this work was to evaluate the available DTPA iron status of soils under five blocks. Specifically, the work was aimed at evaluating the physicochemical properties, selected micronutrient like available DTPA iron in the studied location as well as determining the relationship between iron and selected physico-chemical properties.

2. MATERIAL AND METHODS

2.1 Study Area

Sivagangai district is the southern district of the state of Tamil Nadu. It is located between 77° 47' and 78° 49' of East of longitudes and 9° 43' and 10° 22' North of latitudes with an altitude of 102 m above mean sea level. The district has 9 taluks, 2 revenue division and 655 revenue villages with a total geographical area of

4,189 km^2. The mean annual rainfall is 904.7 mm, mostly received from North East Monsoon. In this district, farmers are mainly cultivating paddy, groundnut and sugarcane apart from it they also grow cotton and vegetables also cultivated. In general, red and black cotton soils are dominant in Sivagangai district. The black soil is found in Thiruppuvanam and thirupachetty blocks of Sivagangai district. The combination of red and black soils are found in the Sivagangai, Kaliayar and Padamathur of Sivagangai district. Alluvial soil is found along the courses of the river.

2.2 Soil Analysis

A total of 500 geo-referenced surface soil samples (0-30 cm) covering all sugarcane growing blocks (Kalaiyarkovil, Padamathur, Sivagangagai, thiruppachetty and thiruppuvanam) were collected during 2017 using Garmin GPS instrument (Table 1). The soil samples were air dried, gently powered with wooden mallet and sieved through 2 mm plastic sieve. The processed soil samples were analyzed for pH, EC [10], organic carbon [11], $CaCO_3$ [12] and CEC [10].

2.3 Available DTPA Iron

The available DTPA iron of soils was estimated by using 0.005*M* DTPA extract through Atomic Absorption Spectrophotometer [13]. Based on the analytical results, these soils were categorized into below critical level (<3.70 mg kg^{-1}), sufficient (>3.7 – 8.0 mg kg^{-1}) and above critical level (>8.0 mg kg^{-1}) outlined by Anon [14].

2.4 Statistical and Spatial Analysis

To construct a correlation coefficient matrix, the Pearson correlation coefficients were computed for all possible paired combinations of the response variables. SPSS 16.0® software was used to calculate these statistical values (SPSS Inc., Chicago, III., USA). In this research, the base map wrested on study area, the GPS points and values (chemically analysis results) are coupled together. The study area boundary was digitized using Arc GIS-10.1 environment and polygonized. The sampling locations' geo coordinates were entered into the Arc GIS environment and then turned into a thematic map using the kriging spatial interpolation technique.

3. RESULTS AND DISCUSSION

3.1 Soil pH

3.1.1 Kalaiyarkovil block

In Kalaiyarkovil the mean minimum and maximum soil pH ranged from 7.11 to 7.92 An overall mean value of 7.48 representing that soil are ranged from neutral to slight alkaline in soil reaction. In this block 55% of samples fell under

Table 1. Soil properties of studied area of Sivagangai District, Tamil Nadu

S No	Block Name	pH	EC(dS m^{-1})	SOC (g kg^{-1})	$CaCO_3$ (%)	CEC (c mol(p^+)kg^{-1})	Soil Texture
1.	Kalaiyarkovil-(33*)	7.11-7.92 (7.48)	0.15-0.41 (0.26)	4.44-7.19 (5.76)	1.52-1.71 (1.50)	14.99-21.05 (18.15)	SL,SCL,CL
2.	Padamathur-(29*)	7.69-8.48 (8.13)	0.18-0.52 (0.30)	2.92-5.47 (4.11)	1.05-1.74 (1.33)	12.92-18.97 (15.86)	SCL,SL,CL
3.	Sivagangai(50*)	7.59-8.23 (7.91)	0.28-0.58 (0.43)	3.79-6.36 (5.05)	1.34-1.95 (1.65)	15.81-20.15 (17.99)	SL,CL,SCL
4.	Thirupachetty-(19*)	7.90-8.63 (8.28)	0.26-0.92 (0.55)	1.35-5.53 (3.05)	0.75-1.90 (1.24)	13.58-22.13 (18.24)	SCL,SL,CL,C
5.	Thiruppuvanam-(35*)	7.85-8.44 (8.16)	0.24-0.46 (0.32)	4.92-6.59 (5.71)	1.02-1.37 (1.17)	14.06-18.83 (16.52)	SCL,SL,CL,C

** Number of villages, SL-Sandy loam, SCL-Sandy clay loam, CL-clay loam and C-clay* the pH value of less than 7.50 and 34% of samples were found to have the pH range of 7.50 – 8.50 and about 11% of soil samples recorded with the pH values of more than 8.50.

3.1.2 Padamathur block

In Padamathur the mean minimum and maximum soil pH ranged from 7.69 to 8.48 with an overall mean value of 8.13 representing that soil are ranged from slight alkaline to moderate alkaline in soil reaction. The results further revealed that 31% of soil samples had fell under less than 7.5 pH and 47% of soil sample had the pH range of 7.50-8.50 while 22% of samples were found to record the pH values of more than 8.50.

3.1.3 Sivagangai block

In Sivagangai the mean minimum and maximum soil pH varied from 7.59 to 8.23 with an overall mean value of 7.91 representing that soil are ranged from slight alkaline to moderate alkaline in soil reaction. The percentage of soil samples fell in the different categories of pH < 7.50, 7.50 – 8.50, >8.50 were 18, 69 and 13% respectively. The soil reaction of most of the villages in this block was found to be alkaline.

3.1.4 Thiruppachetty block

In Thiruppachetty the mean minimum and maximum pH of the soil ranged from7.90 to 8.63 with an overall mean value of 8.28 representing that soil are ranged from slight alkaline to moderate alkaline in soil reaction. In this block, 3.0% of samples fell under the pH value of less than 7.50, 65% of samples were in the pH range of 7.50 – 8.50 and 32% of soil samples had the pH range of > 8.50.

3.1.5 Thiruppuvanam block

In Thiruppuvanam the mean minimum and maximum pH of the soil ranged from 7.85 to 8.44 with a mean value of 8.16 representing that soil are ranged from slight alkaline to moderate alkaline in soil reaction. In this block, 15.0% of samples fell under the pH value of less than 7.50, 71% of samples were in the pH range of 7.50 – 8.50 and 14% of soil samples had the pH range of > 8.50.

Soil pH regulates the solubility of nutrients and thus has a pronounced effect on its availability to the growing plants. The variation in the pH value may be attributed to many factors such as increasing Na^+, clay and $CaCO_3$ content. The most common cations in arid and semi arid area are Ca, Mg and Na. Each of these cations is base farming, which means they contribute to an increased OH^- concentration in the soil solution and trend to decrease H^+ concentration. The relative high pH of the soil might be due to the presence of high degree of base saturation reported by Vijayakumar et al. [15] and Jagamohan singh and Dhaliwal [16].

The variation in pH from slight acidic to mild alkaline range may be attributed due to variation in the parent materials and also variation in the management practices by Sharma et al. [17].The mild to strongly alkalinity could be due to accumulation of exchangeable sodium and calcium carbonate reported by Singh et al. [18].

3.2 Electrical Conductivity

3.2.1 Kalaiyarkovil block

The total soluble salts expressed as electrical conductivity (EC) ranged from 0.15 to 0.41 dS m^{-1} with an average value of 0.26 dS m^{-1}. Among the 33 villages, 84 % of the soils fell under the EC value of < 0.50 dS m^{-1}, 13 % of samples had the EC range of 0.50 – 1.00 dS m^{-1} and only 3 %of samples recorded the EC range of more than 1 dS m^{-1}.

3.2.2 Padamathur block

The EC was found to range from 0.18 to 0.52 dS m^{-1} with an average value of 0.30 dS m^{-1}. More than 68 % of soil samples in Padamathur block were found to be non saline (<0.50 dS m^{-1}) and 25 % of the samples only fell in the EC range of 0.50 to 1.00 dS m^{-1} and 7 % of samples recorded the EC range of more than 1 dS m^{-1}.

3.2.3 Sivagangai block

In Sivagangai block, the EC ranged from the 0.28 to 0.058 dS m^{-1} with an average value of 0.43 dS m^{-1}. Among the 50 villages studied, majority of the soil samples were found to be non saline as the EC values was less than 0.50 dS m^{-1}.

3.2.4 Thiruppachetty block

The EC ranged from 0.26 to 0.92 dS m^{-1} with an average value of 0.55 dS m^{-1}. Among the 19 villages selected for the study, 52 % of the soil samples recorded the EC range of <0.50 dS m^{-1}, 35 % of samples varied from the range of 0.50 -

1.00 dS m^{-1} and 13 % of samples had the EC range of > 1 dS m^{-1}.

3.2.5 Thiruppuvanam block

In Thiruppuvanam block, the EC ranged from the 0.24 to 0.46 dS m^{-1} with an average value of 0.32 dS m^{-1}. Among the 35 villages studied, majority of the soil samples were found to be non saline as the EC values was less than 0.50 dS m^{-1}.

The EC of soil gives an indication of salt concentration. The soil EC less than 0.80 dSm^{-1} are rated as non-saline reported by Bali *et al* [19].

3.3 Soil Organic Carbon

3.3.1 Kalaiyarkovil block

The SOC content ranged from 4.44 to 7.19 g kg^{-1} with an average value of 5.76 g kg^{-1}. The SOC values were grouped into different classes of < 5 g kg^{-1}, 5-7.5 g kg^{-1}, > 7.50 g kg^{-1}. The percentage of samples in various SOC classes differed considerably, its highest percentage (45 %) was found in SOC class of < 5 g kg^{-1} and the lowest percentage (21 %) was found in the SOC class of > 7.50 g kg^{-1}.

3.3.2 Padamathur block

The SOC content ranged from 2.92 to 5.47 g kg^{-1} with an average value of 4.11 g kg^{-1}. The 27% of soil samples of this block were found to be in medium category (5 to 7.50 g kg^{-1}) while 12 % samples were in high category of SOC (>7.50 g kg^{-1}) and 61 % samples were found to be in low category (<5.0 g kg^{-1}).

3.3.3 Sivagangai block

The SOC content was found to range from 3.79 to 6.36 g kg^{-1} with an average value of 5.05 g kg^{-1}. On the basis of per cent distribution of samples in different SOC classes, its highest percentage (53 %) was found in SOC class of <5 g kg^{-1} and the lowest percentage (18 %) were observed under the class of > 7.50 g kg^{-1}.

3.3.4 Thiruppachetty block

The SOC content ranged from 1.35 to 5.53 g kg^{-1} with an average value of 3.05 g kg^{-1}. On the basis of per cent distribution of samples in different SOC classes, its lowest percentage (83 %) was found in SOC class of < 7.50 g kg^{-1} and the medium percentage (10 %) was found in the SOC class of 5.00 -7.50 g kg^{-1}.

3.3.5 Thiruppuvanam block

The SOC content ranged from 4.92 to 6.59 g kg^{-1} with an average value of 5.71 g kg^{-1}. The SOC values were grouped into different classes of <5g kg^{-1}, 5-7.5 g kg^{-1}, > 7.50 g kg^{-1}. The percentage of samples in various SOC classes differed considerably, its highest percentage (42%) was found in SOC class of 5.0-7.50 g kg^{-1} and the lowest percentage (20 %) was found in the SOC class of > 7.50 g kg^{-1}.

Low organic carbon content in soils could be due to poor vegetation and a high rate of organic matter decomposition under hyper thermic temperature regimes, which leads to extremely high oxidising conditions. Low OC content in the soils of the research area could potentially be attributable to sugarcane monoculture and widespread crop residue burning, according to Yadav and Meena and Meena et al. [20,21].

3.4 Soil Calcium Carbonate ($CaCO_3$)

3.4.1 Kalaiyarkovil block

The $CaCO_3$ per cent of the soil ranged from 1.52 to 1.71 % with mean of 1.50 %. The $CaCO_3$ values were grouped into different classes of < 1%, 1.00 – 2.00 % and > 2.00%. The percentage of samples in various $CaCO_3$ classes differed considerably, its highest percentage (72 %) was found in $CaCO_3$ class of 1.00 – 2.00 % and the lowest percentage (13 %) was found in the $CaCO_3$ class of > 2.00 %.

3.4.2 Padamathur block

The $CaCO_3$ content of the soil was found to range from 1.05 to 1.74 % with mean of 1.33 %. On the basis of per cent distribution of samples in different $CaCO_3$ classes, its highest percentage (51 %) was found in $CaCO_3$ class of 1.00 – 2.00 % and the lowest percentage (14 %) was found in the $CaCO_3$) class of > 2.00 %.

3.4.3 Sivagangai block

The $CaCO_3$ content of the soil ranged from 1.34 to 1.95 % with mean of about 1.65 %. On the basis of per cent distribution of samples in different $CaCO_3$ classes, the highest percentage (59%) was found in $CaCO_3$ class of 1.00 – 2.00

% and the lowest percentage (13 %) was found in the $CaCO_3$ class of < 1.00 %.

3.4.4 Thiruppachetty block

The $CaCO_3$ content of the soil varied from 0.75 to 1.90 % with mean of 1.24 %. On the basis of per cent distribution of samples in different $CaCO_3$ classes, the highest percentage (54 %) was found in $CaCO_3$ class of 1.00 – 2.00 % and the lowest percentage (11%) was found in the $CaCO_3$ class of > 2.00 %.

3.4.5 Thiruppuvanam block

The $CaCO_3$ content of the soil was found to range from 1.02 to 1.37 % with mean of 1.17 %. On the basis of per cent distribution of samples in different $CaCO_3$ classes, its highest percentage (61 %) was found in $CaCO_3$ class of 1.00 – 2.00 % and the lowest percentage (6 %) was found in the $CaCO_3$) class of > 2.00 %.

The variation in $CaCO_3$ content of the soil is basically due to soil heterogeneity and differences in pedogenic process. High accumulation of $CaCO_3$ might be due to low intensity of rainfall leading to poor leaching of the initially precipitated $CaCO^3$ in the heavy textured soil and low value of $CaCO_3$ content in moderately coarse textured soil could be attributed to the erosion of $CaCO_3$ by the percolating water reported by Mayalagu [22].

In arid and semi arid regions, rainfall is less as compared to annual evapotranspiration. Hence, less water is available for leaching of insoluble carbonates and bicarbonates of calcium. This may have facilitated the accumulation of $CaCO_3$ in these soils reported by Yadauv and Meena [20].

3.5 Cation Exchange Capacity (CEC)

3.5.1 Kalaiyarkovil block

The CEC of the soil ranged from 14.99 to 21.05 cmol(p^+) kg^{-1} with mean of 18.15 cmol(p^+) kg^{-1}. The variation of CEC values was grouped into three classes of < 10, 10 to 20 and < 20 cmol(p^+) kg^{-1}. On the above basis, 21 % of the soil samples registered the CEC of < 10 cmol(p^+) kg^{-1}, 49 % of the samples fell under the range of 10.00 – 20.00 cmol(p^+) kg^{-1}.

3.5.2 Padamathur block

The CEC the soil varied from 12.92 to 18.97 cmol(p^+) kg^{-1} with mean of 15.86cmol(p^+) kg^{-1}. On the basis of per cent distribution of samples in different CEC classes the highest percentage (52 %) of soil samples recorded by CEC of 10.00- 20.00 cmol(p^+) kg^{-1} and the lowest percentage (23 %) of samples were found in the CEC class of < 10.00 cmol(p^+) kg^{-1}.

3.5.3 Sivagangai block

The CEC of the soil ranged from 15.81 to 20.15 cmol(p^+) kg^{-1} with mean of about 17.99 cmol(p^+) kg^{-1}. On the basis of per cent distribution of samples in different CEC classes, 56 % of soil samples fell under the range of 10.00 to 20.00 cmol(p^+) kg^{-1} and16 % of the samples recorded the CEC value of < 10 cmol(p^+) kg^{-1}.

3.5.4 Thiruppachetty block

The CEC of the soil varied from 13.58 to 22.13 cmol(p^+) kg^{-1} with mean of18.24 cmol(p^+) kg^{-1}. On the basis of per cent distribution of samples in different CEC classes, 59 % samples had the CEC range of 10.00 to 20.00 cmol(p^+) kg^{-1} and 11 % samples fell under the CEC of class < 10 cmol(p^+) kg^{-1}.

3.5.5 Thiruppuvanam block

The CEC the soil varied from 14.06 to 18.83 cmol(p^+) kg^{-1} with mean of 16.52 cmol(p^+) kg^{-1}. On the basis of per cent distribution of samples in different CEC classes the highest percentage (60 %) of soil samples recorded by CEC of 10.00-20.00 cmol(p^+) $kg^{-1}$and the lowest percentage (13 %) of samples was found in the CEC class of< 10.00 cmol(p^+) kg^{-1}.

All the extractable cationic micronutrients exhibited positive relationship with CEC which might be due to retention of micronutrients in exchangeable form led to increased availability in the exchange site observed by Balasubramaniam et al. [23].

Table 2. Available DTPA iron status in sugarcane growing soils of Sivagangai district, Tamil Nadu

S No	Block Name	Available DTPA iron(mg kg^{-1})		
		Min	Max	Mean
1.	Kalaiyarkovil-(33*)	2.95	5.79	4.17
2.	Padamathur-(29*)	2.11	4.31	3.11
3.	Sivagangai-(50*)	3.49	5.59	4.56
4.	Thirupachetty-(19*)	1.99	5.66	3.40
5.	Thiruppuvanam-(35*)	3.94	6.39	4.90

**Number of villages*

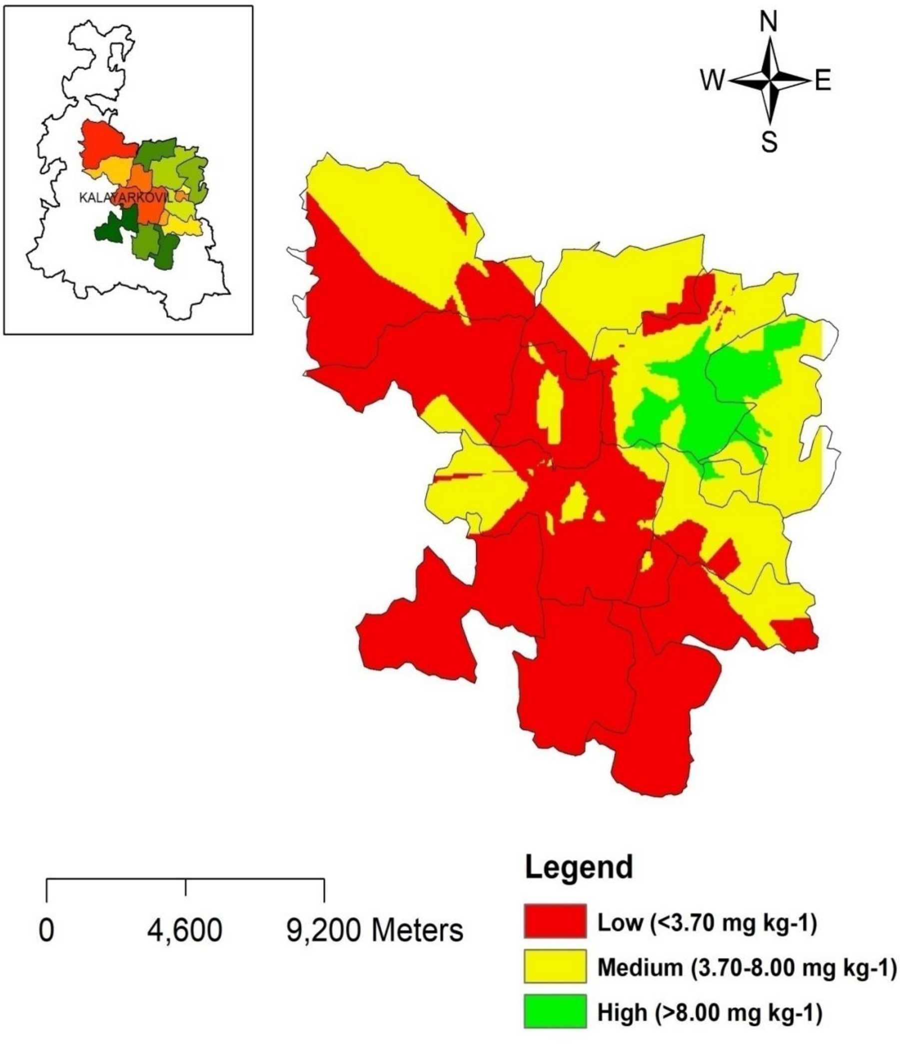

Fig. 1. Soil available iron status of sugarcane growing areas of Kalaiyarkovil block of Sivagangai district

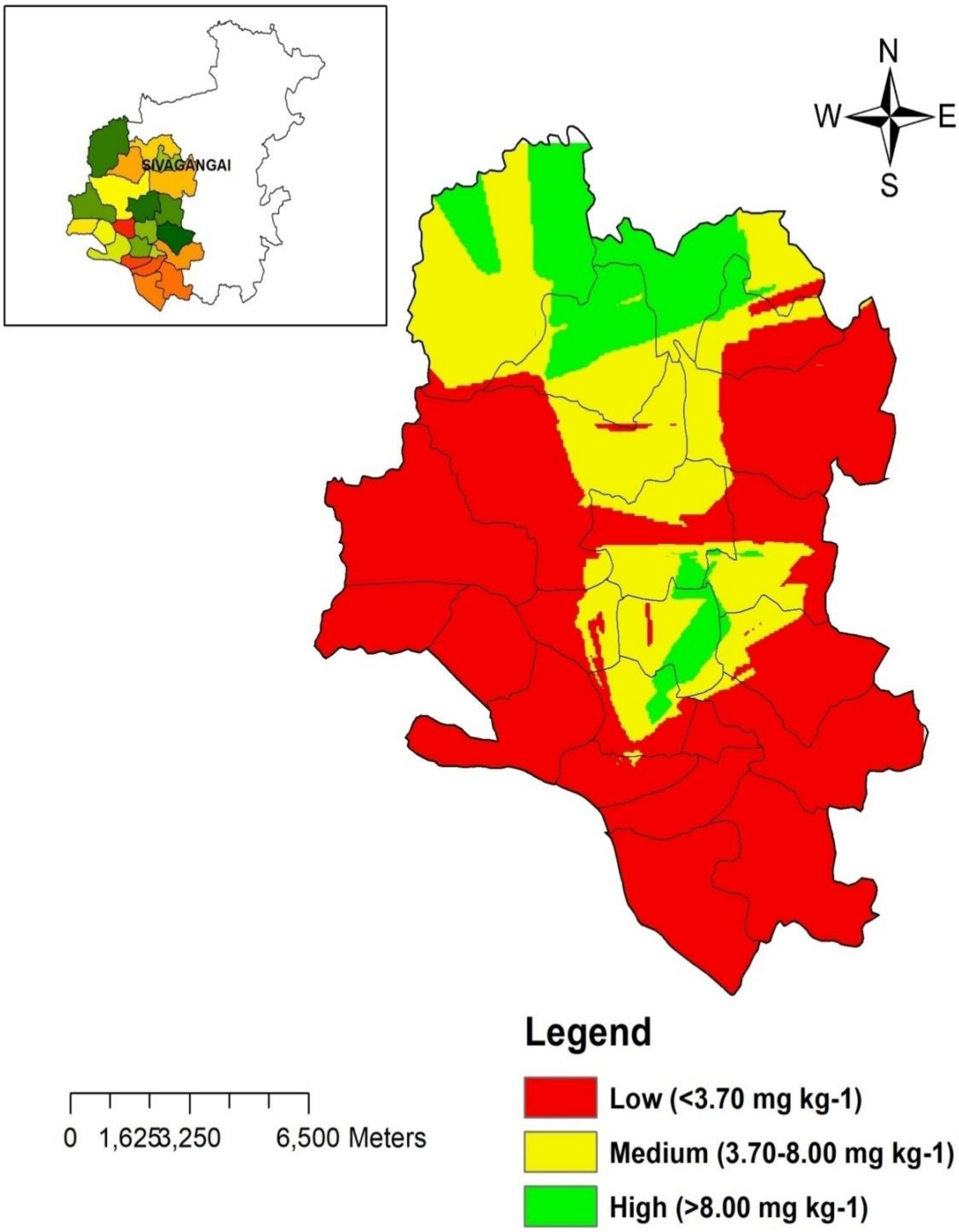

Fig. 2. Soil available iron status of sugarcane growing areas of Padamathur block of Sivagangai district

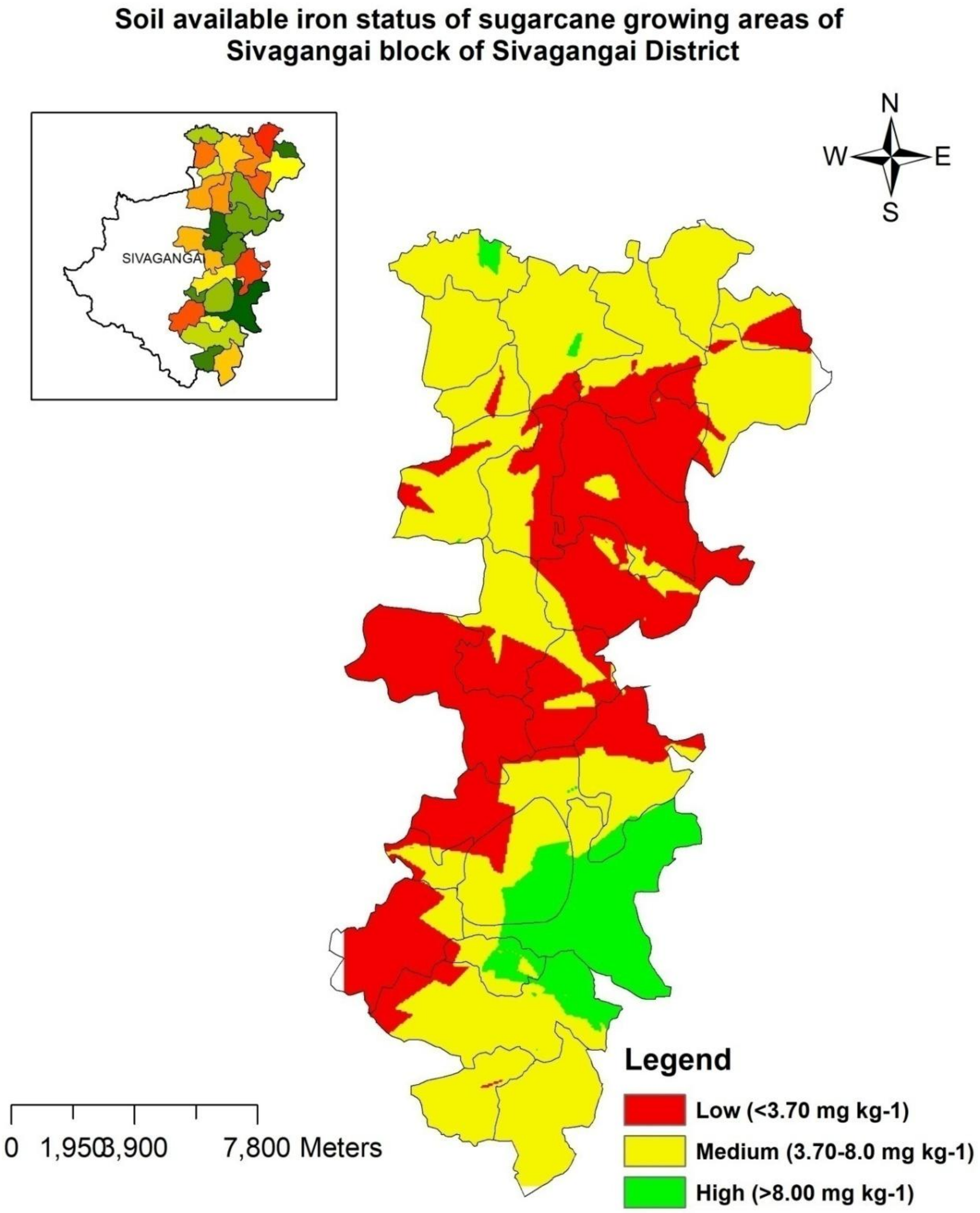

Fig.3. Soil available iron status of sugarcane growing areas of Sivagangai block of Sivagangai district

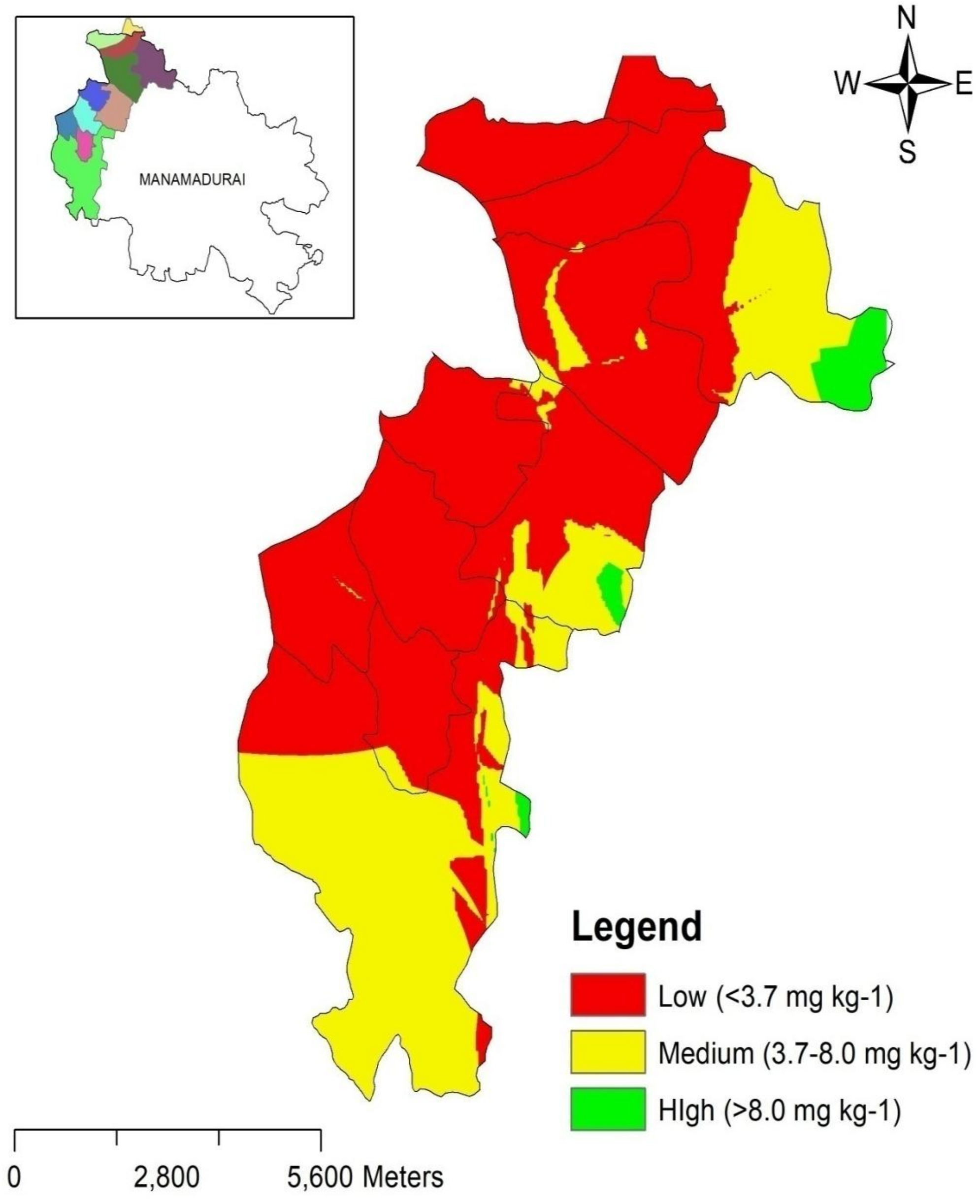

Fig.4. Soil available iron status of sugarcane growing areas of Tiruppachetti block of Sivagangai district

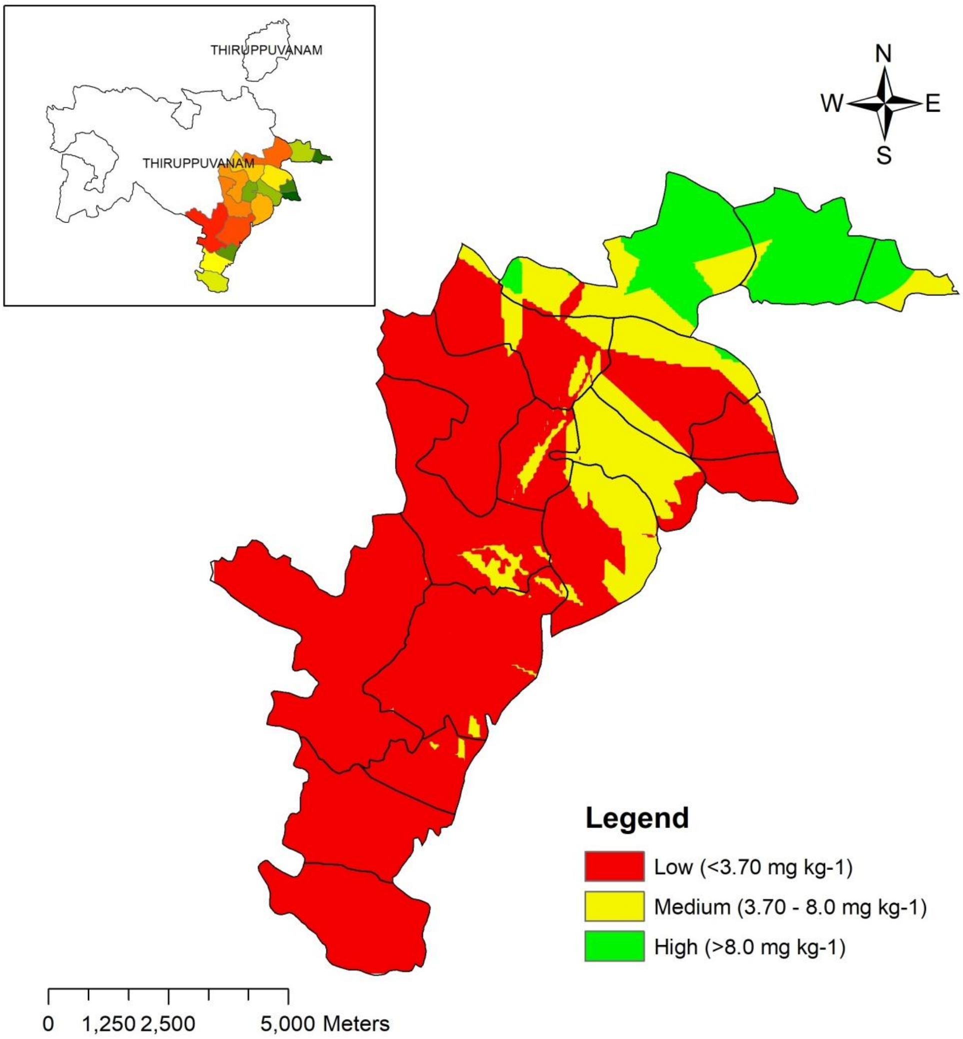

Fig.5. Soil available iron status of sugarcane growing areas of Thiruppuvanam block of Sivagangai district

3.6 DTPA Extractable Micronutrients

3.6.1 Available DTPA-Fe

3.6.1.1 Kalaiyarkovil block

In Kalaiyarkovil block the DTPA-Fe in soil samples ranged from 2.95 to 5.88 mg kg^{-1} with mean value of 4.17 mg kg^{-1}. Considering < 3.7, 3.7 to 8.00 and > 8.00 mg kg^{-1} as deficient, moderate and sufficient in Fe availability, about 52 % soil samples were deficient, 33 % of the samples were moderate and 15 % of samples had sufficient in Fe content.

3.6.1.2 Padamathur block

The DTPA-Fe in soil samples varied from 3.11 to 4.31 mg kg^{-1} with mean, value of 3.11 mg kg^{-1}. Data on available Fe in soil samples indicated that 59 % soil samples were deficient in DTPA-Fe content, 29 % samples were moderate and 12 % of the samples were sufficient in Fe content.

3.6.1.3 Sivagangai block

Available DTPA-Fe in the soil samples varied from 3.49 – 5.59 mg kg^{-1} with an average value of 4.56 mg kg^{-1} in sugarcane growing tracts of Sivagangai block. It was observed that 55 % of soil samples under <3.7 mg kg^{-1}(deficient) and 35 % of soil samples under the range of 3.70 to 8.00 mg kg^{-1} (moderate) and only 10.00 % of samples had > 8.00 mg kg^{-1} (sufficient).

3.6.1.4 Thiruppachetty block

In thiruppachetty block the content of DTPA-Fe in soils ranged from 1.99 to 5.66 mg kg^{-1} with a mean of 3.40 mg kg^{-1}. The status of available Fe indicated that 63 % of the samples were deficient, 32 % samples were moderate and 5 % of the soil samples were sufficient in DTPA-Fe considering < 3.7, 3.7 to 8.00 and > 8.00 mg kg^{-1} as deficient, moderate and sufficient in Fe availability.

3.6.1.5 Thiruppuvanam block

The DTPA-Fe in soil samples varied from 3.94 to 6.39 mg kg^{-1} with mean, value of 4.90 mg kg^{-1}. Data on available Fe in soil samples indicated that 53 % soil samples were deficient in DTPA-Fe content, 30 % samples were moderate and 17 % of the samples were sufficient in Fe content.

The deficiency of Fe in soils might be due to the continuous mining without external sources of iron fertilization, intensive tillage and cultivation, mono cropping without crop rotation, introduction of high yielding variety, imbalanced nutrients devoid micronutrients and reduced application of organic manure and high free $CaCO_3$ content in soil. Followed by it very serious reason such as texture, nature of clay minerals, liming, organic matter content and environmental conditions observed by Singh et al. and Bhanwaria et al. [18,24].

The most common cause of Fe deficiency is alkaline soil pH and when soil pH exceeds 7.00, the availability of Fe in the soil is greatly reduced. At the high pH, Fe may be precipitated as insoluble hydroxides and carbonates observed by Ibrahim and Umar [25].

3.7 Nutrient Index Value (NIV)

According to the notion of soil nutrient index, the soils of the study region had very low fertility ratings of available DTPA-Fe in all five blocks of the study area, with NIV ranging from 1.42 to 1.64., similar result were reported by Singh *et* al. [18]. The lack of area could be attributed to an alkaline reaction with high free $CaCO_3$ content, which could cause soluble Fe to precipitate as insoluble hydroxides [26]. This further confirmed that negative relationship observed between soil pH and DTPA-Fe and similar findings observed by Stood et at. [27]. Hence, there is a need to adopt proper management strategies to restore the Fe availability in soils to achieve optimum production of crops.

3.8 Iron and its Relationship with Soil Characteristics

The data on simple correlation studies between available Fe and soil properties are presented in (Table.2). The available Fe was significantly positively correlated with Soil organic carbon and CEC. While, it was negative influences with pH, EC and $CaCO_3$. The soil having greater surface is expected to retain greater amount of iron. Increases in finer fraction of the soil leads to increases in surface area in ion exchange and hence, can contribute tom greater amount of available Fe observed that Shidhu and Sharma [28].

Table 3. Simple correlation of iron with soil properties of Kalaiyarkovil block

Simple Correlations						
Soil properties	**pH**	**EC**	**SOC**	**CEC**	**$CaCO_3$**	**Fe**
pH	1					
EC	.361**	1				
SOC	-.812**	-.253*	1			
CEC	-.638**	-.309**	.519**	1		
$CaCO_3$	.462**	.147	-.369**	-.128	1	
Fe	-.530**	-.046	.618**	.404**	-.346**	1

***. Significant at the 0.01 level, *. Significant at the 0.05 level*

Table 4. Simple correlation of iron with soil properties of Padamathur block

Simple Correlations						
Soil properties	**pH**	**EC**	**SOC**	**CEC**	**$CaCO_3$**	**Fe**
pH	1					
EC	.508**	1				
SOC	-.814**	-.316**	1			
CEC	.571**	.410**	-.382**	1		
$CaCO_3$	-.409**	-.159	.436**	-.080	1	
Fe	-.711**	-.221*	.827**	-.302**	.406**	1

***.Significant at the 0.01 level, *. Significant at the 0.05 level*

Table 5. Simple correlation of iron with soil properties of Sivagangai block

Simple Correlations						
Soil properties	**pH**	**EC**	**SOC**	**CEC**	**$CaCO_3$**	**Fe**
pH	1					
EC	.711**	1				
SOC	-.721**	-.483**	1			
CEC	.291**	.182	-.149	1		
$CaCO_3$	-.494**	-.400**	.426**	-.155	1	
Fe	-.711**	-.474**	.771**	-.161	.471**	1

***. significant at the 0.01 level, *. significant at the 0.05 level*

Table 6. Simple correlation of iron with soil properties of Thiruppachetty block

Simple Correlations						
Soil properties	**pH**	**EC**	**SOC**	**CEC**	**$CaCO_3$**	**Fe**
pH	1					
EC	.279**	1				
SOC	-.634**	-.224*	1			
CEC	.402**	.012	-.215*	1		
$CaCO_3$	-.386**	-.122	.113	-.198*	1	
Fe	-.612**	-.118	.880**	-.242*	.123	1

***. Significant at the 0.01 level, *. Significant at the 0.05 level*

Table 7. Simple correlation of iron with soil properties of Thiruppuvanam block

Simple Correlations						
Soil properties	**pH**	**EC**	**SOC**	**CEC**	**$CaCO_3$**	**Fe**
pH	1					
EC	.410**	1				
SOC	-.689**	-.098	1			
CEC	-.301**	-.092	.340**	1		
$CaCO_3$	.659**	.334**	-538**	-.139	1	
Fe	-.762**	-.121	.718**	.343**	-.525**	1

***. Significant at the 0.01 level*

4. CONCLUSION

The present investigation revealed that the sugarcane growing soils of study area were slightly acidic to strongly alkaline reaction. In general, higher accumulation of $CaCO_3$ in heavy textured soils induced alkalinity problems in soils. In Kalaiyarkovil, Padamathur, Sivagangai, Thiruppachetty, and Thiruppuvanam, it was also observed that 52 %, 59 %, 55 %, 63 %, and 53 %t of soil samples were deficient in available Fe, while 33 %, 29 %, 35 %, 32 % and 30 % of soil samples had a medium status in available Fe, and 15 %, 12 %, 10%, 5%, 17 %, and 15 % of soil samples was high in available Fe . The geospatial distribution of iron in the soils of the study region will be extremely valuable in assisting sugarcane growers in determining the optimal quantity of iron to apply in order to achieve higher yields and economic returns.

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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