Assessment of soil fertility and creation of thematic mapping in the coastal soils of Ramanathapuram block, Ramanathapuram district in Tamil Nadu, India

ABSTRACT

Aims: A view of the current analysis used GPS and GIS techniques to evaluate and map the soil fertility status of the Ramanathapuram block in the Ramanathapuram district of Tamil Nadu, India.

Study design: In this study, a systematic set of 100 georeferenced soil samples were collected from 100 selected villages and analyzed for 10 chemical parameters and the data along with GPS readings were used for the preparation of soil fertility maps using GIS.

Methodology: Hundred soil samples were collected from the sixteen revenue villages of Ramanathapuram block, Ramanathapuram district, Tamil Nadu during the pre-monsoon season with lat-long coordinates by using GPS to evaluate the soil fertility. Ramanathapuram block is the middle- coastal block of Ramanathapuram district of Tamil Nadu.

Results: In the present study, the mean soil values of pH (8.16), EC (0.74 dSm^{-1}), organic carbon content (2.52 g/kg), Available N (159.36$kgha^{-1}$), Available P (30.83 $kgha^{-1}$), Available K (355.39$kgha^{-1}$) and (Di-Ethylene Triamine Penta Acidic Acid DTPA) extractable micronutrients *viz.,*Fe (7.21), Zn (0.16), Mn (6.46) and Cu (1.36) ppm were recorded respectively in Ramanathapuram block of Ramanathapuram district. Thematic maps pertaining to soil fertility were prepared using Arc GIS software 10.1.

Conclusion: The georeferenced sampling sites can be revisited with the help of GPS, which helps in monitoring the soil fertility changes over long run. Further, it will be useful to the researchers, planners, policymakers, extension workers of the State Department of Agriculture, fertilizer industries, and farmers.

Keywords: pH, EC, organic carbon, available NPK, and DTPA extractable micronutrients

Introduction

Agriculture is an imperative sector for the sustained growth of the Indian economy. About 70 percent of rural households and eight percent of urban households are still dependent on agriculture for employment. Soil is the basic natural resource for agriculture and it supplies essential nutrients for plant growth, the food security and necessary components of human and animal food, and the nutritional security of the country. However continuous cropping of high-yielding varieties without proper substitution of inorganic fertilizers or organic manures/ composts

and non-addition of micronutrients have caused excessive removal of essential nutrients from the soil solution/ reserves that eventually led to the deficiencies of major, secondary, and in particularly micronutrients in soils. The deficiency may either be primarily due to their low contents or secondarily by soil factors that reduce the availability (Sharma and Chaudhary, 2007). Global Positioning System (GPS) and Geographical Information System (GIS) help in collecting a systematic set of geo-referenced samples and generating spatial data about the distribution of nutrients (Sharma, 2004). The estimation, characterization, and comparison of spatial variation of micronutrients are important issues in site-specific crop management, precision farming, and sustainable agriculture (Nayak *et al*., 2006). Soil nutrient maps covering large areas improve understanding of the nature and extent of nutrient problems and aid in determining their relationships with climate, soil properties, and soil genetic characteristics determined at similar scales. Intermediate scale maps can be useful in delineating specific areas where deficiencies or toxicities are likely for agriculture, and in determining localized soil characteristics that may be associated with such problems. The thematic maps for individual nutrient (Fe, Zn, Mn, and Cu) is prepared by using GIS software (Minakshi *et al.*, 2005 and Nayak *et al.*, 2006) and multi micronutrient maps are generated by integrating individual maps of Fe, Zn, Mn and Cu in the GIS (Sood *et al.,* 2004). This will also help in monitoring changes in micronutrient status over a period of time.

Materials and Methods

Hundred soil samples were collected from the sixteen revenue villages of Ramanathapuram block, Ramanathapuram district, Tamil Nadu during the pre-monsoon season with lat-long coordinates by using GPS to evaluate the soil fertility. Ramanathapuram block is the middle- coastal block of Ramanathapuram district of Tamil Nadu. It lies between 9.05° 'to 9.50°' North latitudes and 78.10° 'to 79.27° 'East longitudes at an elevation of 2 m. The Geographical area of this Ramanathapuram district has an area is 4,123 km^2 of rural and urban areas. The main source of irrigation is the Sarugani River, Manimuthar River, Vaigai River, and Vaippar River in the Ramanathapuram district. The total cropped area of the district/ zone is 1,72,469 ha (as per 2016-17 G-return). The area under irrigated agriculture is 63,800 ha, while 1,37,099 hectares is under rainfed Agriculture. The major food grain crops cultivated are Paddy (*Oryza sativa*), cholam(*Zea mays*), cumbu(*Pennisetum glaucum*), Ragi (*Eleusine coracana*)and Blackgram(*Vigna mungo L.*). Cotton (*Gossypium hirsutum*) is the major non-food crop grown.

To delineate the soil fertility, 100 soil samples were collected during the pre-monsoon seasons., in July 2019. The samples were collected in such a manner that they represent the soil fertility of all the revenue villages and the overall soil fertility of the Ramanathapuram block. The soil samples were collected randomly with GPS coordinates. From each revenue village, a minimum of two to a maximum of twenty-four soil samples were collected, properly labeled, and brought to the laboratory for further chemical analysis. Soil samples were collected from Ramanathapuram block, fields were collected from 2 depths i.e. 0-15 cm depth in polythene bags. The soil collected from each depth was mixed, dried, crushed, and sieved with a 2 mm sieve. The prepared soil samples were then stored in polyethylene bags for analysis.

The collected soil samples were analyzed for various parameters by adopting the standard procedures *viz.,* pH by Potentiometry (Jackson, 1958), EC by Conductometry (Jackson 1973), Available Nitrogen by Alkaline Permanganate method (Subbiah and Asija, 1956), Available Phosphorus 0.5 M $NaHCO_3$ extract (Olsen, 1965), Available Potassium by Neutral Normal (1.0 N) Ammonium Acetate extraction method(Stanford and English, 1949), Organic carbon by Chromic acid wet digestion method (Walkley and Black, 1934) and DTPA extractable micronutrients by Atomic Adsorption spectrophotometer (AAS), (Lindsay and Norwell, 1978). Thematic maps pertaining to soil fertility were prepared using Arc GIS software 10.8. Database on soil available nutrient status was generated in Microsoft Excel package at TNAU and the soil fertility maps were prepared at the Indian Institute of Soil Science, Bhopal by using Arc-GIS software version 10.8. The thematic maps on available nutrient status were generated by categorizing the fertility status as 'low', 'medium', and 'high' by showing appropriate legend for OC and available N, P, and K; 'deficient', 'moderate' and 'sufficient' for available DTPA micronutrients. The analytical results of each soil sample were categorized as a low, medium, and high categories for OC and macronutrients and as deficient, moderate, and sufficient based on the critical limits for available micronutrients as followed in Tamil Nadu.

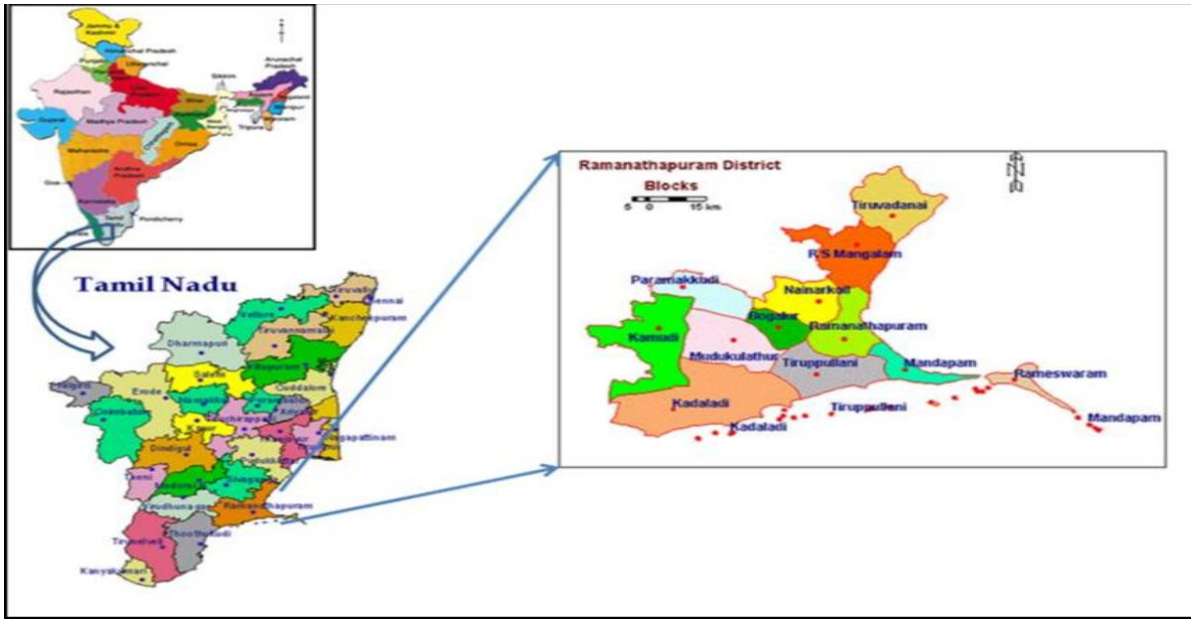


Fig.1. Location map of the study area

Results and Discussion

Soil fertility status of Ramanathapuram block

pH and Electrical Conductivity

The pH (Table 1) of the soil ranged from 6.07 to 9.81 with a mean of 8.16, respectively. Among the revenue villages, the lowest pH of 6.07 has recorded in Therkutharavai which was followed by 6.35 at Ramanathapuram. The highest pH of 9.81 has recorded in peravoor which was followed by 9.65 at kavanoor. Around 73 percent of samples were fallen under Neutral category (pH 6.0-8.5), 27 percent in the Alkaline category, and 0 percent in the Acidic category. The soils of the Ramanathapuram block were predominantly neutral to alkaline. The variation in pH may be due to the inherent heterogeneity of soils and also due to the nature of parent material and differences in cultural and fertilizer management practices (Vijayakumar *et al.,* 2015).

The EC of the soil ranged from 0.05 to 8.88 dS m^{-1} with a mean of 0.74 dS m^{-1}**,** respectively. Among the revenue villages, the lowest EC of 0.05 dS m^{-1} has recorded in Madakottan which was followed by 0.06 dS m^{-1} at Therkutharavai. (Table1) The highest EC of 8.88 dS m^{-1} has recorded in Ramanathapuram which was followed by 6.45 dS m^{-1} at pullankudi. Around 80 percent of samples were fallen under Non – the saline category (<1.0 dS m^{-1}), 13 percent in the slightly saline category, 2 percent in the moderately saline category, and 5 percent in the saline category. The soil samples might be due to proper management and inherent properties of soil as also reported by Sharma *et al*. (2008). The soil samples analyzed were found to be non-saline in nature, which might be attributed to light textured soils resulting in free drainage (Verma *et al.,* 2005; Vijayakumar *et al.,* 2015).

Organic carbon (g kg^{-1})

The overall OC status of the soil (Table 2) ranged from 0.60 to 8.70 gkg^{-1} with a mean value of2.52 gkg^{-1}. Among the revenue villages, the lowest OC of 0.60gkg^{-1}have recorded in both Therkutharavai, Ramanathapuram and Kavanoor which was followed by 0.70 gkg^{-1}at Kusavankudi and Madakottan. The highest OC of 8.70 gkg^{-1}recorded at Chidharkottai which was followed by Pullangudi (6.60 gkg^{-1}) and Melakottai (6.30 gkg^{-1}). About 95 percent of the soil samples in the Ramanathapuram block mostly belong to the Mandapam Soil series which is having loamy sand texture (Very coarser in texture) and with less cultivation due to less water availability which may cause less organic carbon content in the block. The low organic carbon status is primarily due to high temperature leading to a higher rate of organic matter decomposition (Kameriya 1995) and also due to little or no organic matter additions (Rego *et al.* 2003).

Available N, P, and K

The overall available N status (Table 3) ranged from 42 to 455 kg ha^{-1} with a mean value of 159kg ha^{-1}. Similar to OC, a major percentage of soil samples (95%) were under low status. The minimum available N of 42kg ha^{-1}has recorded in Sathankulam which was followed by 45 kg ha^{-1}at Kusavankudi. The maximum available N of 455kg ha^{-1}recorded at Chidarkottai which was followed by Melakottai (328kg ha^{-1}). Around 95 percent of samples were fallen under the low category (<280 $kgha^{-1}$), 5 percent in the medium category, and 95 percent in the low category. As the majority of soils are alkaline in nature and

have a light texture, the applied fertilizers would have been subjected to various losses which resulted in the low amount of available N in the soil. This might be due to the fact that being alkaline in the major area of the district, applied N in soil is lost through various mechanisms like ammonia volatilization, nitrification succeeding denitrification, chemical and microbial fixation, leaching, and runoff (De Datta and Buresh1989) which would have resulted in a low amount of available N in the soil. The flooded condition during the monsoon leads to leaching losses and barren soil after the monsoon leads to volatilization losses in the district.

The Olsen-P (Table 3) ranged from 7.2 to 89.6kg ha^{-1} with an overall mean value of 30.8kg ha^{-1}, respectively. Among the revenue villages, the lowest available P of 7.2kgha^{-1}has was recorded in Devipattinam which was followed by 9.40kgha^{-1}at Chidharkottai. The highest available N of 89.6kgha^{-1}recorded at Madakottan which was followed by Ramanathapuram and Peravoor (78.4kgha^{-1}). Around 68 percent of samples were fallen under high category (> 22 kgha^{-1}), 22 percent in the medium category and 10 percent in low category. The highest P percentage might be due to the continuous application of rice crop cultivation for a prolonged period with the application of Di-Ammonium Phosphate (DAP) that would have built-up soil available P status. High status of P in the majority of the soils might be attributed to continuous application phosphatic fertilizers to crops which would have resulted in a slow build-up phosphorus data as the efficiency of applied P is very low (Aulakh and Pasricha, 1999).

The range of available K was 245.60 to 462.20kg ha^{-1} with a mean of 355.39kg ha^{-1} and the percent sample category under low, medium, and high was nil, 6, and 94%, respectively. The minimum available N of 246kg ha^{-1}has recorded in Kavanoor which was followed by 247 kg ha^{-1}at Ramanathapuram. The maximum available N of 462kg ha^{-1}recorded at Ramanathapuram which was followed by Pullangudi (461kg ha^{-1}). 'High' available K in these soils may be attributed due to the continuous drain of K from the soil reserve over the years with an inadequate supply of chemical fertilizers to meet the crop need, mining of K has started appearing in the soils which is a matter of concern. This shows that if a sufficient quantity of potassium is not added externally there will be potassium mining from the soil. These results are in confirmation by the findings of Bhangu and Sidhu, (1991), and Naidu *et al.* (2011).

Available micronutrients

The available Fe status (Table 4) varied from 1.5 to 19.8 ppm with a mean of 7.2 ppm. Deficient, moderate, and sufficient Fe status was noticed in 31, 36, and 33% of the samples, respectively. Among the revenue villages, the lowest DTPA- Fe of 1.5 ppm has recorded in Valantharavai and Ramanathapuram which was followed by 1.9 ppm at Therkutharavai. The highest DTPA-Fe of 19.8 ppm was recorded at Thoruvalurand followed by Kavanur (19.5 ppm). This might be due to precipitation of Fe^{2+} in higher pH of the sodic soils in these soils which was also reported by Verma *et al.* (2007). Similar results were also reported for villages of northern Madhya Pradesh by Rajput *et al.* (2015), Karajanagi *et*

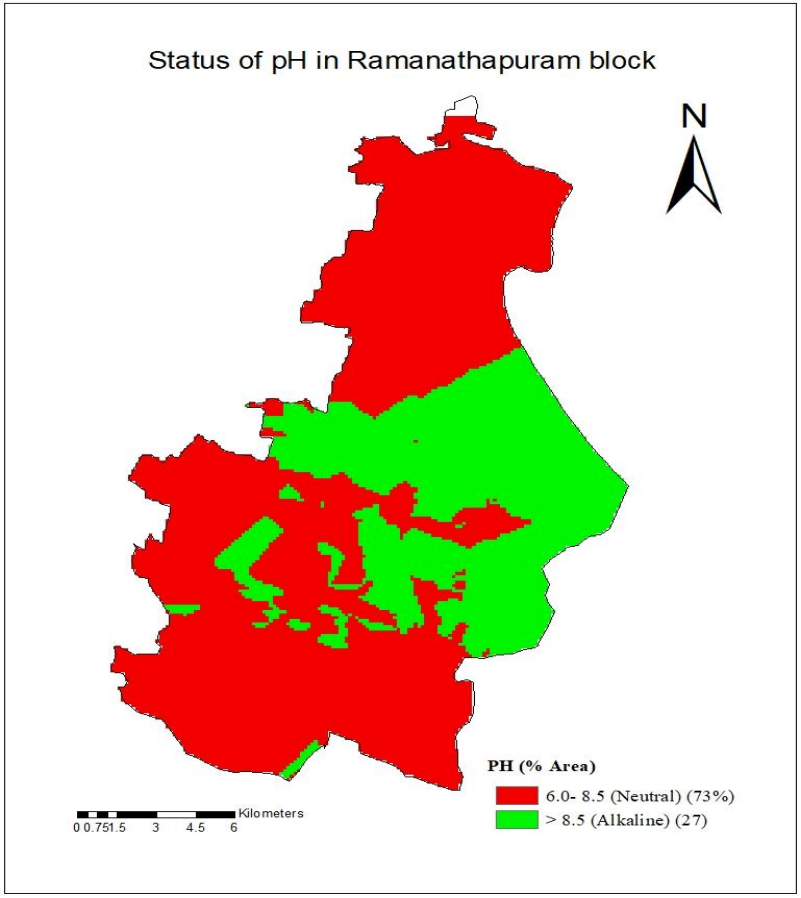
al. (2016) for the Malaprabha command area of Karnataka, for Patan district by Patel *et al.* (2016), Wagh *et al.* (2016) for Nagpur district of Maharashtra.

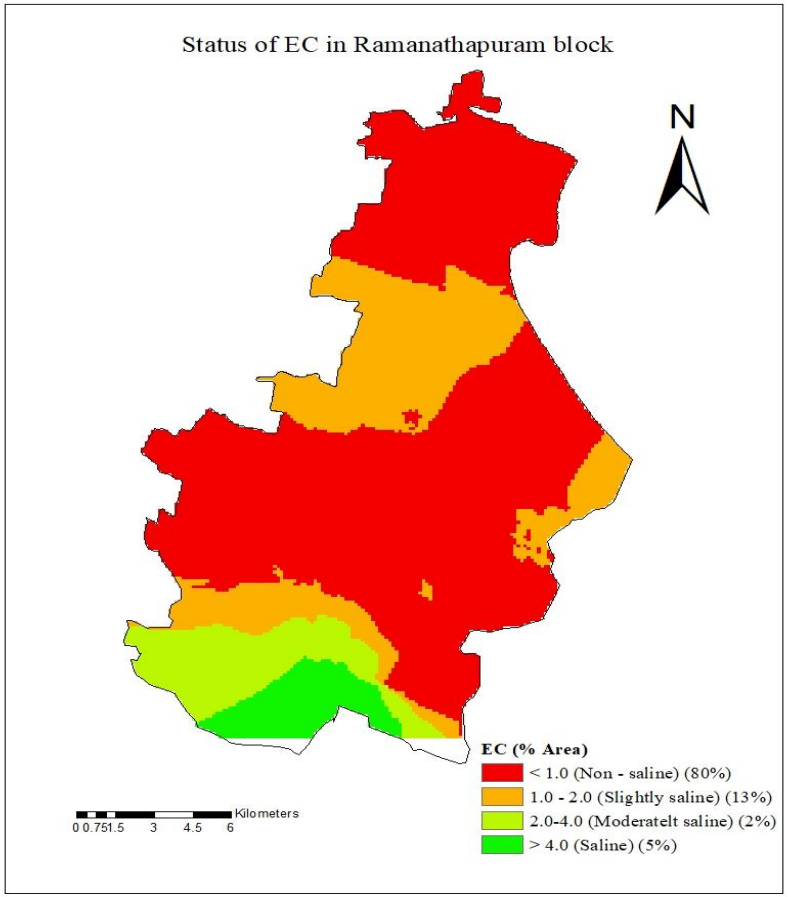
The available Zn status (Table 4) ranged from 0.10 to 0.23ppm with a mean of 0.16ppm. About 100 % of the soil samples were deficient in available Zn with an overall soil status is very low, the present results are in line with the findings of Velu *et al*. (2008). The findings of Shyampura and Seghal (1995) and Katyal and Datta (2004) also subscribe to this view. Climatic conditions, parent materials, and management appeared to be largely responsible for the distribution of Zn in the soil. Coarse texture, high pH, diminishing OC, and leaching often accentuated the Zn deficiency (Katyal and Rattan 1993). Zinc content in the investigated soils might be due to the low OC values in these blocks. The results of the present investigation are in conformity with those of Takkar *et al*. (1997) who envisaged that when the soils are low in organic matter and not supplemented by mineral fertilization they are prone to Zn deficiency.

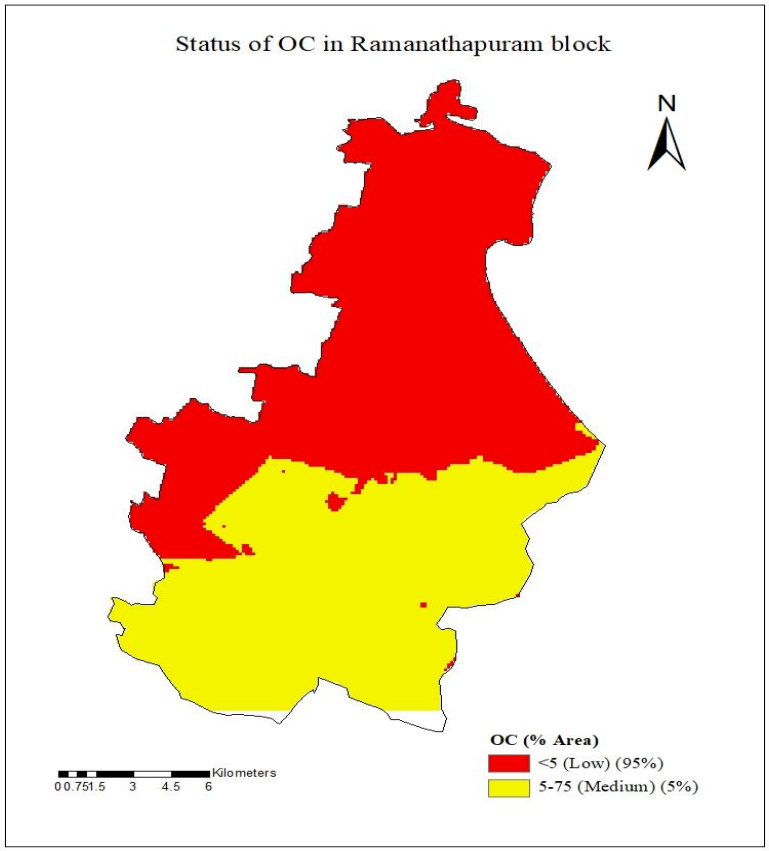
The available Mn status (Table 1) varied from 0.30 to 16.4 ppm with a mean of 6.46 ppm. Deficient, moderate, and sufficient Mn status was noticed in 14, 25, and 61% of the samples, respectively. Among the revenue villages, the lowest DTPA- Mn of 0.3 ppm has recorded in Melakottai and Ramanathapuram which was followed by 0.4 ppm at Therpooki. The highest DTPA-Mn of 16.4 ppm was recorded at Sathankulam and followed by Valantharavai (14.7 ppm). The Mn-bearing minerals in the parent material of these soils might be the reason for the higher Mn content soils. This may be due to the formation of insoluble higher valent oxides of Mn at high pH (Naheed et al., 2010).

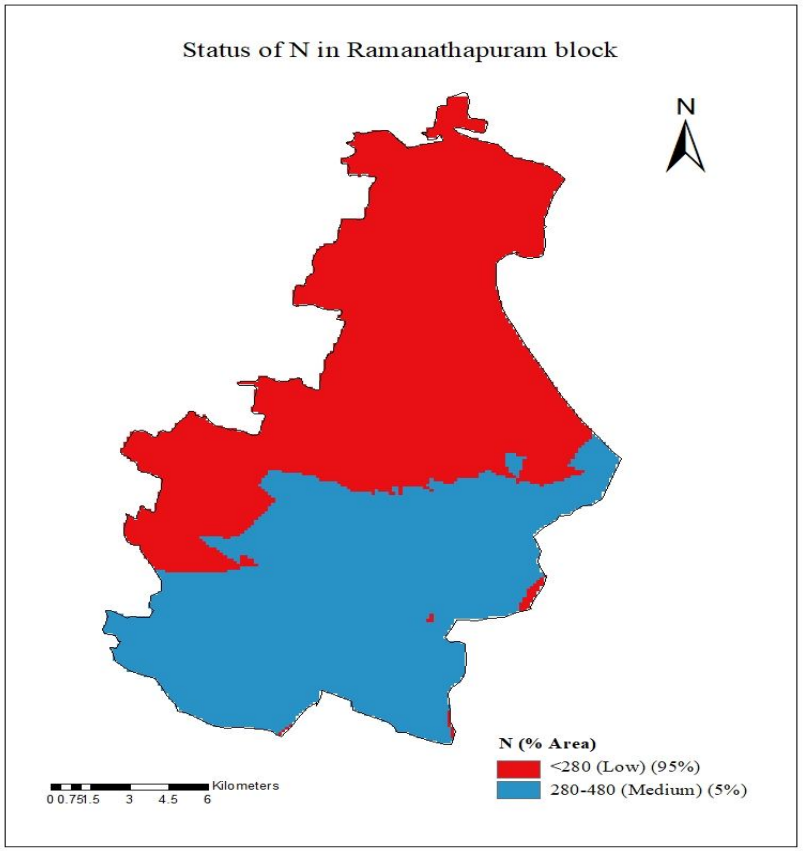
The available Cu status (Table 4) varied from 0.22to 3.89 ppm with a mean of 1.36ppm. Deficient, moderate, and sufficient Cu status was noticed in 51, 33, and 16% of the samples, respectively. Among the revenue villages, the lowest DTPA- Cu of 0.22 ppm has recorded in pullangudi which was followed by 0.23 ppm at Valuthur. The highest DTPA-Cu of 3.89 was ppm recorded at Sathankulam and followed by Kavanur (3.87 ppm). The study area might be due to the fact that the decomposition of organic matter releases micronutrients and also reduces the pH of the soil around the plant roots which helps in increasing the solubility of cationic micronutrients (Sharma and Chaudhary 2007). Hence, deficiencies of micronutrients in the soils are reported to affect the chances of vegetation growth (Arvind Kumar Rai *et al*., 2011). Thus, this shortfall of micronutrients is adjusted by adding the essential nutrients to the soil either naturally or by artificial fertilizers.

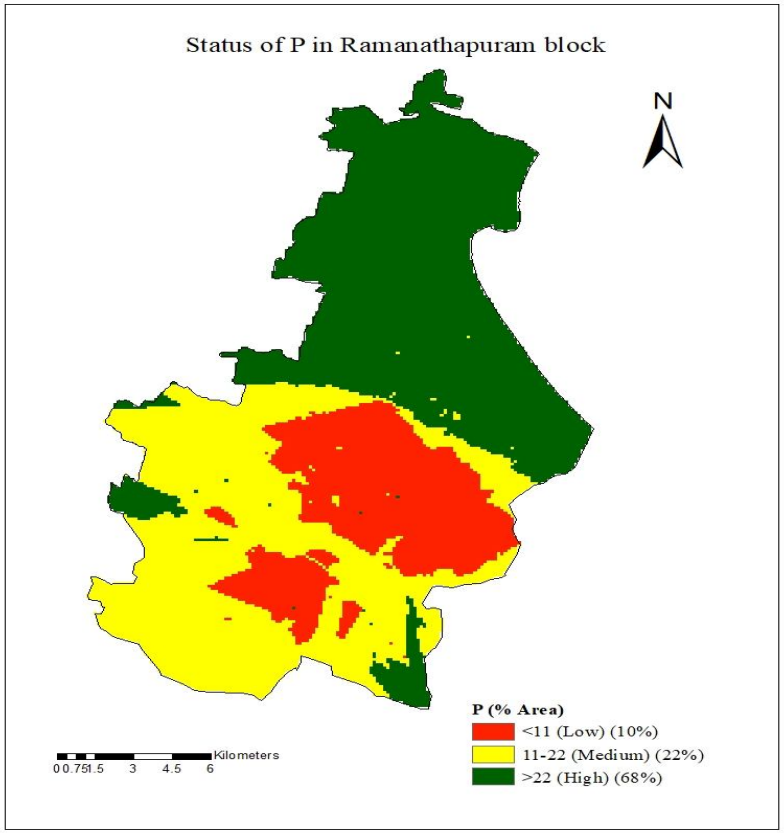
Spatial distribution of different quality parameters of soil fertility in Ramanathapuram block of Ramanathapuram district

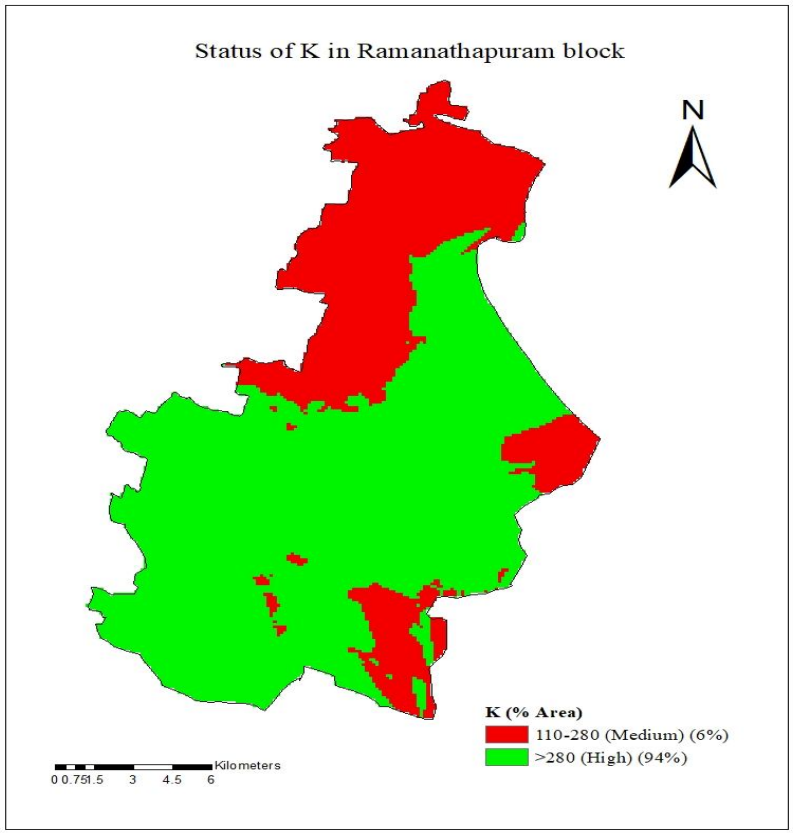


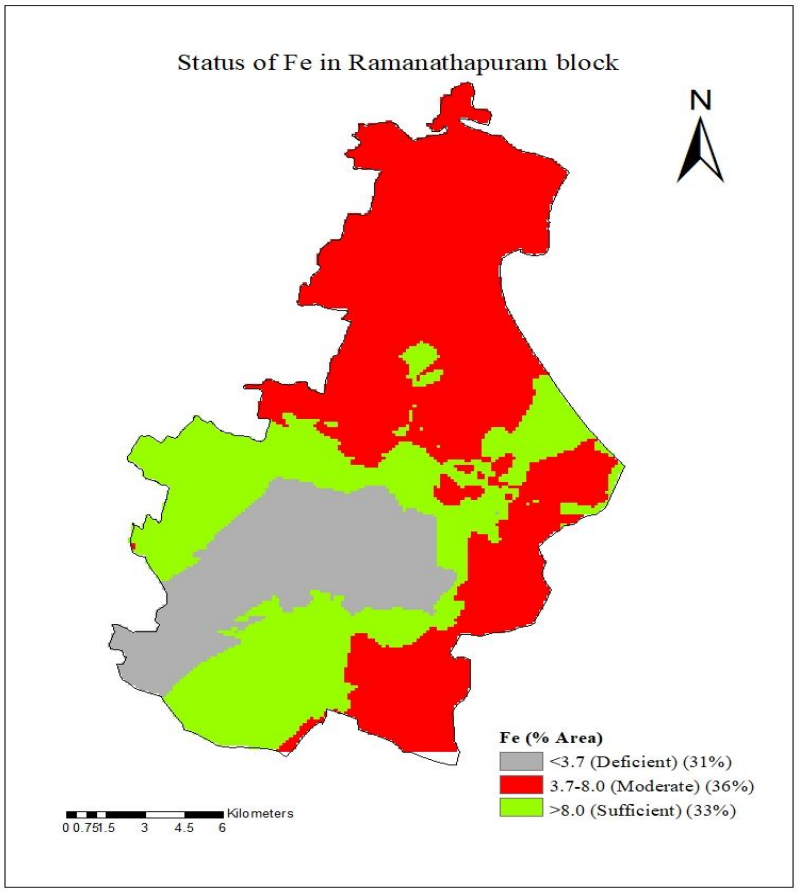


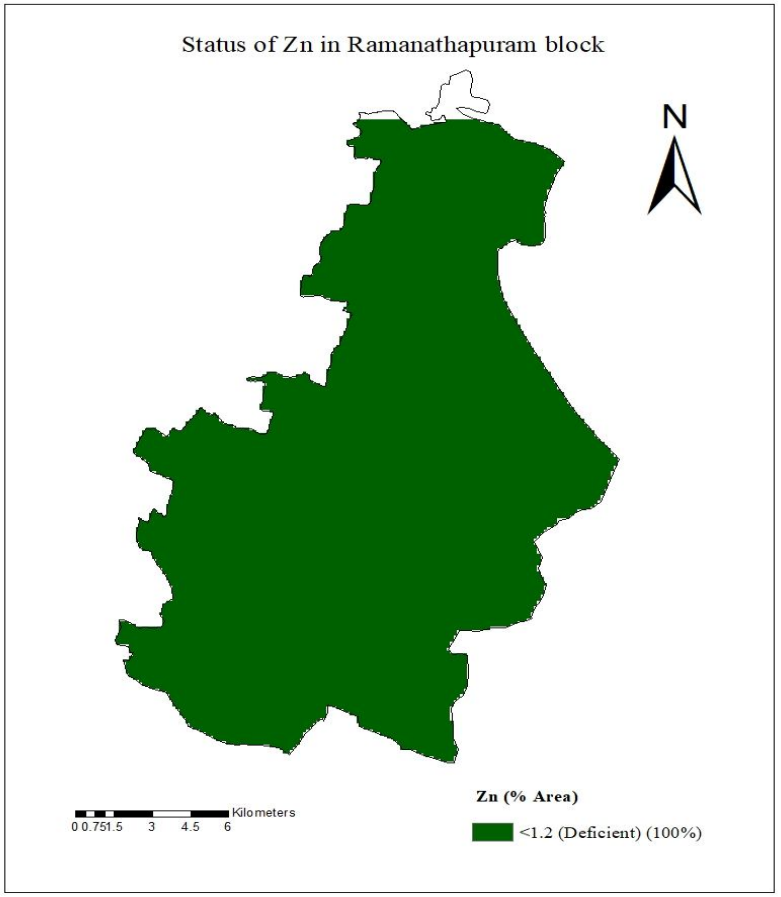

Status of OC in Ramanathapuram block
N
OC (% Area)
<5 (Low) (95%)
5-75 (Medium) (5%)
Kilometers
0 0.751.5 3 4.5 6

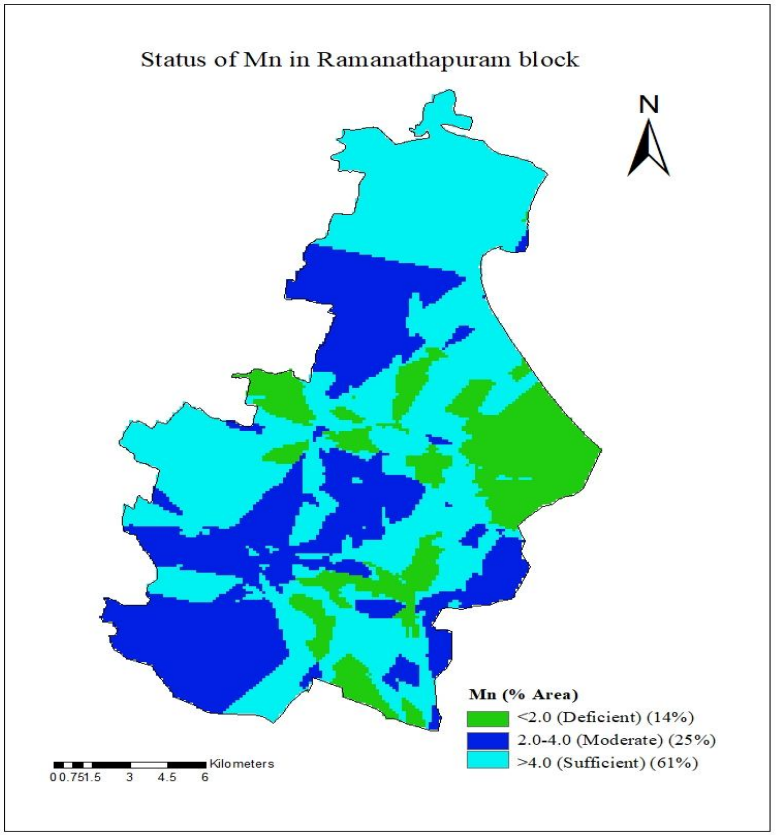

Status of N in Ramanathapuram block
N
N (% Area)
<280 (Low) (95%)
280-480 (Medium) (5%)
Kilometers
0 0.751.5 3 4.5 6

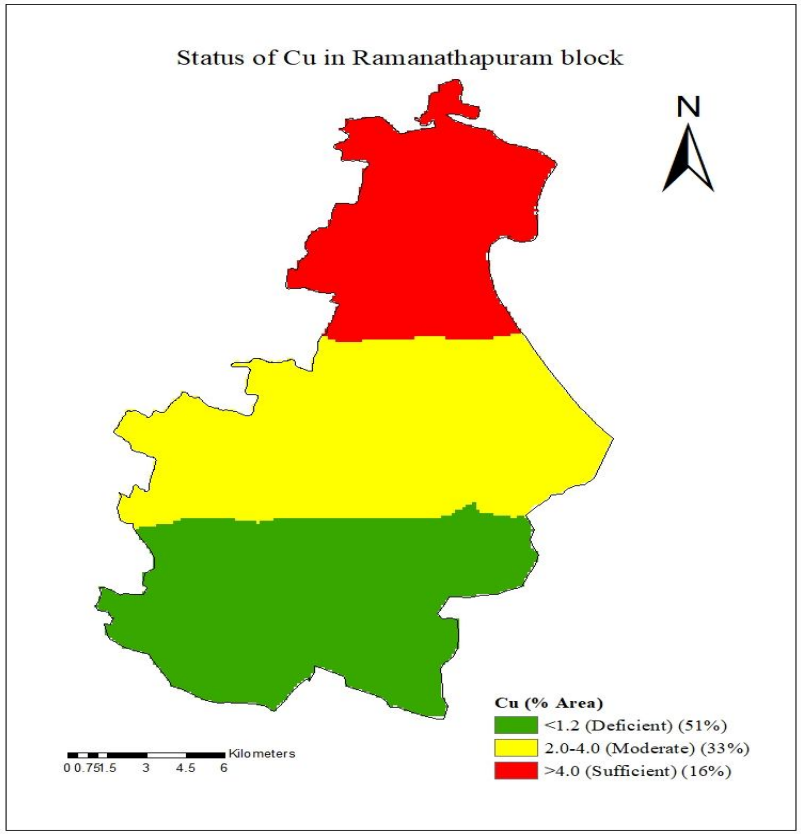

Status of P in Ramanathapuram block
N
P (% Area)
<11 (Low) (10%)
11-22 (Medium) (22%)
>22 (High) (68%)
Kilometers
0 0.75 1.5 3 4.5 6


Status of K in Ramanathapuram block
N
K (% Area)
110-280 (Medium) (6%)
>280 (High) (94%)
Kilometers
0 0.75 1.5 3 4.5 6


Status of Fe in Ramanathapuram block
N
Fe (% Area)
<3.7 (Deficient) (31%)
3.7-8.0 (Moderate) (36%)
>8.0 (Sufficient) (33%)
Kilometers
0 0.751.5 3 4.5 6


Status of Zn in Ramanathapuram block
N
Zn (% Area)
<1.2 (Deficient) (100%)
Kilometers
0 0.751.5 3 4.5 6


Status of Mn in Ramanathapuram block
N
Mn (% Area)
<2.0 (Deficient) (14%)
2.0-4.0 (Moderate) (25%)
>4.0 (Sufficient) (61%)
Kilometers
0 0.75 1.5 3 4.5 6


Status of Cu in Ramanathapuram block
N
Cu (% Area)
<1.2 (Deficient) (51%)
2.0-4.0 (Moderate) (33%)
>4.0 (Sufficient) (16%)
Kilometers
0 0.75 1.5 3 4.5 6

Conclusion

It can be concluded that based on thematic maps, a major area of Ramanathapuram block, Ramanathapuram district was alkaline, nonsaline, low in OC, low, high, and medium in available N, P, and K, respectively; with regard to available DTPA micronutrients, Zn was predominantly deficient and Cu was moderate while, Fe and Mn were insufficient statuses. The georeferenced sampling sites can be revisited with the help of GPS, which helps in monitoring the soil fertility changes over the long run. Further, it will be useful to the researchers, planners, policymakers, extension workers of the State Department of Agriculture, fertilizer industries, and farmers. Thus, higher crop productivity through maintaining the soil health and fertility conditions can be achieved through sustainable crop management, Ramanathapuram block, Ramanathapuram district, Tamil Nadu.

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Appendices

Chart 1 : USDA system of Soil fertility classification

Parameter	Ranges	Soil Fertility Classes
pH	<6.0	Acidic
	6.0 – 8.5	Neutral
	> 8.5	Alkaline
EC (dSm^{-1})	<1.0	Non – saline
	1.0 – 2.0	Slightly saline
	2.0 – 4.0	Moderately saline
	>4.0	Saline
Nitrogen (kg ha^{-1})	<280	Low
	280 – 480	Medium
	>480	High

Phosphorus ($kgha^{-1}$)	<11	Low
	11 – 22	Medium
	>22	High
Potassium ($kg\ ha^{-1}$)	<118	Low
	118 – 280	Medium
	>280	High
Organic carbon (gkg^{-1})	<5	Low
	5 – 7.5	Medium
	>7.5	High

Chart 2 : Micronutrient classification

Parameter (ppm)	**Low (Deficient)**	**Medium (Moderate)**	**High (Sufficient)**
Iron (Fe)	<3.7	3.7 – 8.0	>8.0
Zinc (Zn)	<1.2	1.2 – 1.8	>1.8
Manganese (Mn)	<2.0	2.0 – 4.0	>4.0
Copper (Cu)	<1.2	1.2 – 1.8	>1.8

Table1. Range of values for pH, EC of soil samples of Ramanathapuram block

S. No.	Village Name	No. of samples	pH			EC (dSm^{-1})		
			Min	Max	Mean	Min	Max	Mean
1	Kusavankudi	4	7.13	8.72	7.64	0.09	0.17	0.13
2	Sathankulam	4	7.45	8.70	8.21	0.19	0.90	0.46
3	Pattinamkathan	4	6.79	8.55	7.60	0.13	1.45	0.61
4	Therkutharavai	5	6.07	8.79	7.54	0.06	1.15	0.35
5	Madakottan	9	6.60	8.69	7.89	0.05	1.03	0.46
6	Melakottai	4	7.89	8.86	8.33	0.17	1.33	0.63
7	Devipattinum	5	7.87	9.47	8.29	0.35	0.73	0.46
8	Valanthantharai	8	6.60	8.79	7.80	0.13	1.05	0.58
9	Valathoor	2	8.30	9.09	8.70	0.21	0.85	0.53
10	Pullankudi	6	7.84	8.66	8.19	0.36	6.45	1.65
11	Ramanathapuram	24	6.35	9.50	8.11	0.11	8.88	1.51
12	Chidharkottai	7	7.31	8.76	7.84	0.12	0.89	0.48
13	Therpooki	5	7.57	8.70	8.23	0.24	2.91	1.49
14	Thoruvalur	3	8.45	8.90	8.67	1.04	1.53	1.25
15	Peravoor	2	8.20	9.81	9.01	0.35	1.50	0.93
16	Kavanoor	8	7.49	9.65	8.56	0.17	0.49	0.36

Minimum	6.07	8.55	7.54	0.05	0.17	0.13
Maximum	8.45	9.81	9.01	1.04	8.88	1.65
Mean	7.37	8.98	8.16	0.24	1.96	0.74
SD	0.72	0.40	0.43	0.24	2.35	0.47
Std. Err	0.07	0.04	0.04	0.02	0.23	0.05

Table2. Range of values for OC of soil samples of Ramanathapuram block

S.No.	Village Name	No. of samples	OC (g/kg)		
			Min	Max	Mean
1	Kusavankudi	4	0.70	3.90	2.23
2	Sathankulam	4	0.80	2.80	1.88
3	Pattinamkathan	4	1.40	4.80	2.33
4	Therkutharavai	5	0.60	1.80	1.12
5	Madakottan	9	0.70	4.20	2.18
6	Melakottai	4	0.90	6.30	2.98
7	Devipattinum	5	1.10	1.80	1.38
8	Valanthantharai	8	1.50	4.30	3.03
9	Valathoor	2	2.70	3.90	3.30
10	Pullankudi	6	2.10	6.60	3.65

11	Ramanathapuram	24	0.60	4.80	1.95
12	Chidharkottai	7	1.10	8.70	3.29
13	Therpooki	5	1.10	4.20	2.32
14	Thoruvalur	3	3.90	5.30	4.70
15	Peravoor	2	1.30	2.10	1.70
16	Kavanoor	8	0.60	4.00	2.35
Minimum			0.60	1.80	1.12
Maximum			3.90	8.70	4.70
Mean			1.32	4.34	2.52
SD			0.90	1.83	0.92
Std. Err			0.09	0.18	0.09

Table 3. Range of values for N, P and K of soil samples of Ramanathapuram block

S. No.	Village Name	No. of samples	N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1	Kusavankudi	4	45	246	148	10.2	44.8	30.6	293	400	332
2	Sathankulam	4	42	188	126	11.2	56.0	33.6	249	376	329
3	Pattinamkathan	4	78	277	134	9.2	56.0	35.9	330	385	346
4	Therkutharavai	5	64	137	94	10.2	33.6	24.4	270	379	327

5	Madakottan	9	50	216	129	9.2	89.6	38.4	317	418	361
6	Melakottai	4	95	328	178	22.4	56.0	42.0	294	365	340
7	Devipattinum	5	95	126	112	7.2	67.2	30.6	318	457	399
8	Valanthantharai	8	106	241	179	11.2	44.8	25.2	267	369	333
9	Valathoor	2	154	204	179	34.8	44.1	39.5	437	452	444
10	Pullankudi	6	115	319	207	10.1	44.8	20.4	250	461	338
11	Ramanathapuram	24	50	266	141	11.2	78.4	32.7	247	462	347
12	Chidharkottai	7	101	455	200	9.4	33.6	17.3	291	426	361
13	Therpooki	5	76	266	157	10.2	22.4	15.5	326	418	364
14	Thoruvalur	3	227	300	263	22.4	44.8	33.6	314	350	337
15	Peravoor	2	112	182	147	33.6	78.4	56.0	337	368	353
16	Kavanoor	8	73	213	156	9.5	33.6	17.9	246	446	375
Minimum			42	126	94	7.2	22.4	15.5	246	350	327
Maximum			227	455	263	34.8	89.6	56.0	437	462	444
Mean			93	248	159	14.5	51.8	30.8	299	408	355
SD			46.91	80.79	41.45	8.83	18.70	10.65	48.71	38.95	30.41
Std. Err			4.69	8.08	4.15	0.88	1.87	1.07	4.87	3.90	3.04

Table4. Range of values for Fe, Zn, Mn, and Cu of soil samples of Ramanathapuram block

S.No.	Village Name	No. of samples	Fe (ppm)			Zn (ppm)			Mn (ppm)			Cu (ppm)		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1	Kusavankudi	4	2.8	13.2	7.4	0.11	0.17	0.14	5.0	11.3	8.4	1.23	3.51	1.98
2	Sathankulam	4	3.3	11.7	6.6	0.11	0.20	0.18	4.1	16.4	9.8	0.80	3.89	2.06
3	Pattinamkathan	4	7.5	15.9	12.2	0.20	0.22	0.21	1.9	8.5	5.0	1.13	1.44	1.28
4	Therkutharavai	5	1.9	14.4	6.5	0.11	0.21	0.16	3.1	14.1	10.2	0.59	3.01	1.88
5	Madakottan	9	2.5	12.9	5.6	0.12	0.19	0.15	3.1	13.9	6.9	0.30	1.51	1.06
6	Melakottai	4	6.8	19.0	11.9	0.12	0.17	0.15	0.3	9.5	4.2	0.63	3.60	1.90
7	Devipattinum	5	3.1	7.5	5.2	0.11	0.16	0.13	0.7	12.7	6.7	0.34	2.52	1.35
8	Valanthantharai	8	1.5	7.8	4.0	0.11	0.19	0.15	2.7	14.7	9.1	0.34	1.53	1.00
9	Valathoor	2	2.0	3.2	2.6	0.15	0.19	0.17	0.7	4.5	2.6	0.23	1.11	0.67
10	Pullankudi	6	2.6	14.4	7.8	0.12	0.19	0.16	1.5	12.3	6.5	0.22	1.90	1.08
11	Ramanathapuram	24	1.5	15.2	7.3	0.11	0.19	0.15	0.3	12.5	5.8	0.36	3.82	1.30
12	Chidharkottai	7	2.6	14.8	7.4	0.11	0.19	0.15	1.5	12.9	6.0	0.38	3.01	1.45
13	Therpooki	5	2.4	18.8	7.1	0.11	0.17	0.15	0.4	11.5	3.6	0.55	1.19	0.93
14	Thoruvalur	3	3.8	19.8	9.5	0.10	0.19	0.14	0.5	7.0	3.6	1.15	1.82	1.47
15	Peravoor	2	2.8	3.4	3.1	0.13	0.19	0.16	5.1	10.4	7.7	0.66	1.03	0.85
16	Kavanoor	8	4.7	19.5	11.0	0.12	0.23	0.18	0.5	14.2	7.3	0.59	3.87	1.58

Minimum	1.5	3.2	2.6	0.10	0.16	0.13	0.3	4.5	2.6	0.22	1.03	0.67
Maximum	7.5	19.8	12.2	0.20	0.23	0.21	5.1	16.4	10.2	1.23	3.89	2.06
Mean	3.2	13.2	7.2	0.12	0.19	0.16	2.0	11.6	6.5	0.59	2.42	1.36
SD	1.7	5.3	2.9	0.02	0.02	0.02	1.7	3.1	2.3	0.33	1.09	0.43
Std. Err	0.2	0.5	0.3	0.002	0.002	0.002	0.2	0.3	0.2	0.03	0.11	0.04