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Generation of cadastral level thematic maps on soil fertility in Naluvedapathi village of Nagapattinam district, Tamil Nadu using GIS techniques for micro-level planning

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Abstract
Geospatial technologies play a key role in generating timely and reliable information for planning and decision making at all the levels from macro to micro. With a view to develop a database for the development of action plans on micro level, a coastal village of Naluvedapathi village in Nagapattinam district, Tamil Nadu was selected and an attempt has been made to inventory the soil and irrigation water of the study area by using Geographic Information System (GIS).The study area is spanning from 79° 49' 30" to 79° 51' 30"East Longitudes and 10° 35' 00" to 10° 36' 30" North Latitudes. Thematic maps on soil characteristics *viz.*, Soil pH, Electrical Conductivity (EC), soil available macro nutrient status (NPK), and micro nutrients (Zn, Cu, Fe and Mn) were prepared in Arc GIS environment. Map area analysis for each theme provided statistical information for each thematic map. The irrigation water was grouped under two salinity classes *viz.*, high and very high salinity classes. The thematic maps prepared using GIS techniques facilitated in identifying potentialities and limitations of cultivated soil and also in developing management strategies for increasing crop production.

Keywords: GIS, Vizhunthamavadi, micro level study, thematic maps

Introduction
GIS has a significant role to play in agriculture at several scales from local to global. The development of several new digital databases at regional and larger scales, the advent of new continuous data collection and remote sensing techniques at the farm scale, and the continued migration of GIS to more and more powerful desktop computers have caused an explosive growth in the number and variety of agricultural applications during the past few years. Many site-specific farming systems utilize GIS and several related technologies (global positioning system, receivers, continuous yield sensors, remote sensing instruments) to collect spatially referenced data, perform spatial analysis and decision making. A comprehensive inventory of soil resources is the backbone of land use planning. Soil properties vary spatially from a small to the larger area might be due to the effect of intrinsic (parent materials and climate) and extrinsic factors such as soil management practices, indigenous fertility status, crop rotation and nature of standing crop (Cambardella and Karlen 1999) [1]. Soil fertility status is influenced by many factors. The soil variability within a municipality, district or zone influences the use of soils for different purposes. In order to make optimum use of our limited soil resources, we need detailed information about their characteristics, types, and distribution on landscape. The use of high spatial resolution maps and digital techniques to map soil properties is of particular importance. Describing the spatial variability of soil fertility across a field has been difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced. The use of GIS and GPS for soil fertility mapping is popular and gaining acceptance worldwide. The collection of soil samples using GPS for the preparation of thematic soil fertility maps is very important (Mishra *et al*. 2013) [2]. It helps to formulate site-specific nutrient management for the location. Based on the geostatistical analysis, several studies have been conducted to characterize the spatial variability of different soil properties (Huang *et al*. 2007; Liu *et al*. 2013; Weindorf and Zhu 2010) [3, 4, 5]. GIS generated soil fertility maps may serve as a decision support tool for nutrient management (Iftikar *et al*. 2010) [6] and it also helps to determine plant nutrient availability and distribution and the pattern of nutrient depletion in the project area. The cadastral level soil resource database is needed for effective implementation of all technologies and agricultural developmental programme at farm level.

The micro level database at farm level can help in identifying farm specific problems and potentials and to provide technologies and amelioration measures for increasing the agricultural production. Further the micro level database on soil and land resource will serve as an important decision making tool for agricultural planning and implementation of soil and crop related management technologies.
Keeping in view of the importance of the developing cadastral level information on the soil resources of the state at panchayat level, the soil fertility maps has been developed at micro level using cadastral maps of 1:5000 scale as base map on Soils of Naluvedapathi village of Nagapattinam district.

Materials and Methods

The study area is spanning from 79° 49' 30" to 79° 51' 30"East Longitudes and 10° 35' 00" to 10° 36' 30" North Latitudes. The cadastral map of Naluvedapathi village at 1:5000 scale has been procured from Soil Survey and Land Records Division, Chennai. The cadastral map was scanned, from the scanned cadastral map, digital cadastral map is prepared by digitization method in Arc GIS software. The village map sheets of the study area on 1:5000 scale were digitally encoded. The digitized cadastral map was geo-referenced directly using GPS based ground control points (GCP's) which were taken during field survey and also by using survey of India Toposheets (58 M15, M16, 58 N13,14 &15) corresponding to the study area and converted to coverage file to create the topology and to calculate the areas of land parcels.
The digitized data *viz.*, cadastral map on 1:5000 Scale formed the spatial data base. The attribute data base comprised the soil characteristics *viz.*, Soil pH, Electrical Conductivity (EC), soil available macro nutrient status (NPK), and micro nutrients (Zn, Cu, Fe and Mn). Map area analysis for each theme provided statistical information for each thematic map. Integration of attribute data at field level (survey number wise) was done in Microsoft Excel spreadsheet. The results from the Excel sheet were used as input for preparation of thematic maps.
Thematic maps were generated by linking the categories, generated after analyzing different attribute data for each survey number, with map objects. Different thematic maps prepared were Soil pH, Electrical Conductivity (EC), major soil available nutrients *viz.*, nitrogen, phosphorus and potassium, micro nutrients like zinc, copper, iron and manganese of soil. Randomly ten irrigation water samples were also collected in the study area and the following methodology was used to analyze the water samples to find out different quality parameters of irrigation water.

Table 1: Methods of water analysis

S. No	Analytical parameter	Methodology	Author (s)
1.	pH	pH meter with glass electrode	United states salinity laboratory staff (1968)
2.	Electrical Conductivity (EC)	Conductometry	United states salinity laboratory staff (1968)
3.	Calcium & Magnesium	Versenate titration	Diehl *et al.* (1950)
4.	Sodium & Potassium	Flame Photometry	Stanford and English (1949)
5.	Carbonate & bicarbonate	Titration with acid	Association of Official Agricultural Chemist (1950)
6.	chloride	Titration with silver nitrate	Association of Official Agricultural Chemist (1950)
7.	Sulphate	Turbidimetry	Tandon (1995)

To find out the pH, EC and fertility status of the soil, the following rating levels were used to compute different characteristics of the soil.

Ratings used to group the soils into various classes are

Table 2: Soil pH

Soil pH	Acidic	Neutral	Alkaline
pH	< 6.5	6.5 – 7.5	> 7.5

Table 3: Soil EC

Soil EC	Harmless	Injurious	Critical
EC (dsm^{-1})	0.0 – 1.0	1.0 - 3.0	> 3.0

Table 4: Available macro nutrient status

Macro nutrients	Low	Medium	High
Available Nitrogen (kg ha^{-1})	< 250	250 – 450	> 450
Available Phosphorus (kg ha^{-1})	0 - 11	11 – 22	> 22
Available Potassium (kg ha^{-1})	0 - 118	118 – 280	> 280

Table 5: Available micro nutrient status

Micro nutrients	Sufficient (> critical level)	Deficient (< critical level)
Available Zinc and Copper (ppm)	> 1.2	< 1.2
Available Iron (ppm)	> 6.3	< 6.3
Available Manganese (ppm)	>2.0	< 2.0

Table 6: Water salinity based on EC Ratings used to group the water into various classes are

Soil EC	Low salinity	Medium salinity	High salinity	Very high salinity
EC (dsm^{-1})	< 0.25	0.25 – 0.75	0.75 – 2.25	2.25 – 5.0

Results and Discussion

Soil pH

The pH (1:2.5 soil: water) of the surface soil samples ranges from 6.10 to 9.30 with a mean value of 7.27. Three soil reaction classes were observed in the surface soils of the Naluvedapathi village (Acidic – 9.37%, 95.23 ha; Neutral – 64.63%, 656.70 ha; Alkaline – 22.31%, 226.65 ha).The neutral class was the major soil reaction class observed in Naluvedapathi village (Table. 2, 6 & Fig. 1).

Electrical Conductivity (EC) (dSm^{-1})

The Electrical Conductivity of the soils varied from 0.26 to 3.92 dS m^{-1} with a mean value of 0.96dS m^{-1}. There were two electrical conductivity classes (Harmless – 80.29%, 815.73 ha; Injurious – 15.37%, 156.12 ha; Critical – 0.66%, 6.74 ha) observed in the study area (Table. 2, 4 & Fig. 1).

Soil Fertility Status

Available Macronutrients (kg ha^{-1})

Soil fertility data showed that the available N, P and K ranged from 25.00 to 111.0, 3.50 to 32.00 and 55.00 to 328.0 kg ha^{-1}

respectively with a mean value of 67.81, 14.67, 128.47 kg ha^{-1} respectively for N P and K. Based on the results of available macronutrients, it is observed that the available nitrogen content was low in all the survey numbers, available phosphorus was grouped under three classes (Low – 33.75%, 342.95 ha; Medium – 49.24%, 500.33 ha; High – 13.32%, 135.32 ha) and there were three available potassium classes (Low – 50.72%, 515.37 ha; Medium – 43.17%, 438.61ha; High – 2.42%,24.62 ha) (Table. 2, 5 & Fig. 2).

Available Micro nutrients (mg kg $^{-1}$)

Among the micronutrients, zinc deficiency commonly prevailed in Naluvedapathi village. (85.67%, 870.44 ha). The DTPA-Zn content in the soils varied from 0.11 to 2.12 mg $kg^{-1}$with a mean value of 0.70 mg kg^{-1}.Considering 1.2 mg kg^{-1}as critical limit, 10.64% (108.15 ha) of the soil samples were sufficient and 85.67% (870.44ha) were deficient in available Zn. The reason for low fertility may be the intensive cropping system which causes nutrient mining along with imbalanced use of fertilizer (Panday *et al*. 2018) [7]. Balanced use of fertilizers in conjunction with organic inputs and chemical fertilizers is key to sustainable agriculture and restoring soil fertility under intensive cropping (Dwivedi *et al*. 2003; Timsina and Connor 2001) [8, 9].

The content of DTPA Cu in soils varied from 0.63 to 7.80 mg $kg^{-1}$with an average value of 3.39 mg kg^{-1}. Considering 1.2 mg kg^{-1}as critical limit for Cu, 79.44% (807.12 ha) of the soil samples were sufficient and 16.88% (171.47ha) were deficient in available Cu. All other micronutrients (Fe and Mn) were found to be present in sufficient levels in all the soils of Naluvedapathi village. The content of DTPA Fe in soils varied from 9.56 to 63.50 mg $kg^{-1}$with an average value of 35.16mg kg^{-1}. The DTPA Mn in the soil samples varied from 3.76 to 35.00 mg $kg^{-1}$with an average value of 16.47 mg kg^{-1}. Data on available Fe in soil samples indicated that none of the samples were deficient in available Fe with 6.3mg kg^{-1}as critical limit. Considering 2.0 mg kg^{-1}as critical limit for Mn deficiency, none of the samples were deficient in Mn in this village (Table 7, 11 & Fig. 3).

Table 7: Range and mean values of soil reaction, electrical conductivity and available nutrient status of surface soils of Naluvedapathi village of Nagapattinam district

Properties	Range		Mean
	Minimum	Maximum	
pH	6.10	9.30	7.27
EC(dSm^{-1})	0.26	3.92	0.96
Available macro nutrients (kg ha^{-1})			
$KMnO_4$ - N	25.00	111.00	67.81
Olsen's - P	3.50	32.00	14.67
NH_4OAC – K	55.00	328.00	128.47
Available micro nutrients (mg kg^{-1})			
DTPA - Zn	0.11	2.12	0.70
DTPA - Cu	0.63	7.80	3.39
DTPA - Fe	9.56	63.50	35.16
DTPA - Mn	3.76	35.00	16.47

(n = 317)

Table 8: Different classes of soil reaction in the study area soil of Nagapattinam district

Village Name	Acidic		Neutral		Alkaline	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Naluvedapathi	95.23	9.37	656.70	64.63	226.65	22.31

Table 9: Different classes of Electrical Conductivity (dSm^{-1}) in the study area soil of Nagapattinam district

Village Name	Harmless		Injurious		Critical	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Naluvedapathi	815.73	80.29	156.12	15.37	6.74	0.66

Table 10: Different classes of available macro nutrient status (kg ha^{-1}) in the study area soil of Nagapattinam district

Particulars	Low		Medium		High	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Available Nitrogen	978.59	96.31	0.00	0.00	0.00	0.00
Available Phosphorus	342.95	33.75	500.33	49.24	135.32	13.32
Available Potassium	515.37	50.72	438.61	43.17	24.62	2.42

Table 11: Different classes of available micro nutrient status (ppm) in the study area of soil Nagapattinam district

Particulars	Deficient		Sufficient	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Zinc	870.44	85.67	108.15	10.64
Copper	171.47	16.88	807.12	79.44
Iron	0.00	0.00	978.59	96.31
Manganese	0.00	0.00	978.59	96.31

Chemical composition of ground water

The overall mean values of ground water quality parameter on hydrogen ion concentration collected from the different seasons, did not vary much and the mean values in general ranged from 7.00 to 8.80 during the pre-monsoon season and post monsoon periods studied. Salinity plays a vital role in the suitability of water for irrigation. EC (dSm^{-1}) is used to assess the salinity, as it reflects the TDS in groundwater. The overall mean values of Electrical conductivity showed an increasing trend during pre-monsoon season and the values ranged from 0.90 to 9.80 dSm^{-1}. The values of TDs showed a similar trend. Among different cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) analysed in ground water, sodium was found as the most dominant cation, followed by calcium, magnesium and potassium during both pre-monsoon, and post-monsoon periods. The mean value of Na^+, K^+, Ca^{2+} and Mg^{2+} ions concentration in the groundwater samples were 14.24, 1.60, 11.35 and 11.08 $meqL^{-1}$ during premonsoon and 12.66, 1.52, 10.54 and 9.08 $meqL^{-1}$ during post-monsoon period, respectively. However, among anions (CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-},), chloride has the highest mean concentration in the ground water during both premonsoon (15.84 $meqL^{-1}$) and post-monsoon (13.50 $meqL^{-1}$) periods. The mean values of bicarbonate and sulphate concentrations were 11.94 and 9.63 $meqL^{-1}$ during pre-monsoon, while these were 10.73 and 8.96 $meqL^{-1}$ during post-monsoon, respectively.

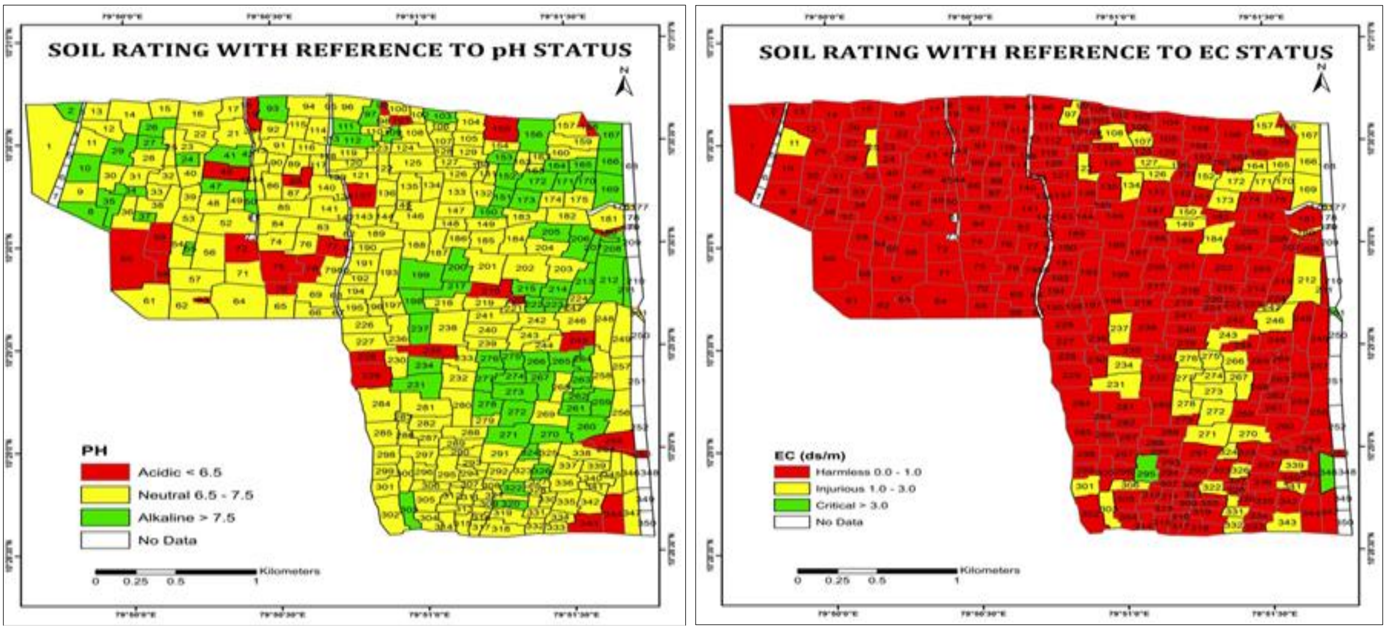


Fig 1: Thematic maps on pH and EC (dS m^{-1}) status in the soil of Naluvedapathi village of Nagapattinam district

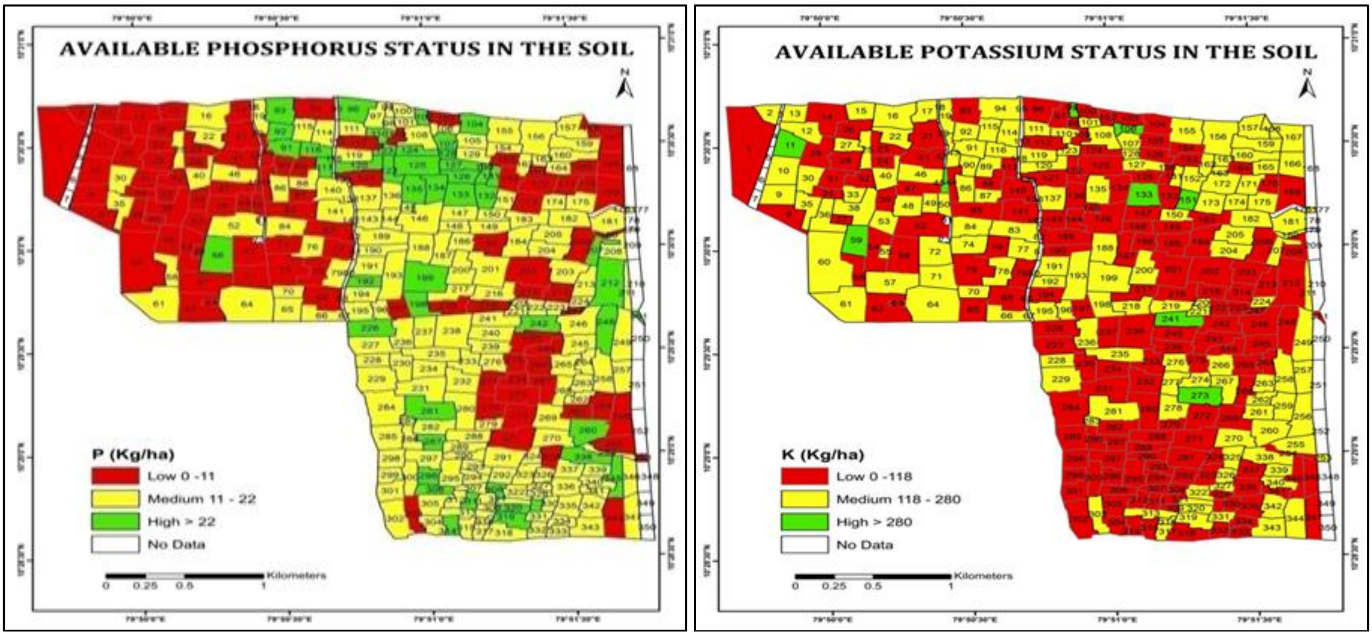
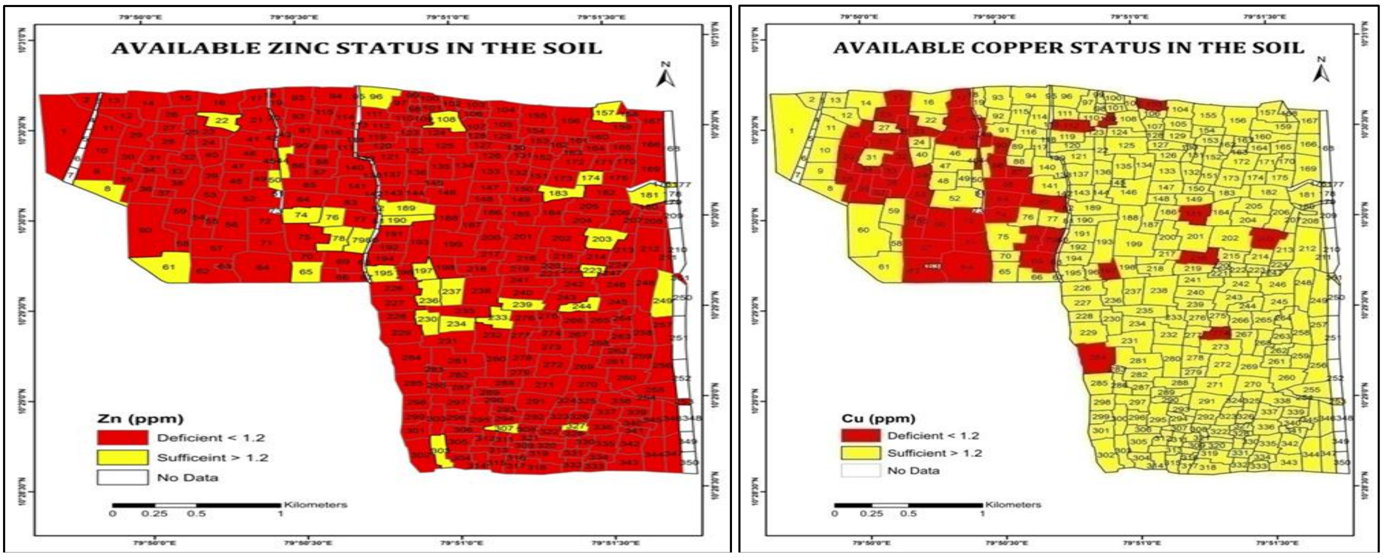


Fig 2: Thematic maps on Available P and K (Kg ha^{-1}) status in the soil of Naluvedapathi village of Nagapattinam district



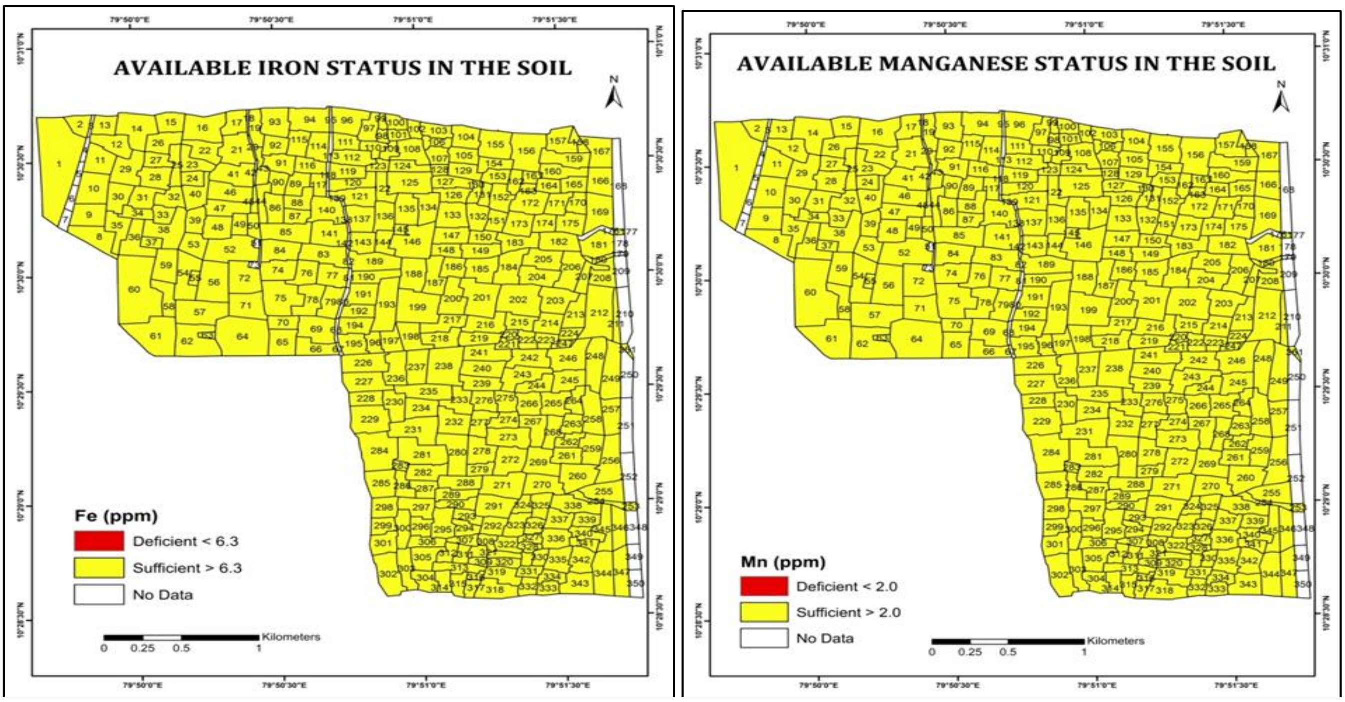


Fig 3: Thematic maps on Available Zn, Cu, Fe and Mn (Kg ha^{-1}) status in the soil of Naluvedapathi village of Nagapattinam district

Conclusion

The thematic maps prepared on 1:5000 scale using GIS techniques provide information on Soil fertility aspects consisting of Soil pH, Electrical conductivity, Status of major nutrients *viz*., Nitrogen, Phosphorus, Potassium, micronutrients *viz*., zinc, copper, iron and manganese status of soils on per plot/survey number basis to the stakeholders. Based on the results of available macronutrients, it is observed that the available nitrogen content was low in all the survey numbers, available phosphorus and available potassium was grouped under three classes *viz*., Low, Medium and High. Among the micronutrients, zinc deficiency commonly prevailed in the study area. Copper deficiency is also emerging in low scale (16.8%, 171 ha) and may cause decline in crop yields and total productivity in future. All other micronutrients (Fe and Mn) were found to be present in sufficient levels in all the soils. These thematic maps facilitated in identifying potentialities and limitations of cultivated soil and also in developing management strategies for increasing crop production. It is also useful to the farmers in adopting site specific nutrient management, areas of low, medium, high fertility status were identified, scope for rationalizing the usage of fertilizers in the areas where the soil fertility is high and avoids under usage of fertilizers in nutrient deficient areas. The prepared spatial distribution and fertility maps will aid farmers and planners in understanding the existing soil conditions and making judicious decisions to better manage the soil for sustainability and productivity.

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