



# GIS-Based Soil Mapping of Nagapattinam District, Tamil Nadu, India: A Study on Sulphur Content and Associated Soil Properties

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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 importance of sulphur in agriculture is evident because plants require sulphur for the synthesis of essential amino acids, proteins, vitamins, and coenzymes and to activate certain enzymes. Advanced techniques like global positioning systems (GPS), geographic information systems (GIS) and precision agriculture facilitate soil secondary nutrient mapping, providing quantitative support for decision and policy-making to improve agricultural approaches for balanced nutrition. Thus,

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thematic maps help design appropriate strategies to enhance the productivity of crops. A study was carried out in the Nagapattinam district to assess sulphur status and soil properties, create a data bank, and prepare thematic maps. A total of 1631 geo-referenced surface soil samples covering 11 blocks in Nagapattinam district were collected randomly at 0-15 cm depth and analyzed for various soil properties, such as pH, electrical conductivity (EC), organic carbon (OC), free CaCO<sub>3</sub>. The overall soil reaction in the Nagapattinam district at different blocks was mainly neutral, with low soil salinity hazards. The data on organic carbon status in the soils was medium. The average free calcium carbonate status in the soils of different blocks revealed moderately calcareous. The average available sulphur was found to be in the range of 54.4 to 153 mg kg<sup>-1</sup>. Higher availability of sulphur with a combined average of 84.8 mg kg<sup>-1</sup> was noticed in the soils of the entire district and could be attributed to the high organic carbon content and heavy texture of the soils.

*Keywords: GIS; mapping; organic carbon; sulphur; electrical conductivity; soil survey.*

## 1. INTRODUCTION

Sulphur in agricultural soils occurs in organic and inorganic forms, with organic Sulphur accounting for more than 95 per cent of the total sulphur. Indian soils show sulphur depletion, as deficiencies are emerging fast in several areas and causing a decline in crop yields and total productivity [1,2]. In the absence of sulphur, the plant shows deficiency symptoms, resulting in disorders such as yellowing of leaves and chlorotic symptoms. In agriculture, global positioning system (GPS) and geographic information system (GIS) technologies have been adopted for better management of land and other resources for sustainable crop production [3-5]. Fertilizer is one of the costliest inputs in agriculture, and using the right amount of fertilizer is fundamental for farm profitability and environmental protection [6]. GIS generated soil fertility maps may serve as a decision-support tool for nutrient management [7,8]. The importance of sulphur from a crop production point of view is well known. Hence, the study attempted to create a data bank and thematic map for available sulphur in Nagapattinam district using GIS to suggest suitable management strategies and site-specific nutrient management. Geo-referenced surface soil samples covering 11 blocks in Nagapattinam district were collected randomly and analyzed for various soil properties to correlate with nutrient availability.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Nagapattinam is the 4th largest district, lies on the east coast of Tamil Nadu, with a total geographical area of 2,58,136 ha and lies

between 100 16' and 110 25' degrees north and 790 30' and 800 01' degrees east longitude (Fig. 1). The district consists of 11 blocks viz. Vedaranyam, Nagapattinam, Keelaiyur, Talanayar, Kilvelur, Thirumarugal, Kuttalam, Kollidam, Mayiladuthurai, Sirkazhi, Sembanar Koil and 7 talukas. Soil is predominantly sandy in texture, and clayey is present in certain pockets, with slight salinity and alkalinity. Sand dunes dominate the area between Nagapattinam and Vedaranyam, and the soil under cultivation is mostly sandy in texture [9]. The major area is covered under the wealthy Cauvery delta zone; the rest is the coastal zone. The climate of the study area is semi-arid and receives a mean annual rainfall of 1337 mm. The mean annual air temperature is 31.17° C. The major crops grown in this region are Rice, Sugarcane, Coconut, Mango, Casurina, Brinjal and Cashew, with vegetable crops such as brinjal, lady's finger, chilli, cucumber, melons, gourds, and fruit crops like mango, cashew, guava, and sapota are also raised in lesser extent [9].

### 2.2 Soil Sampling

The GPS data (Latitude °N and Longitude °E) were collected from each sampling site distributed over the entire Nagapattinam district using the Garmin GPS 76CS model. Locations of soil sampling sites of Nagapattinam district were marked on the base map on 1: 50,000 scales prepared from State Revenue Maps and digitized using Arc-info GIS. For taking soil samples, surface litter was removed and a 'V' shaped cut to a depth of 15 cm was made in the sampling spot. Soil from top to bottom of exposed face of the 'V' shaped cut (0 to 15 cm depth) was sliced and collected in sampling bags [10]. All the samples were collected during summer to avoid seasonal variations and processed after shade

drying. They were pounded, ground using a wooden mallet, passed through a 2 mm sieve, and analyzed for various physicochemical properties. The sampling station map is shown in Fig. 2.

### 2.3 Soil Analysis

The soil samples collected during the survey were processed after shade drying and passed through a 2 mm sieve and analyzed for pH, electrical conductivity (EC) at 27°C using Eutech PC-700, tabletop pH meter. Organic carbon was estimated by Walkley and Black [11] method, and free CaCO<sub>3</sub> status by Piper [12] method. The

available sulphur content of the soil was estimated using the 0.15% CaCl<sub>2</sub> extractant method [13].

### 2.4 Generation of Map

The Nagapattinam district map (1:50,000) was vectorized using Raster to Vector software (R<sub>2</sub>V) and then exported into Arc-GIS software. Database on soil available sulphur was developed using Microsoft Excel package. The database was exported to Arc GIS 9 software via dBase IV format, and the attribute table was geocoded using the mapping unit as the critical field.

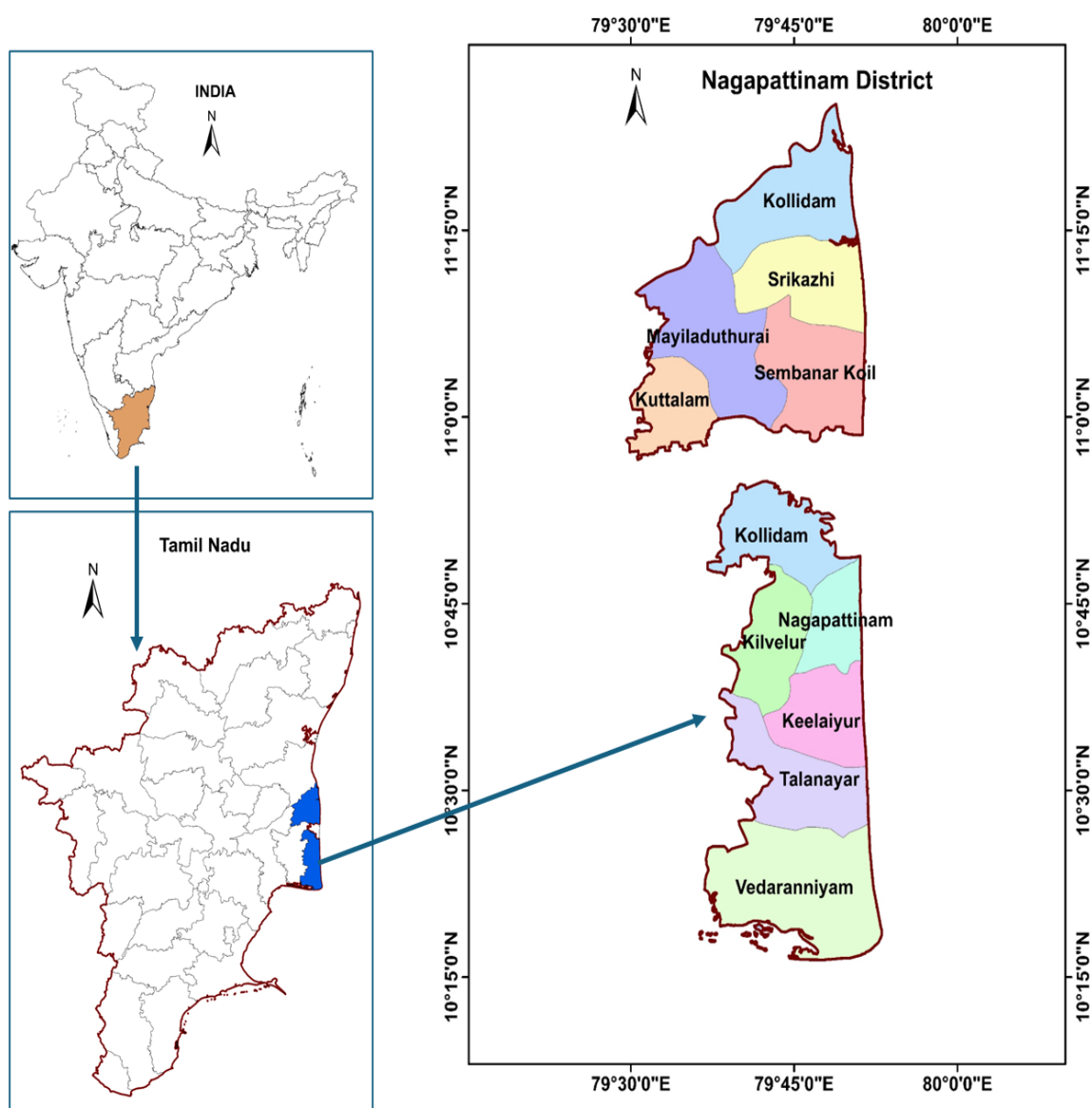
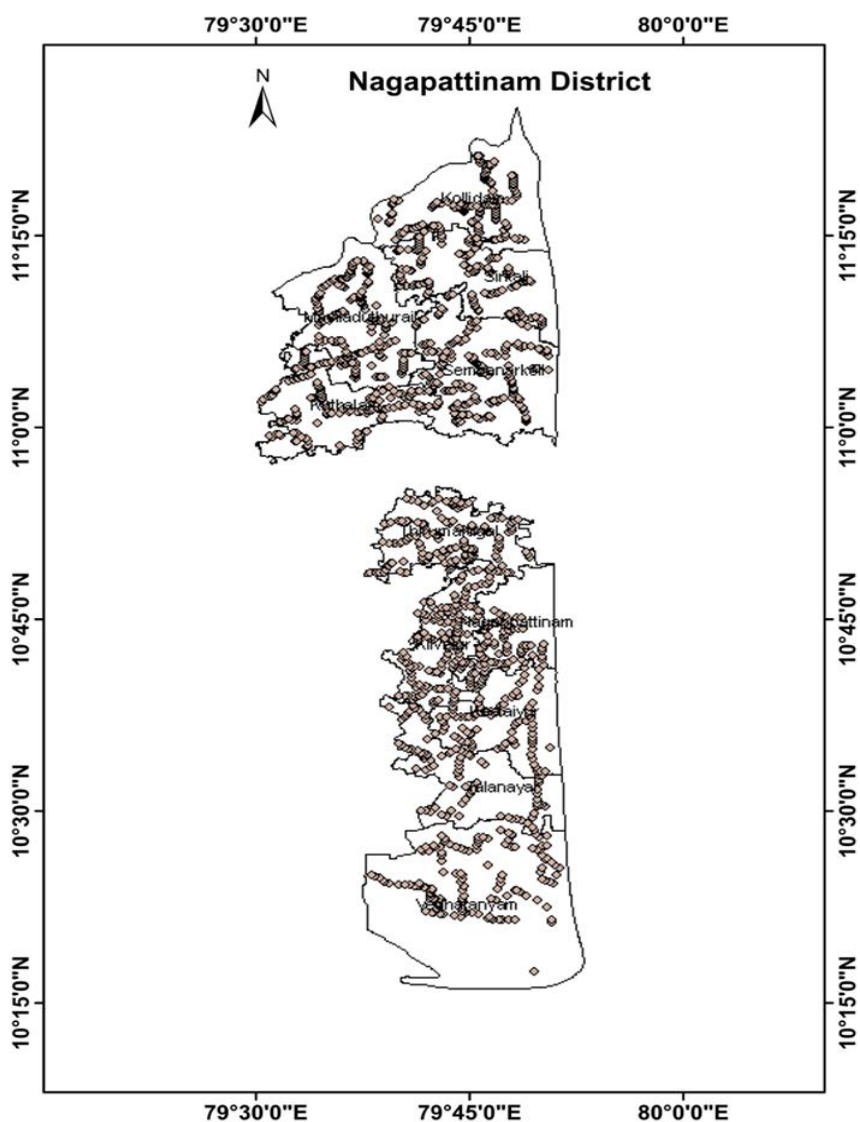


Fig. 1. Location map of Nagapattinam district (Tamil Nadu), India



**Fig. 2. Sampling point map**

### 3. RESULTS

Data on basic parameters like pH, EC, OC and free  $\text{CaCO}_3$  are presented in Table 1. Range and mean values of soil available sulphur status in different blocks of Nagapattinam district are presented in Table 2. The pH ranged from 3.90 to 9.60, with a mean value 6.63. The electrical conductivity (EC) of the soils varied from 0.079 to 2.59  $\text{dS m}^{-1}$  with a mean value of 0.404  $\text{dS m}^{-1}$ . The organic carbon content of soils ranged from 0.178 to 1.42 per cent, with a mean value of 0.717 per cent. Almost all the soils were moderately calcareous, with values ranging from 2.30 to 38.3 per cent and a mean value of 12.6 per cent.

The average available sulphur ( $\text{CaCl}_2\text{-S}$ ) content of the soils of Nagapattinam district ranged from 35.3 to 192  $\text{mg kg}^{-1}$  with a mean value of 84.8  $\text{mg kg}^{-1}$ , indicating that the entire soils of the district were high in available sulphur (Table 2). The highest mean soil available sulphur content was noticed in Nagapattinam (153  $\text{mg kg}^{-1}$ ) and Keelaiyur blocks (118  $\text{mg kg}^{-1}$ ). The lowest S content was found in the Mayiladuthurai block (49.2  $\text{mg kg}^{-1}$ ), followed by Vedaranyam (54.4  $\text{mg kg}^{-1}$ ) and Sirkazhi blocks (55.9  $\text{mg kg}^{-1}$ ). On average basis, all the blocks of Nagapattinam district revealed a sufficient sulphur status. However, some of the soil samples from Mayiladuthurai block exhibited S deficiency ( $<10 \text{ mg kg}^{-1}$ ) and a few from Vedaranyam block

showed medium S availability range (10 – 15 mg kg<sup>-1</sup>). A thematic map was prepared for available sulphur by considering the block means (Fig. 3).

The relationship between soil properties and sulphur was tested using the simple correlation tool [14].

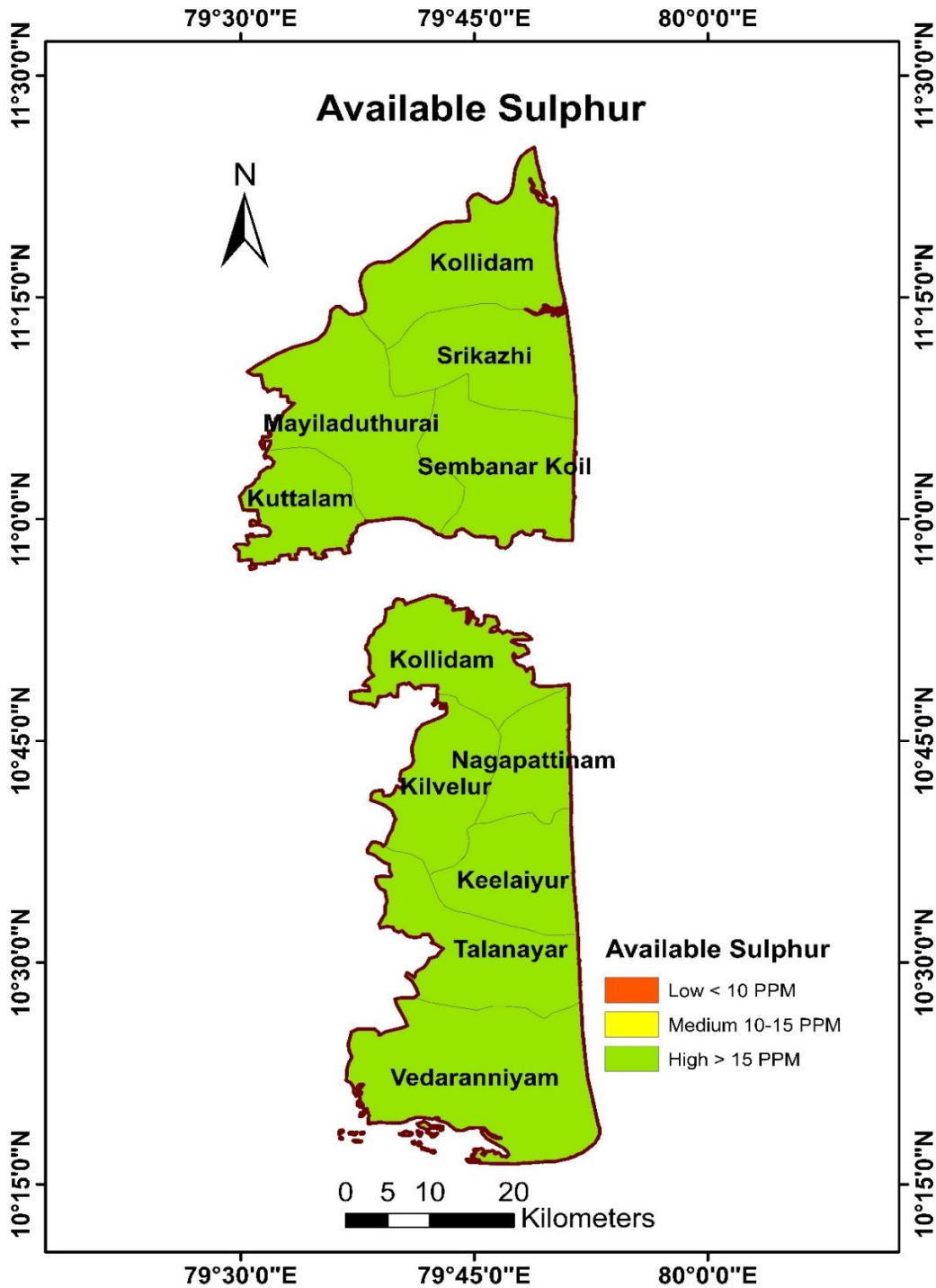


Fig. 3. Thematic map of the available sulphur status of Nagapattinam district

**Table 1. Range and mean values of soil properties in different blocks of Nagapattinam district**

S. No.	Name of the block	Soil properties			
		pH	EC (dS m <sup>-1</sup> )	OC (per cent)	CaCO <sub>3</sub> (per cent)
1	Vedaranyam	4.30 - 8.90(6.55)	0.060 - 2.50(0.168)	0.120 - 0.990(0.356)	1.00 - 26.0(9.07)
2	Nagapattinam	5.70 - 7.90(6.76)	0.080 - 8.03(1.14)	0.097 - 1.14(0.457)	3.00 - 39.0(11.1)
3	Keelaiyur	4.70 - 8.40(6.45)	0.110 - 6.29(1.31)	0.150 - 1.29(0.657)	5.00 - 24.0(13.6)
4	Talanayar	4.50 - 9.60(6.20)	0.060 - 6.12(0.571)	0.120 - 1.89(0.816)	2.30 - 44.0(12.1)
5	Kilvelur	6.00 - 8.10(7.13)	0.100 - 1.70(0.293)	0.300 - 1.20(0.729)	2.40 - 52.0(18.3)
6	Thirumarugal	3.90 - 8.60(6.18)	0.090 - 1.59(0.263)	0.120 - 1.26(0.568)	2.00 - 26.0(11.1)
7	Kuttalam	5.36 - 8.51(7.06)	0.070 - 0.800(0.104)	0.150 - 1.80(0.956)	2.00 - 65.0(20.6)
8	Kollidam	4.00 - 7.51(6.24)	0.060 - 0.220(0.105)	0.300 - 1.56(0.954)	2.00 - 27.0(6.11)
9	Mayiladuthurai	5.64 - 8.27(6.91)	0.070 - 0.190(0.104)	0.120 - 1.47(0.938)	1.60 - 13.4(8.36)
10	Sirkazhi	5.40 - 7.80(6.75)	0.070 - 0.560(0.154)	0.300 - 1.53(0.805)	2.00 - 85.0(18.0)
11	Sembanar Koil	5.20 - 7.80(6.65)	0.100 - 0.450 (0.228)	0.180 - 1.50 (0.654)	2.00 - 20.0 (10.3)
<b>Overall Mean</b>		<b>3.90-9.60(6.63)</b>	<b>0.079-2.59(0.404)</b>	<b>0.178-1.42(0.717)</b>	<b>2.30-38.3(12.61)</b>

( ) values in parentheses indicate the mean values

**Table 2. Range and mean values of soil available sulphur status in different blocks of Nagapattinam district**

S. No.	Name of the block	CaCl <sub>2</sub> - S(mg kg <sup>-1</sup> )
1	Vedaranyam	13.8 - 162(54.4)
2	Nagapattinam	97.5 - 238(153)
3	Keelaiyur	52.5 - 236(118)
4	Talanayar	26.3 - 214(79.4)
5	Kilvelur	17.5 - 238(101)
6	Thirumarugal	38.8 - 234(72.3)
7	Kuttalam	42.5 - 215(90.6)
8	Kollidam	30.0 - 238(81.2)
9	Mayiladuthurai	8.75 - 108(49.2)
10	Sirkazhi	27.5 - 100(55.9)
11	Sembanar Koil	33.8 - 139(77.3)
<b>Overall Mean</b>		<b>35.3-192(84.8)</b>

( ) values in parentheses indicate the mean values

## 4. DISCUSSION

### 4.1 Soil Reaction

The overall data on soil properties shows that soil was neutral in reaction. In some blocks such as Thirumarugal, Kollidam and Vedaranyam, a slightly acidic soil reaction was observed (< 4.00), which may be due to more leaching of bases by heavy rainfall during monsoon season at coastal regions [15]. The high alkaline soil reaction observed in the soils of the Talanayar block (> 9.60) may be due to the high CaCO<sub>3</sub> content in the surface soils of these regions.

### 4.2 Electrical Conductivity

Predominantly low soil salinity hazards (0.404 dS m<sup>-1</sup>) were noticed in the entire Nagapattinam district, which may be due to the application of acidulating fertilizers in salt-affected areas and more leaching of bases [16]. More than 90.0 per cent % of the soil samples were found to have low salt concentration, and few blocks viz. Nagapattinam (8.03 dS m<sup>-1</sup>), Keelaiyur (6.29 dS m<sup>-1</sup>) and Talanayar (6.12 dS m<sup>-1</sup>) showed higher electrical conductivity, which might be due to seawater intrusion in these coastal regions and a similar observation was reported by Choudhary et al. [17].

### 4.3 Organic Carbon

The highest organic carbon content was evidenced in the soils of Kuttalam, Kollidam and Mayiladuthurai blocks, possibly due to high organic matter addition through crop residues, green manures and their decomposition [18]. Further, rice is the predominant crop grown in these blocks; hence, the contribution from root biomass also accounted for higher carbon status in the soils. Similarly, low carbon status was observed in Vedaranyam, Nagapattinam and Thirumarugal blocks, which might be attributed to erosion, leaching, rapid oxidation and decomposition of organic matter [19]. Generally, the organic matter content of coastal soils is relatively high compared to non-coastal soils under coastal humid climatic conditions. Such data are comparable to Bandyopadhyay et al. [20] and Ghosh et al. [21].

#### 4.3.1 Free CaCO<sub>3</sub>

The average free calcium carbonate status in the soils of different blocks revealed 'Moderately

calcareous'. Higher free calcium carbonate content observed in Kuttalam, Sirkazhi and Kilvelur blocks may be due to more lime deposition in and around the clay particles or calcification, as Pandey et al. [22] outlined.

#### 4.3.2 CaCl<sub>2</sub>-S

All the blocks of the Nagapattinam district were found to have high sulphur content on average (Fig. 3 & Table 2). This high S content could be attributed to the high organic carbon content and heavy texture of the soils in contrast to Entisol and Inceptisol, where poor infiltration retarded the loss of sulphur through leaching [23]. However, lower sulphur availability was noticed in some samples from Mayiladuthurai block (<10 mg kg<sup>-1</sup>). Similarly, a few samples from the Vedaranyam block showed the S content, which comes under the medium availability range (10 – 15 mg kg<sup>-1</sup>). The special status of these two blocks with lower S content could be ascribed to the soils' low organic carbon and coarse texture, conducive to enhanced leaching by heavy rainfall [24]. The average available sulphur was found to be in the range of 54.4 to 153 mg kg<sup>-1</sup>. Higher availability of sulphur with a combined average of 84.8 mg kg<sup>-1</sup> was noticed in the soils of the entire district and could be attributed to the high organic carbon content and heavy texture of the soils.

## 5. CONCLUSION

From the present study, it can be concluded that the chemical properties such as pH, EC, organic carbon and free CaCO<sub>3</sub> content of the soils were ideal for growing all the crops in this region, and sufficient availability of sulphur was noticed in all the blocks of Nagapattinam district. It also confirms that a wide range of cereals, fruit crops, vegetable crops and plantation crops can be grown in this soil type.

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### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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