Original Research Article

GEOSPATIAL DISTRIBUTION OF IRON IN MAJOR SUGARCANE GROWING SOILS OF SIVAGANGAI, TAMIL NADU, INDIA

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. The results revealed that 52, 59,55, 53 and 51 per cent of the soils were deficient in available DTPA iron, while 33,29, 35, 30 and 32 percent and 15, 12, 10,5 and 17 per cent soils were medium and high in available DTPA iron in the soil samples of Kalaiyarkovil, Padamathur, Sivagangai, Thiruppachetty and Thiruppuvanam respectively. As per the nutrient index study, the soils of study area recorded marginal 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. Among the soil properties SOC, and CEC had a positive influence on the availability of iron whereas, EC, $CaCO_3$, contents had negative impact on available DTPA iron.

Keywords: Sugarcane, DTPA-Fe, pH, EC, $CaCO_3$, 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 gur and khandasari

(Vijayakumar *et* al, 2020). 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 tonnes ha^{-1}(India agristat, 2018-2019). In Tamil Nadu, sugarcane is cultivated to the extent of 1.664 million hectare (m ha) with the production of 171.40 million tonnes of cane and an average productivity of 103 tonnes ha^{-1} (India agristat, 2018-2019)). 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 (Joint Director of Agriculture office, Sivagangai, 2020).

Micronutrients play a vital role in crop growth, crop productivity, soil fertility and human nutrition. Among the micronutrients Iron is essential for chlorophyll and protein formation, photosynthesis, electron transfer, oxidation and reduction of nitrates and sulphates and other enzyme activities (Udayakumar and Jemila, 2016). 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 (Singh, 1972).

Micronutrient deficiency in soil is one of the yield limiting factors (Savangikar *et al*., 1999). 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 deplection (Rakkiyappan and Thangavelu, 2000). 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 (Sharma and Kumar, 2016).

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 in the soil (Yadav, 2011).

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 grown 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 (Jackson, 1973), Organic carbon (Walkley and Black method, 1934), CaCO3 (Piper method, 1966) and CEC (Jackson, 1973).

2.3. Available DTPA iron

The available DTPA iron of soils was estimated by using 0.005M DTPA extract through Atomic Absorption Spectrophotometer. 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 Berger and Truog (1940).

2.4. Statistical and Spatial Analysis

The Pearson correlation coefficients were estimated for all possible paired combinations of the response variables to generate a correlation coefficient matrix. These statistical parameters were calculated with SPSS 16.0® software (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 geo coordinates of sampling sites was fed into the Arc GIS environment and finally transformed in to thematic map by spatial interpolation technique of kriging.

Table 1: Soil properties of Sugarcane growing soils 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})
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)
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)
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)
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)
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)

* Number of villages

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. The lowest pH 6.35 in soil samples was observed in Noothakanmai village as slightly acidic and the highest value 9.15 was recorded in Andoorani village as strongly alkaline soil reaction. In this block 55 per cent of samples fell under the pH value of less than 7.50 and 34 per cent of samples were found to have the pH range of 7.50 – 8.50 and about 11 per cent 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 lowest and highest pH values 6.75 and 8.91 were recorded in the villages of Eluppakudi as slight alkaline and Chithalangudi as moderate alkaline soil reaction, respectively. The results further revealed that 31 per cent of soil samples had fell under less than 7.5 pH and 47 per cent of soil sample had the pH range of 7.50-8.50 while 22 per cent of samples were found to recorded 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 highest pH of 8.99 and the lowest pH of 6.80 were recorded in Kooturauvpatty as moderate alkaline and Vallani village as slight acidic soil reaction, respectively. 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 The highest pH (9.05) was registered in Tiuppachetty west village as strongly alkaline and the lowest pH (7.37) was observed in Vellikurichi village as slightly alkaline soil reaction. In this block, 3.00 per cent of samples fell under the pH value of less than 7.50, 65 per cent of samples were in the pH range of 7.50 – 8.50 and 32 per cent of soil samples had the pH range of > 8.50.

3.1.5. Thiruppuvanam block

In Thiruppuvanam the the mean minimum and maximum pH of the soil ranged from7.85 to 8.44 with a mean value of 8.16 representing that soil are ranged from slight alkaline to moderate alkaline in soil reaction The highest pH (9.10) was registered in Kalugarkadai village as strongly alkaline and the lowest pH (7.02) was observed in Sottathatty village as slightly acidic soil reaction. In this block, 15.00 per cent of samples fell under the pH value of less than 7.50, 71.00 per cent of samples were in the pH range of 7.50 – 8.50 and 14.00 per cent of soil samples had the pH range of > 8.50.

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.(2006).The mild to strongly alkalinity could be due to accumulation of exchangeable sodium and calcium carbonate reported by Singh *et al*. (2014).

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}. The highest EC of 1.15 dS m^{-1} and the lowest EC of 0.05 dS m^{-1} were recorded in Sannaoorani and Thoovarankanmai villages, respectively. Among the 33 villages, 84 per cent of the soils fell under the EC value of < 0.50 dS m^{-1}, 13 per cent of samples had the EC range of 0.50 – 1.00 dS m^{-1} and only 3 per cent 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}. The highest and lowest EC values 1.16 and 0.06 dS m^{-1} were recorded in the villages of pathinettankottai and Eluppakudi respectively. More than 68 per cent of soil samples in

Padamathur block were found to be non saline (<0.50 dS m^{-1}) and 25 per cent of the samples only fell in the EC range of 0.50 to 1.00 dS m^{-1} and 7 per cent 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}. The highest EC (1.21 dS m^{-1}) was registered in Nedungulam village and the lowest EC (0.08 dS m^{-1}) was observed in Periyakannanur village. Among the 50 villages studied, majority of the soil samples were found to be non saline as the EC values were 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}. The lowest EC of 0.09 dS m^{-1} and the highest of 1.57 dS m^{-1} were observed in villages of Vellikuruchi and Thiruppachetty west respectively. Among the 19 villages selected for the study, 52 per cent of the soil samples recorded the EC range of <0.50 dS m^{-1}, 35 per cent of samples varied from the range of 0.50 -1.00 dS m^{-1} and 13 per cent 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}. The highest EC (1.12 dS m^{-1}) was registered in Vadagankulam village and the lowest EC (0.03 dS m^{-1}) was observed in Sottathatty village. Among the 35 villages studied, majority of the soil samples were found to be non saline as the EC values were less than 0.50 dS m^{-1}.

The electrical conductivity of soil gives an indication of salt concentration. The soil EC less than 0.80 dS m^{-1} are rated as non-saline reported by Bali *et al*.(2010).

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}. The highest SOC 9.55 g kg^{-1} was observed in Noothukanmai village and the lowest value 2.10 g kg^{-1} was recorded in Pallithambam village.

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 per cent of soil samples of this block were found to be in medium category (5 to 7.50 g kg^{-1}) while 12 per cent samples were in high category of SOC (>7.50 g kg^{-1}) and 61 per cent samples were found to be in low category (<5.0 g kg^{-1}). The highest and lowest SOC values 9.90 and 1.30 g kg^{-1} were recorded in the villages of Vembathur and Meenakshipuram, respectively.

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}. The highest SOC (9.36 g kg^{-1}) was noted in Uyyavanthan village and the lowest value (2.25 g kg^{-1}) was found in Malampatti village.

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}. The highest SOC (9.10 g kg^{-1}) was registered in Maaranadu village and lowest SOC (0.65 g kg^{-1}) was observed in Thoothai village.

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}. The highest SOC 8.81 g kg^{-1} was observed in Poovanthi village and the lowest value 3.30 g kg^{-1} was recorded in Kaliyanthur village.

The low organic carbon content in these soils could be due to poor vegetation and high rate of organic matter decomposition under hyper thermic temperature regime which leads to extremely higher oxidizing conditions and also monoculture of sugarcane and wide spread crop residue burning might be the major reason for low OC content in the soils of study area and also coarse textured soils are generally low in organic carbon reported by Yadav and Meena (2009)

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 per cent with mean of 1.50 per cent. The highest $CaCO_3$ content value (2.33 %) was registered in Puliyadithambam village and the lowest value (0.45%) was observed in Manthalai village. The $CaCO_3$ values were grouped into different classes of < 1 per cent, 1.00 – 2.00 per cent and > 2.00 per cent. 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 per cent and the lowest percentage (13 %) was found in the $CaCO_3$ class of > 2.00 per cent.

3.4.2. Padamathur block

The $CaCO_3$ content of the soil was found to ranged from 1.05 to 1.74 per cent with mean of 1.33 per cent. 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 per cent and the lowest percentage (14 %) was found in the $CaCO_3$) class of > 2.00 per cent. The highest and lowest $CaCO_3$values of 3.10 and 0.57 per cent were recorded in Pethananthal and Lakshmipuram villages, respectively.

3.4.3. Sivagangai block

The $CaCO_3$ content of the soil ranged from 1.34 to 1.95 per cent with mean of about 1.65 per cent. The highest $CaCO_3$ content of 3.32 per cent and the lowest $CaCO_3$ content of 0.58 per cent were recorded in Saathani and Sengulam villages, respectively. 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 per cent and the lowest percentage (13 %) was found in the $CaCO_3$ class of < 1.00 per cent.

3.4.4. Thiruppachetty block

The $CaCO_3$ content of the soil varied from 0.75 to 1.90 per cent with mean of 1.24 per cent. The highest and lowest $CaCO_3$ content of 2.80 and 0.45 per cent were observed in Maaranadu and Thanjakur villages, respectively. 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 per cent and the lowest percentage (11 %) was found in the $CaCO_3$ class of > 2.00 per cent.

3.4.5. Thiruppuvanam block

The $CaCO_3$ content of the soil was found to ranged from 1.02 to 1.37 per cent with mean of 1.17 per cent. 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 per cent and the lowest percentage (6 %) was found in the $CaCO_3$) class of > 2.00 per cent. The highest and lowest $CaCO_3$values of 2.15 and 0.60 per cent were recorded in Kalugarkadai and Kalungupatty villages, respectively.

The accumulation of $CaCO_3$ in soils might be due to Soil haterogenity and differences in pedogenic process and also climatic conditions. 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(2009).

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 were grouped into three classes of < 10, 10 to 20 and < 20 cmol(p$^+$) kg^{-1}. On the above basis, 21 per cent of the soil samples registered the CEC of < 10 cmol(p$^+$) kg^{-1}, 49 per cent of the samples fell under the range of 10.00 – 20.00 cmol(p$^+$) kg^{-1}. The highest and lowest CEC values of 25.60 and 7.95 cmol(p$^+$) kg^{-1} were recorded in Sannaoorani and Andoorani villages, respectively.

3.5.2. Padamathur block

The CEC the soil varied from 12.92 to 18.97 cmol(p$^+$) kg^{-1} with mean of 15.86 cmol(p$^+$) kg^{-1}. The highest CEC of 27.30 cmol(p$^+$) kg^{-1} and lowest CEC of 7.50 cmol(p$^+$) kg^{-1} were recorded in the villages of Manappatti and Kallurani, respectively. 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 per cent of soil samples fell under the range of 10.00 to 20.00 cmol(p$^+$) kg^{-1} and 16 per cent of the samples recorded the CEC value of < 10 cmol(p$^+$) kg^{-1}. The highest and lowest CEC values of 24.50 and 8.10 cmol(p$^+$) kg^{-1} were recorded in Malapatti and Sonapatti villages, respectively.

3.5.4. Thiruppachetty block

The CEC of the soil varied from 13.58 to 22.13 cmol(p$^+$) kg^{-1} with mean of 18.24 cmol(p$^+$) kg^{-1}. The highest CEC 24.50 cmol(p$^+$) kg^{-1} was noted in Sambarayendal village and the lowest CEC 8.20 cmol(p$^+$) kg^{-1} was recorded in Avarangadu villages. On the basis of per cent distribution of samples in different CEC classes, 59 per cent samples had the CEC range of 10.00 to 20.00 cmol(p$^+$) kg^{-1} and 11 per cent 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}. The highest CEC of 25.51 cmol(p^+) kg^{-1} and lowest CEC of 8.30 cmol(p^+) kg^{-1} were recorded in the villages of Kaliyanthur and Vaviyarendal, respectively. 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 were 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*. (2005)

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

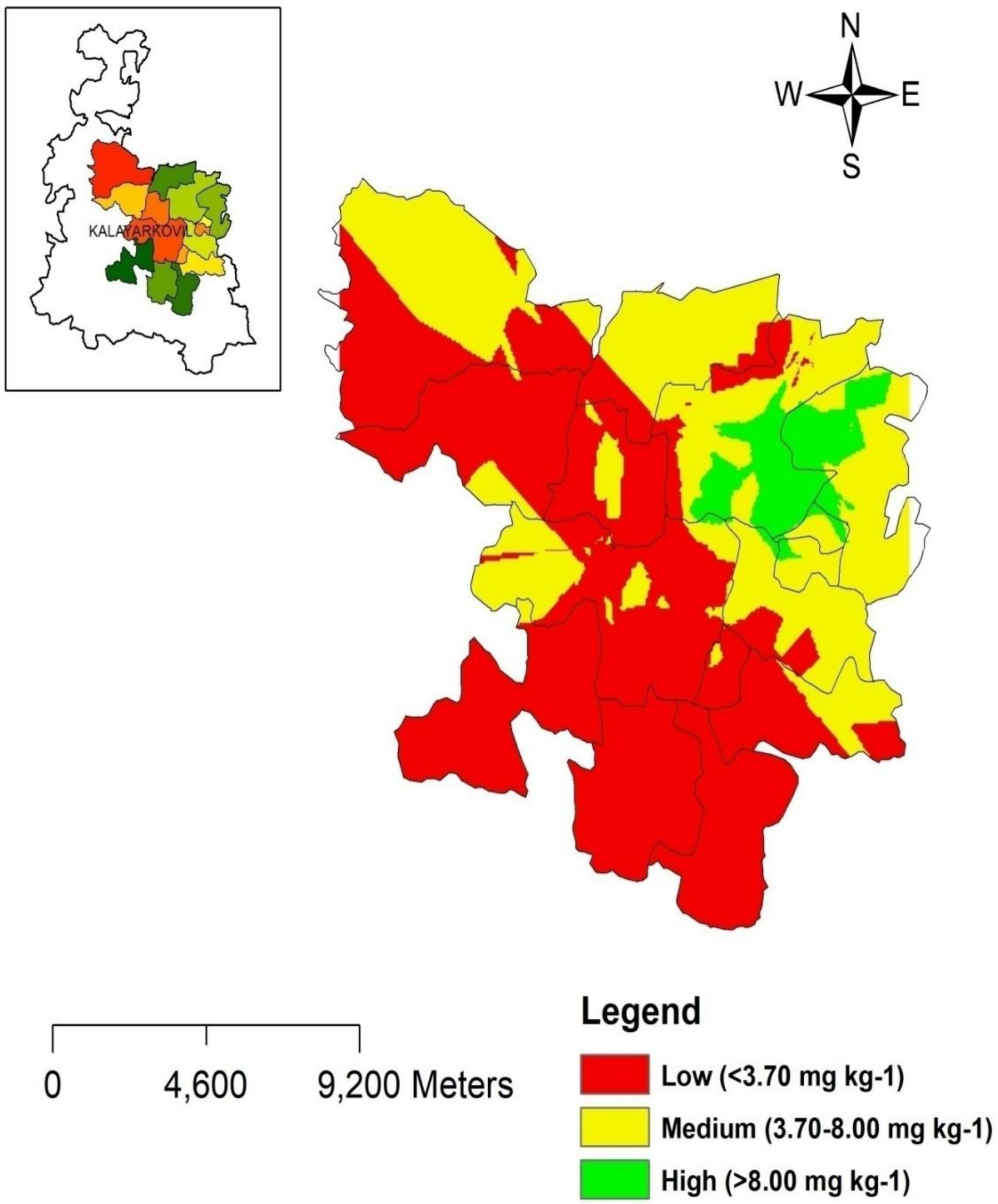
KALAYARKOVIL
N
W
E
S
0
4,600
9,200 Meters
Legend
Low (<3.70 mg kg-1)
Medium (3.70-8.00 mg kg-1)
High (>8.00 mg kg-1)

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

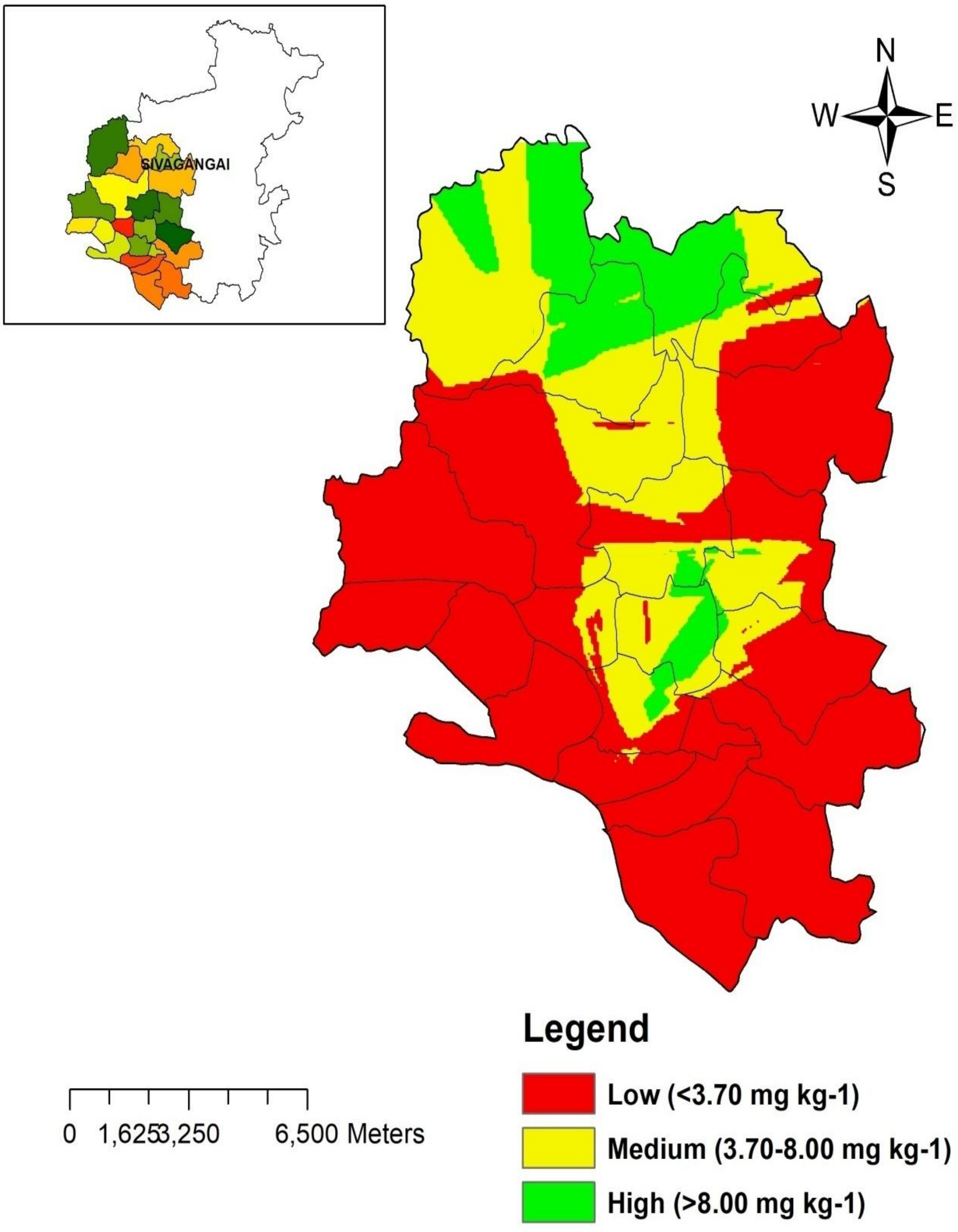

Fig.3 Soil available iron status of sugarcane growing areas of Sivagangai block of Sivagangai District

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

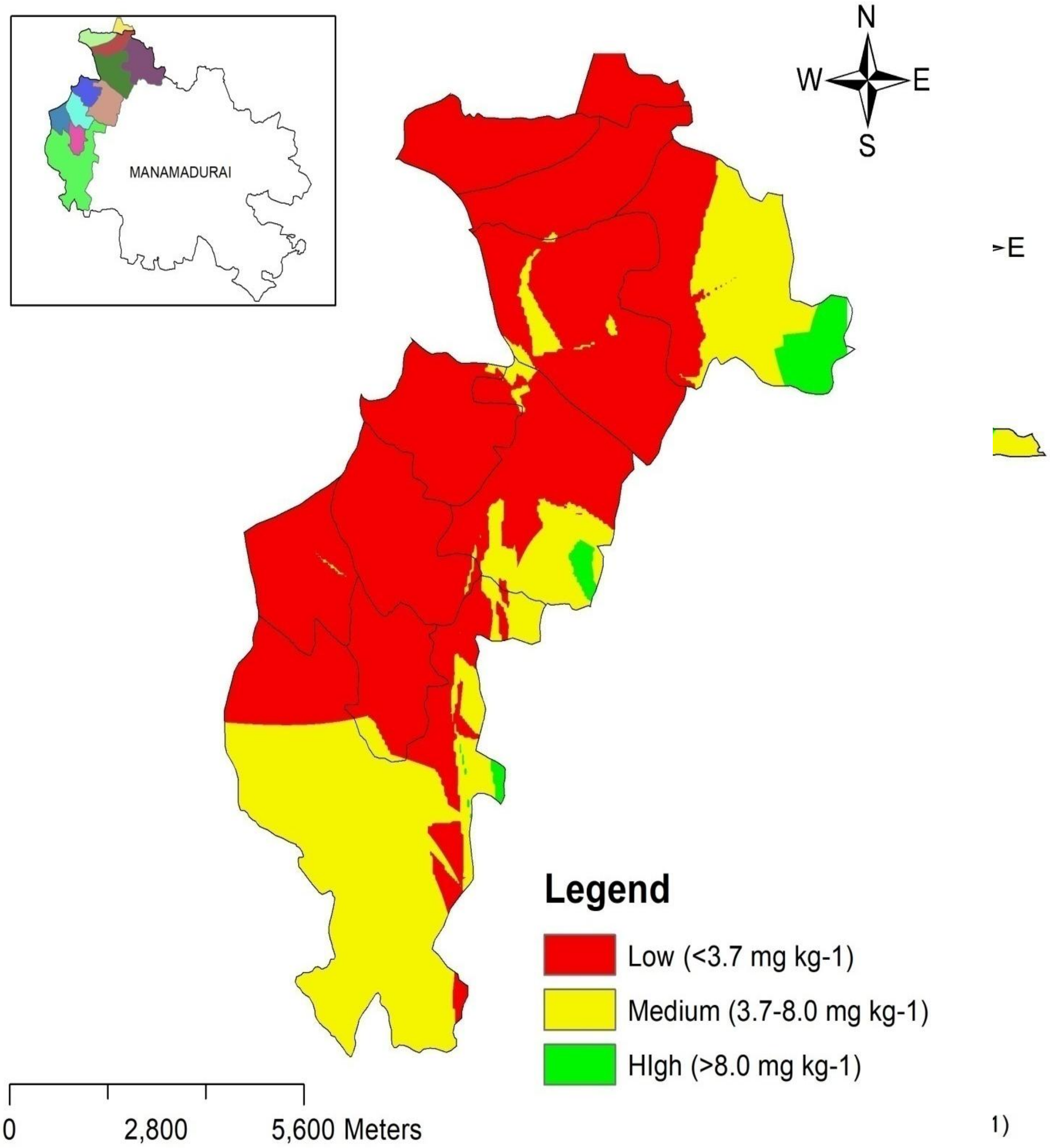

Fig.5 Soil available iron status of sugarcane growing areas of Thiruppuvanam block of Sivagangai District

3.6. DTPA extractable micronutrients

3.6. Available DTPA-Fe

3.6.1 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}. The average Fe content among the collected samples was highest in the soils of Noothakanmai village (9.50mgkg^{-1}) and lowest in soils of Manthikanmai (1.12 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 per cent soil samples were deficient, 33 per cent of the samples were moderate and 15 per cent of samples had sufficient in Fe content.

3.6.2. 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}. The average Fe content among the collected samples was highest in th soils of Kallurani village (9.35 mg kg^{-1}) and lowest in soils of Usilampatty (1.11 mg kg^{-1}). Data on available Fe in soil samples indicated that 59 per cent soil samples were deficient in DTPA-Fe content, 29 per cent samples were moderate and 12 per cent of the samples were sufficient in Fe content.

3.6.3. 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. The highest and lowest Fe content of 9.70 and 2.00 mg kg^{-1} was reported in the villages of Periyakkannanur and Kooturauvpatty, respectively. It was observed that 55 per cent of soil samples under <3.7 mg kg^{-1}(deficient) and 35 per cent of soil samples under the range of 3.70 to 8.00 mg kg^{-1} (moderate) and only 10.00 per cent of samples had > 8.00 mg kg^{-1} (sufficient).

3.6.4. 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 average Fe content among the collected samples was highest in the soils of Maranaadu village (8.70 mg kg^{-1}) and lowest in soils of Sembarayanendal (1.02 mg kg^{-1}). The status of available Fe indicated that 63 pe cent of the samples were deficient, 32 per cent samples were moderate and 5 per cent 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.

3.6.5. 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}. The average Fe content among the collected samples was highest in th soils of Keeladi village (9.70 mg kg^{-1}) and lowest in soils of Kanjirankulam (2.35 mg kg^{-1}). Data on available Fe in soil samples indicated that 53 per cent soil samples were deficient in DTPA-Fe content, 30 per cent samples were moderate and 17 per cent of the samples were sufficient in Fe content.

The deficiency of iron 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 CaCO3 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*.(2014)

3.7. Nutrient Index value (NIV)

Based on the nutrient index values the soils were grouped under different fertility rating of very low (<1.33), low (1.33 – 1.66), marginal (1.66 – 2.00), adequate (2.00 – 2.33), high (2.34 – 2.66) and very high (>2.66).

Considering the concept of soil nutrient index, the soils of study area was found in low fertility rating of available DTPA-Fe in all the five blocks of study area. The values for available Fe worked out from nutrient index value in the sugarcane growing soils of Sivagangai district in block viz., Kalaiyarkovil, Padamathur, Sivagangai,Thiruppachetty and Thiruppuvanam block were 1.63, 1.53, 1.55,1.42 and 1.64, respectively.

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 correlation 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 (2010).

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						

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 CaCO3 in heavy textured soils induced alkalinity problems in soils. It was further observed that 52%, 33%,15% and 59%,29%,12% and 55%,35%, 10% and 63%,32%,5% and 53%,30% and 17% of deficient, medium and higher of iron per cent in Kalaiyarkovil, Padamathur, Sivagangai, Thiruppachetty and Thiruppuvanam respectively. Geospatial distribution of iron in the soils of study area will highly useful for guiding the sugarcane growing farmers to decide the optimum amount of iron to be applied for getting higher yield and economic returns.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. 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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