

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

**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, 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  $\text{CaCO}_3$ . 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  $\text{mg kg}^{-1}$ . Higher availability of sulphur with a combined average of 84.8  $\text{mg kg}^{-1}$  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.

## 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 (Zenda et al., 2021; Narayan et al., 2023). 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 (Arunkumar et al., 2024; Palaniswami et al., 2011, Tsuji et al., 2005). Fertilizer is one of the costliest inputs in agriculture, and using the right amount of fertilizer is

33 fundamental for farm profitability and environmental protection (Mahendra, 2010). GIS  
34 generated soil fertility maps may serve as a decision-support tool for nutrient management  
35 (Iftikar et al., 2010, Rodríguez-Lado L & Macías F, 2006). The importance of sulphur from a  
36 crop production point of view is well known. Hence, the study attempted to create a data bank  
37 and thematic map for available sulphur in Nagapattinam district using GIS to suggest suitable  
38 management strategies and site-specific nutrient management. Geo-referenced surface soil  
39 samples covering 11 blocks in Nagapattinam district were collected randomly and analyzed for  
40 various soil properties to correlate with nutrient availability.

## 41 **Materials and Methods**

42 **Study Area:** Nagapattinam is the 4th largest district, lies on the east coast of Tamil Nadu, with a  
43 total geographical area of 2,58,136 ha and lies between 100 16' and 110 25' degrees north and  
44 790 30' and 800 01' degrees east longitude (Fig.1). The district consists of 11 blocks viz.  
45 Vedaranyam, Nagapattinam, Keelaiyur, Talanayar, Kilvelur, Thirumarugal, Kuttalam, Kollidam,  
46 Mayiladuthurai, Sirkazhi, Sembanar Koil and 7 talukas. Soil is predominantly sandy in texture,  
47 and clayey is present in certain pockets, with slight salinity and alkalinity. Sand dunes dominate  
48 the area between Nagapattinam and Vedaranyam, and the soil under cultivation is mostly sandy  
49 in texture (Chaudhary et al., 2006). The major area is covered under the wealthy Cauvery delta  
50 zone; the rest is the coastal zone. The climate of the study area is semi-arid and receives a mean  
51 annual rainfall of 1337 mm. The mean annual air temperature is 31.17<sup>0</sup> C. The major crops  
52 grown in this region are Rice, Sugarcane, Coconut, Mango, Casurina, Brinjal and Cashew, with  
53 vegetable crops such as brinjal, lady's finger, chilli, cucumber, melons, gourds, and fruit crops  
54 like mango, cashew, guava, and sapota are also raised in lesser extent (Chaudhary et al., 2006).

55 **Soil Sampling:** The GPS data (Latitude °N and Longitude °E) were collected from each  
56 sampling site distributed over the entire Nagapattinam district using the Garmin GPS 76CS  
57 model. Locations of soil sampling sites of Nagapattinam district were marked on the base map  
58 on 1: 50,000 scales prepared from State Revenue Maps and digitized using Arc-info GIS. For  
59 taking soil samples, surface litter was removed and a 'V' shaped cut to a depth of 15 cm was  
60 made in the sampling spot. Soil from top to bottom of exposed face of the 'V' shaped cut (0 to  
61 15 cm depth) was sliced and collected in sampling bags (Pal, 2013). All the samples were  
62 collected during summer to avoid seasonal variations and processed after shade drying. They  
63 were pounded, ground using a wooden mallet, passed through a 2 mm sieve, and analyzed for  
64 various physicochemical properties. The sampling station map is shown in Figure 2.

65 **Soil Analysis:** The soil samples collected during the survey were processed after shade drying  
66 and passed through a 2 mm sieve and analyzed for pH, electrical conductivity (EC) at 27°C using  
67 Eutech PC-700, tabletop pH meter. Organic carbon was estimated by Walkley and Black (1934)  
68 method, and free CaCO<sub>3</sub> status by Piper (1966) method. The available sulphur content of the soil  
69 was estimated using the 0.15% CaCl<sub>2</sub> extractant method (Williams and Steinbergs, 1959).

## 70 **Generation of map**

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

## 75 **Results**

76 Data on basic parameters like pH, EC, OC and free CaCO<sub>3</sub> are presented in Table 1. Range and  
77 mean values of soil available sulphur status in different blocks of Nagapattinam district are  
78 presented in Table 2. The pH ranged from 3.90 to 9.60, with a mean value 6.63. The electrical  
79 conductivity (EC) of the soils varied from 0.079 to 2.59 dS m<sup>-1</sup> with a mean value of 0.404  
80 dS m<sup>-1</sup>. The organic carbon content of soils ranged from 0.178 to 1.42 per cent, with a mean  
81 value of 0.717 per cent. Almost all the soils were moderately calcareous, with values ranging  
82 from 2.30 to 38.3 per cent and a mean value of 12.6 per cent.

83 The average available sulphur (CaCl<sub>2</sub>-S) content of the soils of Nagapattinam district ranged  
84 from 35.3 to 192 mg kg<sup>-1</sup> with a mean value of 84.8 mg kg<sup>-1</sup>, indicating that the entire soils of the  
85 district were high in available sulphur (Table.2). The highest mean soil available sulphur content  
86 was noticed in Nagapattinam (153 mg kg<sup>-1</sup>) and Keelaiyur blocks (118 mg kg<sup>-1</sup>). The lowest S  
87 content was found in the Mayiladuthurai block (49.2 mg kg<sup>-1</sup>), followed by Vedaranyam (54.4  
88 mg kg<sup>-1</sup>) and Sirkazhi blocks (55.9 mg kg<sup>-1</sup>). On average basis, all the blocks of Nagapattinam  
89 district revealed a sufficient sulphur status. However, some of the soil samples from  
90 Mayiladuthurai block exhibited S deficiency (<10 mg kg<sup>-1</sup>) and a few from Vedaranyam block  
91 showed medium S availability range (10 – 15 mg kg<sup>-1</sup>). A thematic map was prepared for  
92 available sulphur by considering the block means (Figure 3). The relationship between soil  
93 properties and sulphur was tested using the simple correlation tool (Das et al. 2021).

94 **Discussion**

95 ***Soil reaction***

96 The overall data on soil properties shows that soil was neutral in reaction. In some blocks such as  
97 Thirumarugal, Kollidam and Vedaranyam, a slightly acidic soil reaction was observed ( $< 4.00$ ),  
98 which may be due to more leaching of bases by heavy rainfall during monsoon season at coastal  
99 regions (Mini et al., 2007). The high alkaline soil reaction observed in the soils of the Talanayar  
100 block ( $> 9.60$ ) may be due to the high  $\text{CaCO}_3$  content in the surface soils of these regions.

101 ***Electrical conductivity***

102 Predominantly low soil salinity hazards ( $0.404 \text{ dS m}^{-1}$ ) were noticed in the entire Nagapattinam  
103 district, which may be due to the application of acidulating fertilizers in salt-affected areas and  
104 more leaching of bases (Kumaraperumal, 2006). More than 90.0 per cent % of the soil samples  
105 were found to have low salt concentration, and few blocks viz. Nagapattinam ( $8.03 \text{ dS m}^{-1}$ ),  
106 Keelaiyur ( $6.29 \text{ dS m}^{-1}$ ) and Talanayar ( $6.12 \text{ dS m}^{-1}$ ) showed higher electrical conductivity,  
107 which might be due to seawater intrusion in these coastal regions and a similar observation was  
108 reported by Choudhary et al., (2008).

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110 ***Organic carbon***

111 The highest organic carbon content was evidenced in the soils of Kuttalam, Kollidam and  
112 Mayiladuthurai blocks, possibly due to high organic matter addition through crop residues, green  
113 manures and their decomposition (Bayala et al., 2007). Further, rice is the predominant crop  
114 grown in these blocks; hence, the contribution from root biomass also accounted for higher  
115 carbon status in the soils. Similarly, low carbon status was observed in Vedaranyam,  
116 Nagapattinam and Thirumarugal blocks, which might be attributed to erosion, leaching, rapid  
117 oxidation and decomposition of organic matter (Saha et al., 1996). Generally, the organic matter  
118 content of coastal soils is relatively high compared to non-coastal soils under coastal humid  
119 climatic conditions. Such data are comparable to Bandyopadhyay et al. (1998) and Ghosh et al.  
120 (2007).

121 ***Free  $\text{CaCO}_3$***

122 The average free calcium carbonate status in the soils of different blocks revealed 'Moderately  
123 calcareous'. Higher free calcium carbonate content observed in Kuttalam, Sirkazhi and Kilvelur  
124 blocks may be due to more lime deposition in and around the clay particles or calcification, as  
125 Pandey et al. (2000) outlined.

#### 126 *CaCl<sub>2</sub>-S*

127 All the blocks of the Nagapattinam district were found to have high sulphur content on average  
128 (Fig.3 & Table 2). This high S content could be attributed to the high organic carbon content and  
129 heavy texture of the soils in contrast to Entisol and Inceptisol, where poor infiltration retarded  
130 the loss of sulphur through leaching (Borkotoki and Das, 2008). However, lower sulphur  
131 availability was noticed in some samples from Mayiladuthurai block (<10 mg kg<sup>-1</sup>). Similarly, a  
132 few samples from the Vedaranyam block showed the S content, which comes under the medium  
133 availability range (10 – 15 mg kg<sup>-1</sup>). The special status of these two blocks with lower S content  
134 could be ascribed to the soils' low organic carbon and coarse texture, conducive to enhanced  
135 leaching by heavy rainfall (Takkar,1987). The average available sulphur was found to be in the  
136 range of 54.4 to 153 mg kg<sup>-1</sup>. Higher availability of sulphur with a combined average of 84.8 mg  
137 kg<sup>-1</sup> was noticed in the soils of the entire district and could be attributed to the high organic  
138 carbon content and heavy texture of the soils.

#### 139 **Conclusion**

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

145 Disclaimer (Artificial intelligence)

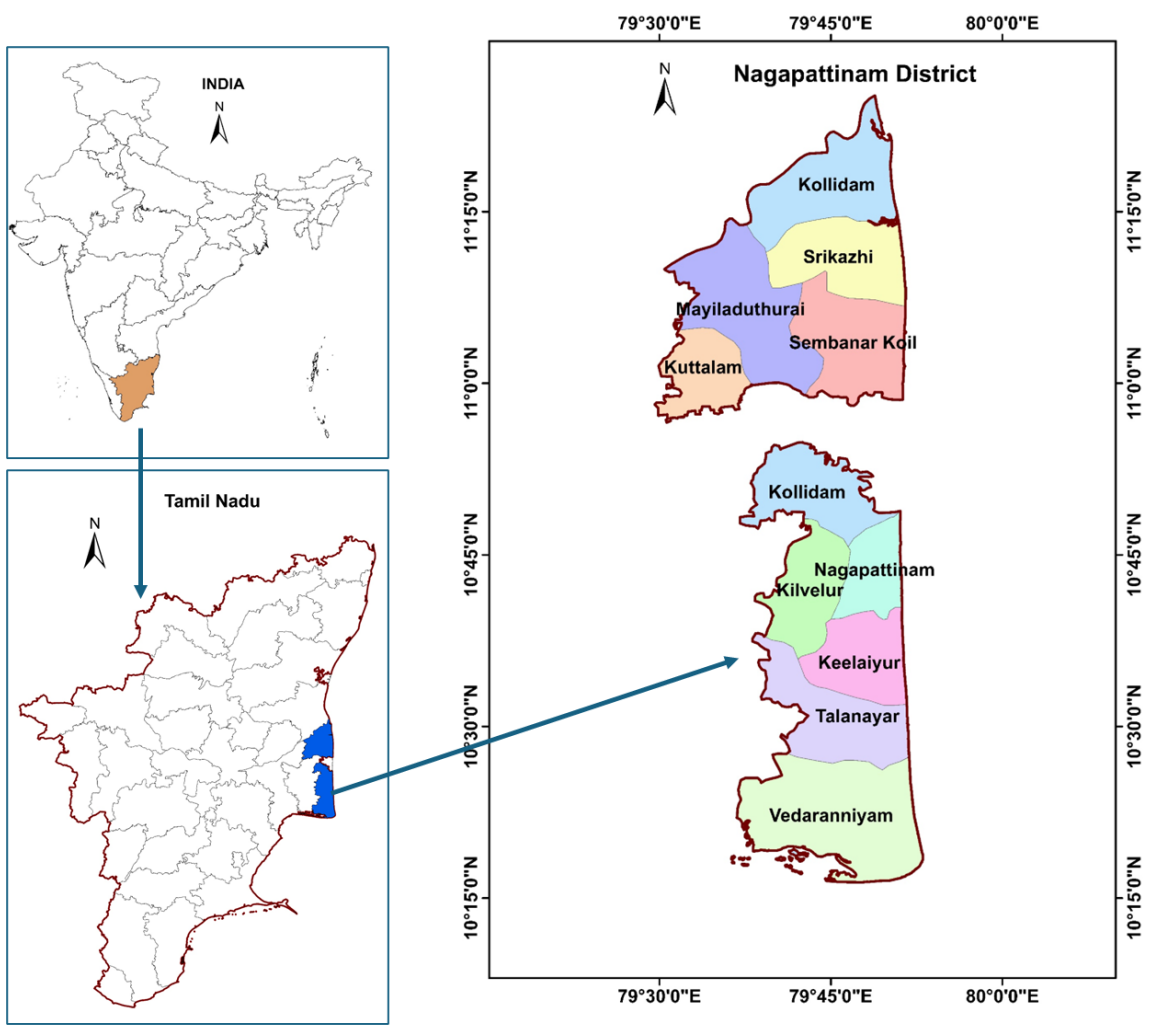
146 Option 1:

147 Author(s) hereby declare that NO generative AI technologies such as Large Language Models  
148 (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or  
149 editing of manuscripts.

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151 Author(s) hereby declare that generative AI technologies such as Large Language Models, etc  
152 have been used during writing or editing of manuscripts. This explanation will include the name,  
153 version, model, and source of the generative AI technology and as well as all input prompts  
154 provided to the generative AI technology  
155 Details of the AI usage are given below:

- 156 1.
- 157 2.
- 158 3.



159  
160 Figure 1. Location map of Nagapattinam district (Tamil Nadu), India.

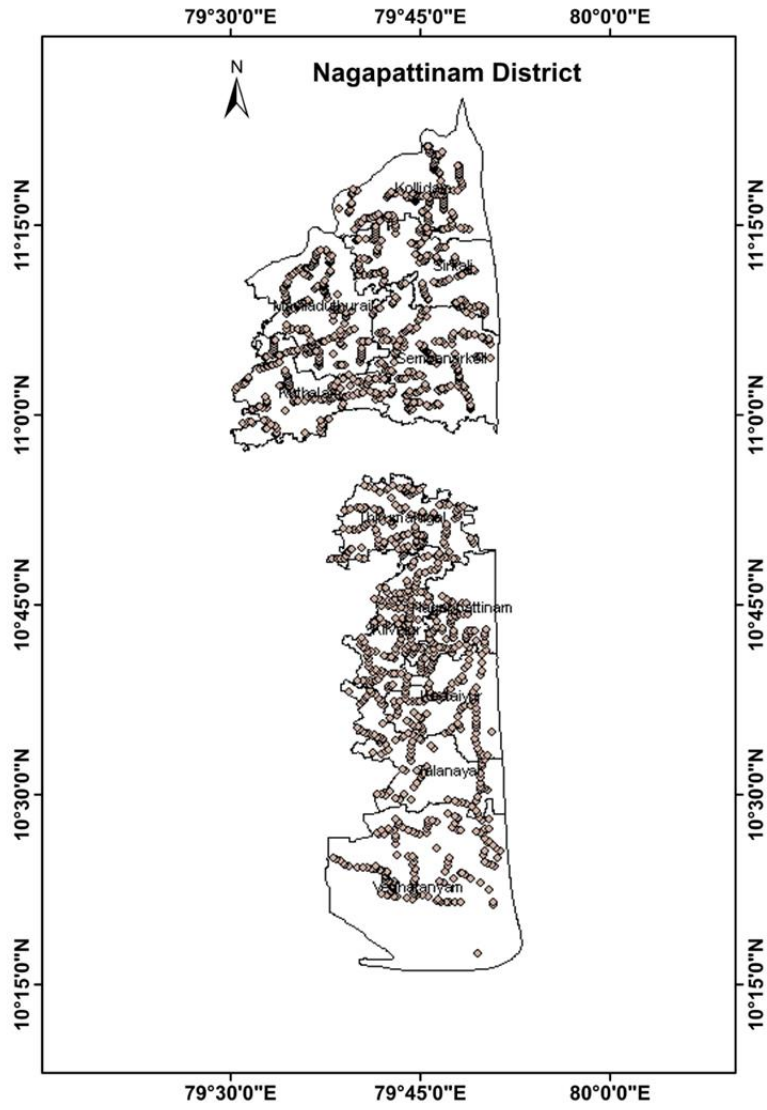
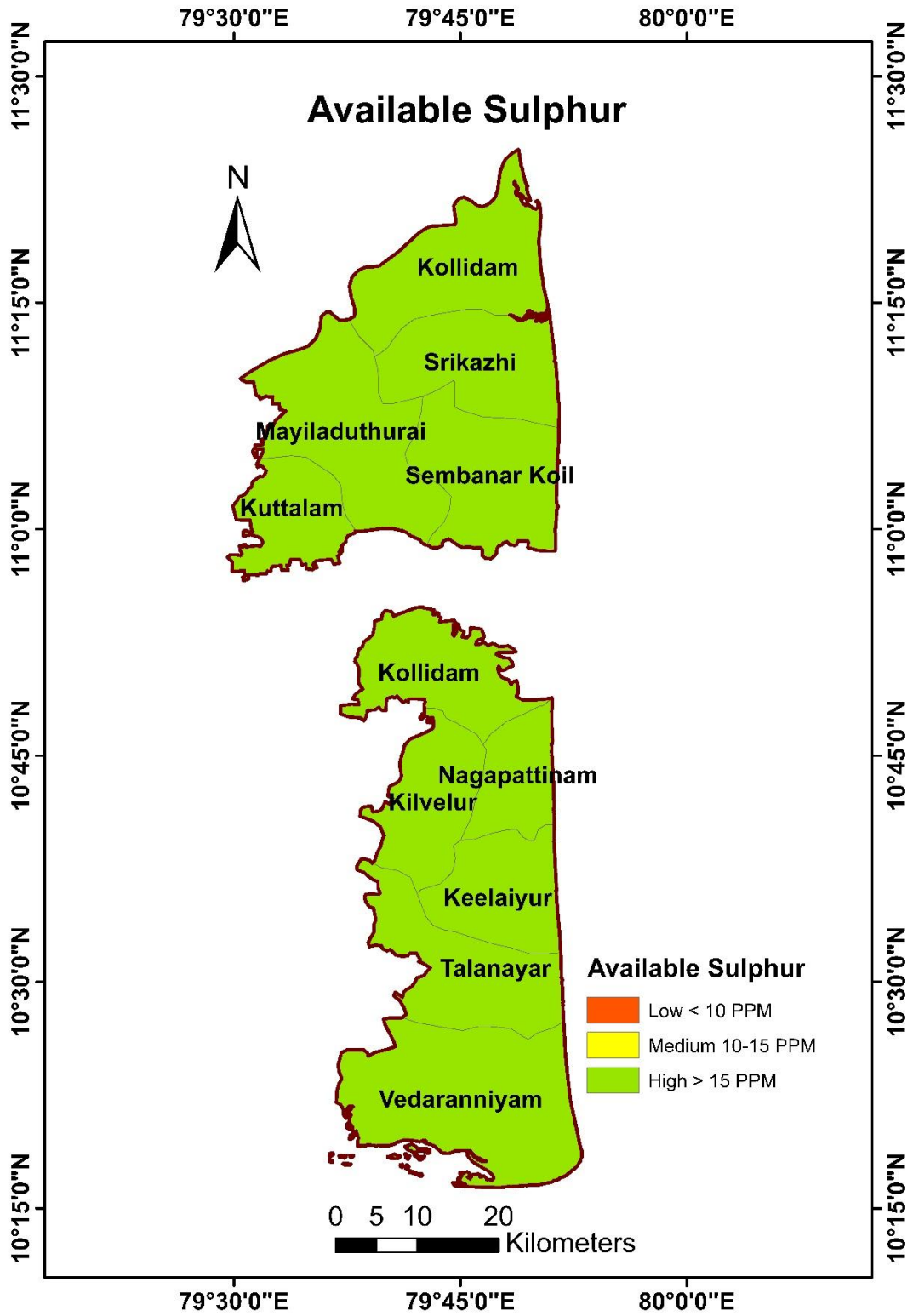


Figure 2. Sampling point map

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Figure 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</b> <b>(6.63)</b>	<b>0.079-2.59</b> <b>(0.404)</b>	<b>0.178-1.42</b> <b>(0.717)</b>	<b>2.30-38.3</b> <b>(12.61)</b>

( ) values in parentheses indicate the mean values

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

174 ( ) values in parentheses indicate the mean values

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