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Assessment of available DTPA-zinc status in major Sugarcane growing soils of Sivagangai district, Tamil Nadu, India

K Chandrasekar, J Prabhaharan, PP Mahendran, P Saravana Pandiyan, A Gurusamy, RP Gnanamalar and P Kannan

Abstract
The present study was undertaken to assess the available DTPA zinc status in the major Sugarcane growing soils of Sivagangai district, Tamil Nadu. A total of 500 geo referenced surface soil samples (0-30 cm) were collected from five blocks *viz.*, Kalaiyarkovil, Padamathur, Sivagangai, Thiruppachetty and Thiruppuvanam and analyzed for basic soil properties and available DTPA zinc. Simple correlation was worked out to ascertain the degree of relationship between soil properties and available DTPA zinc status of soil study area. The available DTPA zinc in the entire Sugarcane growing soils ranged from 0.89 to 1.76 mg kg^{-1}, 0.63 to 1.40 mg kg^{-1}, 0.80 to 1.41 mg kg^{-1}, 0.48 to 1.49 mg kg^{-1} and 0.98 to 1.55 mg kg^{-1} in soil samples of Kalaiyarkovil, Padamathur, Sivagangai, Thiruppachetty and Thiruppuvanam respectively. The results revealed that 59, 61,60, 69 and 56 per cent of the soils were deficient in available DTPA zinc, while 24, 25, 29, 23 and 28 percent and 17, 14, 11, 8 and 16 per cent soils were medium and high in available DTPA zinc 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 medium fertility rating for available DTPA zinc and the mean nutrient index value (NIV) ranged from 1.39 to 1.60 in the soil of the study area. Among the soil properties SOC, and CEC had a positive influence on the availability of zinc and whereas, EC, $CaCO_3$, contents had negative impact on available DTPA zinc.

Keywords: Sugarcane, DTPA-Zinc, pH, EC, $CaCO_3$, CEC, SOC and simple correlation, Sivagangai, GPS and GIS

1. Introduction
Sugarcane is one of the most important industrial crop in India occupying about 5.0 million hectares (M ha) in area *i.e.*, 3% of the gross cultivable area in the country. Sugarcane is an economically important crop. It provides a rich source of sucrose, alcohol and organic matter waste which is utilized as fertilizer (Christy Nirmala Mary and Anitha, 2019) [9].
Sugarcane crop growing only in 3% of the gross cropped area contributes a significant 1.1% to the national GDP. In the past two decades the contribution of sugarcane to the agricultural GDP has increased steadily from about 5% to 10% growing at an average annual growth of about 2.6% in comparison to 3% in agriculture sector in the country (Abhishek Rajan *et al*., 2020) [1].
Sugar industry, one among the largest agro-based industries, contributes significantly to the rural economy. About 0.5 million people in sugar mills and 6 million sugarcane farmers, their dependents and a large mass of agricultural labour are involved in sugarcane cultivation, harvesting and ancillary activities, constituting 7.5% of the rural population (Venkatesh and Venkateswarlu, 2017) [22].
Sugarcane during 2017-2018 in India was 5.00 lakh hectares with total production of 3400 lakh metric tonnes and average productivity 68 t ha^{-1} (Anonymous, 2018) [2]. However, the productivity of sugarcane can't be improved further due to deficiency of micronutrients.
Micronutrients are playing important role in deciding yield potential of crops and the probable role of micronutrients in sugarcane is the synthesis and translocation of sugar, catalytic and other activities in metabolic processes.(Pawar *et al.*, 2003) [14]. Though these elements are requires in lesser amount but are essential as macronutrients. Furthermore deficiency of micronutrient in soil as well as in plants develops symptoms of crop malignancy (Bowen 1975) [8].
Micronutrient requirement of sugarcane crop varies with soil type and agro climatic conditions of an area (Li 1985) [11]. In Indian soils, iron is the limiting micronutrient next only to zinc.

The micronutrient content of Indian soils was Zn (44%), B (33%), Fe (15%), Mo (13%), Cu (8%) and Mn (6%) respectively (Sharma and Kumar, 2016) [17].

Zinc is essential for production of growth substances, required for the synthesis of tryptophan, responsible for indole acetic acid production, which is essential for the protein metabolism. (Udaykumar and Jemila, 2016) [21].

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) [25].

Evaluation of zinc status of soils has become very vital in making role and recommendations for sustainable agricultural development; Sivangangai is a southern region where lands are put into different uses especially for agricultural purposes, these agricultural lands are re-evaluated to determine the status of micronutrient especially zinc in the soil. Therefore, the objective of this work was to evaluate the zinc status of soils under five blocks. Specifically, the work was aimed to evaluate the physicochemical properties, selected micronutrient (zinc) in the studied location as well as determine the relationship between micronutrients 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, Kaliayarkovil 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) [10], Organic carbon (Walkley and Black method, 1934) [23], $CaCO_3$ (Piper method, 1966) [15] and CEC (Jackson, 1973) [10].

2.3 Available DTPA zinc

The available DTPA zinc of soils was estimated by using ((i). DTPA 0.005 M (ii). $CaCl_2$ $2H_2O$-0.01M and (iii). Triethanolamine (TEA) 0.1M Solution. The DTPA extractant solution is prepared by dissolving 13.1ml of TEA, 1.967 of AR grade DTPA and 1.47g of $CaCl_2$ in 100 ml glass distilled water. The content are allowed for some times so that the DTPA will dissolve and then diluted to about 900 ml. The pH of the solution is adjusted to7.3+-0.05 with 1:1 HCL by stirring and the volume made upto 1litre.) 0.005 M DTPA extract through Atomic absorption spectrophotometer. Based on the analytical results, these soils were categorized into below critical level (< 1.20 mg kg^{-1}), medium (1.20 – 1.80 mg kg^{-1}) and above critical level (>1.80 mg kg^{-1}) outlined by Berger and Truog (1940) [5].

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). The simple correlation was arrived at as per the method. 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 of **t**he soil pH ranged from 7.11 to 7.92 with 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 of **t**he 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 record the pH values of more than 8.50.

3.1.3 Sivagangai block
In Sivagangai the mean minimum and maximum of the soil pH ranged 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 of **t**he pH of the soil ranged from 7.90 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 neutral 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 mean minimum and maximum of **t**he pH of the soil ranged from 7.85 to 8.44 with an overall 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 the pH from mild to strong alikalinity due to due to mineralogical composition of the parent materials and soils were not subjected to intensive leaching losses of cations. Therefore, higher amount of basic cations and $CaCO_3$ accumulated on the surface of the soil resulting high soil pH (Nadaf *et al.,* 2015, Binita *et al.* 2009 and Pulakeshi *et al.* 2012) [13, 6, 16].

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 highet 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 0.58 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 and more than 0.80 dS m-1 are rated as saline soil. Similar result were reported by Bali *et al*. (2010) [4].

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 of5.76gkg^{-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 per centage (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 <5.0 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 < 5.0 g kg^{-1} and the medium percentage (10 %) was found in the SOC class of 5.00 -7.50 g kg^{-1} and high percentage (7%) was found in SOC class of >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 < 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 (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 could be due to lack of crop residue or organic manure application and soils were intensively cultivated with commercial crops which removed more nutrients from these soils. Hyper thermic temperature regime which leads to faster degradation of organic matter, which are responsible for less chance for accumulation of soil organic carbon (Binita *et al*., 2009 and Patel *et al*., 2011) [7].

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.

In arid and semi-arid regions, rainfall is less as compared to annual evapotranspiration. Hence, the calcareousness was due to less water available for leaching of insoluble carbonates and bicarbonates of calcium from the surface soil Binita *et al*., (2009) [7] and Manojkumar (2011).

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<10cmol(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}.CEC governs the overall nutrient supplying capacity of the soil.

Table 2: Available DTPA iron status in Sugarcane growing Soils of Sivagangai district, Tamil Nadu

S. No	Block Name	Available DTPA Zinc (mg kg^{-1})		
		Min	Max	Mean
1.	Kalaiyarkovil-(33*)	0.89	1.76	1.27
2.	Padamathur-(29*)	0.65	1.40	0.97
3.	Sivagangai-(50*)	0.80	1.41	1.11
4.	Thirupachetty-(19*)	0.48	1.49	0.85
5.	Thiruppuvanam-(35*)	0.98	1.55	1.23

*Number of villages

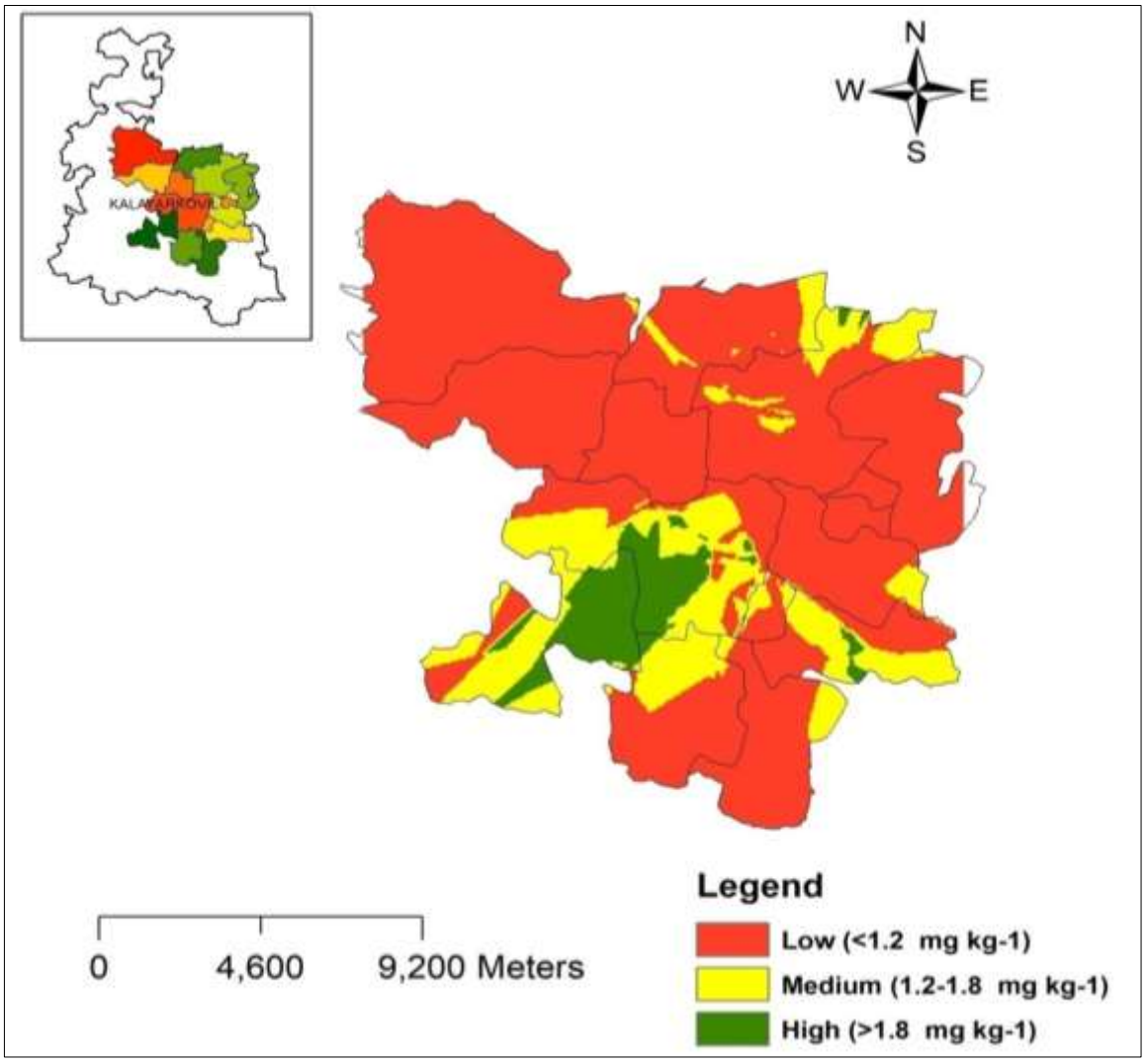

Fig 1: Soil available zinc status of sugarcane growing areas of Kalaiyarkovil block of Sivagangai District

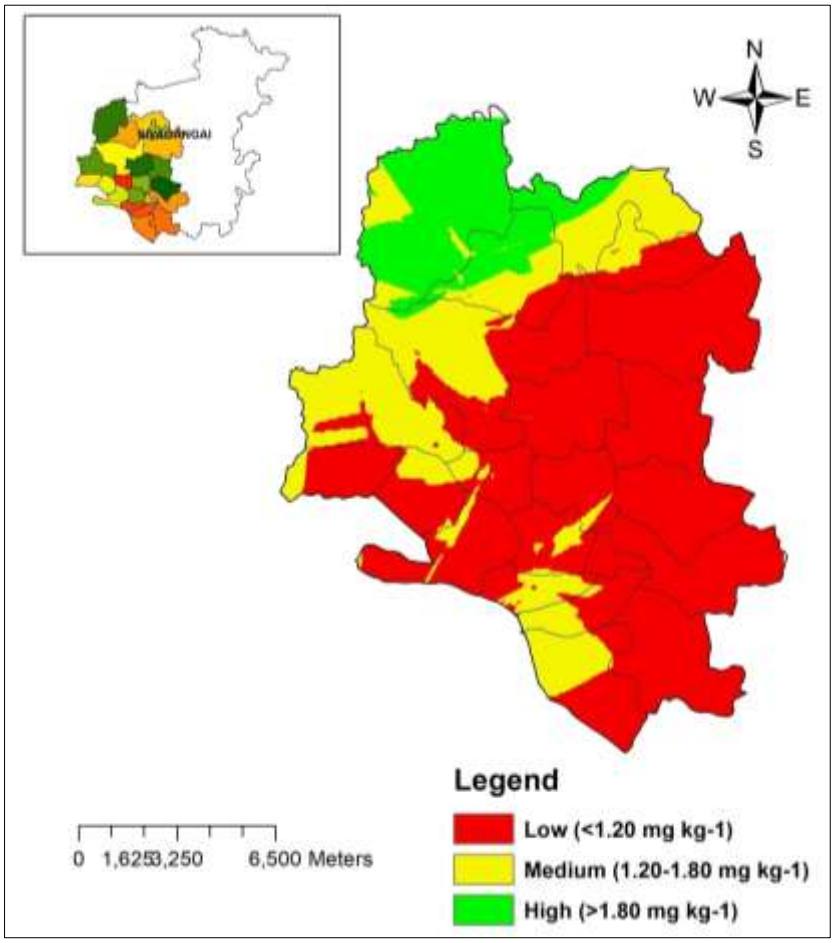

Fig 2: Soil Available zinc status of sugarcane growing areas of Padamathur block of Sivagangai District

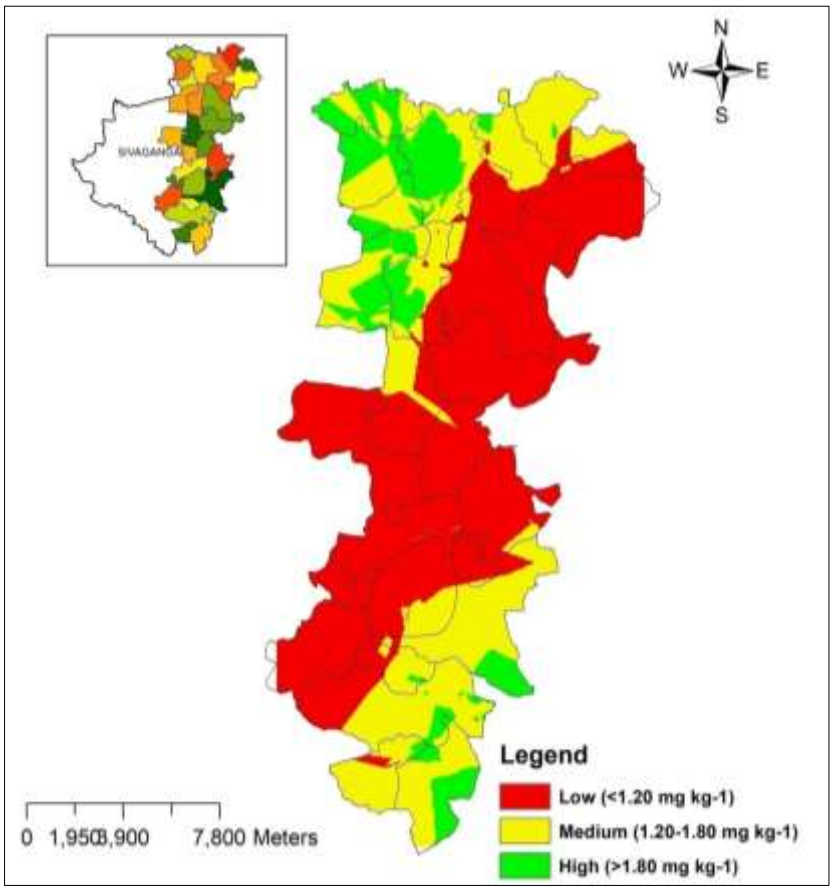

Fig 3: Soil available zinc status of sugarcane growing areas of Sivagangai block of Sivagangai District

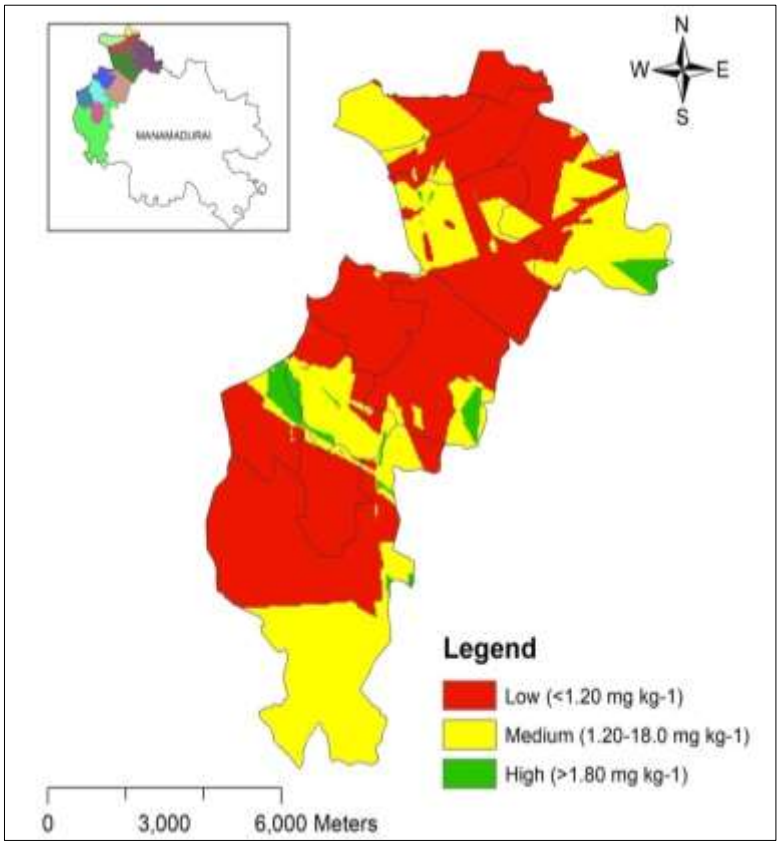

Fig 4: Soil available zinc status of sugarcane growing areas of Tiruppachetti block of Sivagangai District

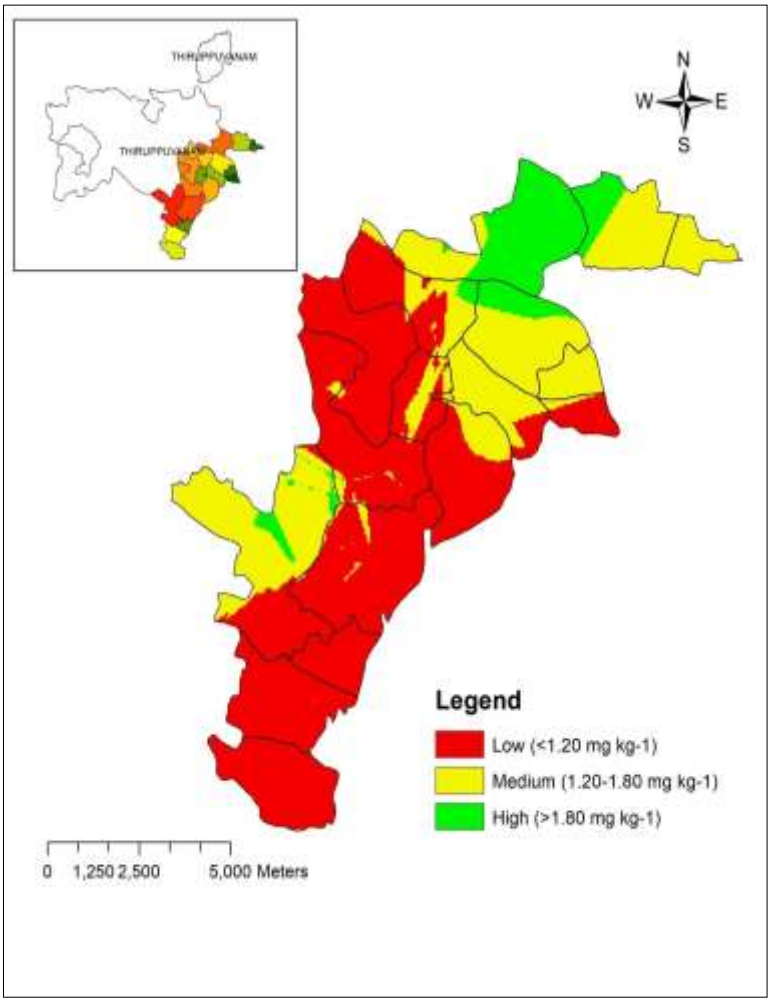

Fig 5: Soil available zinc status of sugarcane growing areas of Thirupuvanam block of Sivagangai District

3.6 DTPA extractable micronutrients

3.6 Available DTPA-Zn

3.6.1 Kalaiyarkovil block

The DTPA-Zn in soils varied from 0.89 to 1.76 mg kg^{-1} with the mean value of 1.27 mg kg^{-1} in Sugarcane growing soils of Kalaiyarkovil block. Considering < 1.2, 1.2 to 1.8 and < 1.80 mg kg^{-1} as deficient, moderate and sufficient in Zn availability, 59 per cent soil samples were deficient, 24 per cent of the samples were moderate and about 17 per cent of the samples and sufficiency status of DTPA-Zn. The average Zn content among the collected samples was highest in the soils of Maruthur village (3.59 mg kg^{-1}) and lowest in soils of Paruthikanmai (0.33 mg kg^{-1}).

3.6.2 Padamathur Block

Available Zn content in the soil samples ranged from 0.63 – 1.40 mg kg^{-1} with an average value of 0.96 mg kg^{-1}. The average Zn content among the collected samples was highest in the soils of Pathinettankottai village (3.10 mg kg^{-1}) and lowest in soils of Alagapuri (0.23 mg kg^{-1}). Data on available Zn in soil samples indicated that 61 per cent soil samples were deficient in DTPA-Zn status, 25 per cent of the samples were moderate and 14 per cent of the samples were sufficient in Zn content.

3.6.3 Sivaganagai block

The availability of Zn in the soils under the study varied from 0.80 – 1.41 mg kg^{-1} with the mean value of 1.11 mg kg^{-1}. The highest concentration of available Zn (2.15 mg kg^{-1}) was observed in soils of Othikulam and the lowest value (0.29 mg kg^{-1}) was noted in soils of Ponnangulam village. Taking 1.2 mg kg^{-1} as threshold value for available Zn, nearly 60 per cent of the samples showed low test value for Zn (<1.2 mg kg^{-1}), 29 per cent had shown the Zn between 1.2 to 1.8 mg kg^{-1} (medium) and 11 per cent of the samples had Zn value above > 1.80 mg kg^{-1} (high).

3.6.4 Thiruppachetty block

The DTPA-Zn content of soil varied from 0.48 – 1.49 mg kg^{-1} with a mean of 0.85 mg kg^{-1}. The highest and lowest Zn content of 1.95 and 0.20 mg kg^{-1} were recorded in Thanjakur and Maravarayanendal villages, respectively. The status of DTPA-Zn indicated that about 69 per cent of the samples were found below the critical level of Zn, 23 per cent samples had DTPA-Zn from 1.2 – 1.8 mg kg^{-1} and about 8 per cent soil samples contained more than 1.8 mg kg^{-1}.

3.6.5 Thiruppuvanam Block

Available Zn content in the soil samples ranged from 0.98 – 1.55 mg kg^{-1} with an average value of 1.23 mg kg^{-1}. The average Zn content among the collected samples was highest in the soils of T Pudur village (3.45 mg kg^{-1}) and lowest in soils of Agraram (0.40 mg kg^{-1}). Data on available Zn in soil samples indicated that 56 per cent soil samples were deficient in DTPA-Zn status, 28 per cent of the samples were moderate and 16 per cent of the samples were sufficient in Zn content.

The zinc deificiency in soils might be due to the continued submergence of soils, calcareousness, HCO_3 rich in ground water and poor organic matter status and also indiscriminate use of phosphatic fertilizers and copper fungicides (Arokiaraj *et al*., 2011 and Nadaf *et al*., 2015) [13].

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-Zn in all the five blocks of study area. The values for available DTPA Zn 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 1.58, 1.53, 1.51, 1.39 and 1.60, respectively.

3.8 Zinc and its relationship with soil Characteristics

The data on simple correlation studies between available Zn and soil properties are presented in (table.2). The available DTPA Zn was significantly positively correlated with Soil organic carbon and CEC. While it was negative correlation with pH, $CaCO_3$. 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 DTPA zinc Talukadar *et al*. (2009) and Yadav (2011) [25].

Table 3: Simple correlation of Zinc with soil properties of Kalaiyarkovil block

Soil properties	pH	EC	SOC	CEC	$CaCO_3$	Zn
pH	1					
EC	.361**	1				
SOC	-.812**	-.253*	1			
CEC	-.638**	-.309**	.519**	1		
$CaCO_3$	.462**	.147	-.369**	-.128	1	
Zn	-.527**	-.123	.615**	.378**	-.365**	1

Table 4: Simple correlation of Zinc with soil properties of Padamathur block

Soil properties	pH	EC	SOC	CEC	$CaCO_3$	Zn
pH	1					
EC	.508**	1				
SOC	-.814**	-.316**	1			
CEC	.571**	.410**	-.382**	1		
$CaCO_3$	-.409**	-.159	.436**	-.080	1	
Zn	-.627**	-.194	.695**	-.228*	.367**	1

Table 5: Simple correlation of Zinc with soil properties of Sivagangai block

Soil properties	pH	EC	SOC	CEC	$CaCO_3$	Zn
pH	1					
EC	.711**	1				
SOC	-.721**	-.483**	1			
CEC	.291**	.182	-.149	1		
CaCO3	-.494**	-.400**	.426**	-.155	1	
Zn	-.670**	-.397**	.696**	-.229*	.441**	1

Table 6: Simple correlation of Zinc with soil properties of Thiruppachetty block

Soil properties	pH	EC	SOC	CEC	$CaCO_3$	Zn
pH	1					
EC	.279**	1				
SOC	-.634**	-.224*	1			
CEC	.402**	.012	-.215*	1		
CaCO3	-.386**	-.122	.113	-.198*	1	
Zn	-.491**	-.203*	.767**	-.205*	.133	1

Table 7: Simple correlation of Zinc with soil properties of Thiruppuvanam block

Soil properties	pH	EC	SOC	CEC	CaCO3	Zn
pH	1					
EC	.410**	1				
SOC	-.689**	-.098	1			
CEC	-.301**	-.092	.340**	1		
CaCO3	.659**	.334**	-.538**	-.139	1	
Zn	-.688**	-.100	.599**	.154	-.491**	1

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. It was further observed that 59%, 24%, 17% and 61%, 25%, 14% and 60%, 29%, 11% and 69%, 23%, 8% and 56%, 28% and 16% of deficient, medium and higher of zinc per cent in Kalaiyarkovil, Padamathur, Sivagangai, Thiruppachetty and Thiruppuvanam respectively. Geospatial distribution of Zinc in the soils of study area will highly useful for guiding the sugarcane growing farmers to decide the optimum amount of zinc to be applied for getting higher yield and economic returns. Further, the findings of the present investigation underline the importance of complete soil testing for micronutrient along with macronutrients which will pave the way for adoption of site specific micronutrient for Sugarcane crops.

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