Chapter 5

SOIL FERTILITY MAP OF THE STUDY AREA DEPICTING THE EXTENT OF DEFICIENCY AND TOXICITIES OF NUTRIENTS USING GIS

5.1. Introduction

Soil is the most essential natural resource for sustained quality of human life and foundation of agricultural development. Effective management of soil is a major challenge for scientists, planners, administrators and farmers to ensure food and environmental security for the present and future generations (Kanwar, 2000). Geographic Information System (GIS) can be used in producing soil fertility map of an area, which will help in formulating balanced fertilizer recommendation and understanding the status of soil fertility spatially and temporarily. GIS is a computerized system that record, store, analyze, and produce maps based on information obtained from different sources. It is an efficient and versatile tool to automate the transformation of soil data into soil information. GIS maps can communicate information effectively. Use of GIS with facilities like GPS (Global Positioning System) and soil fertility mapping are useful to know the fertility status of a particular village, taluk, district or even state and the country. Hence, Soil fertility maps prepared on the basis of analysed data of soil samples has greater use. It not only gives an idea about fertility status of the soil of a particular place under discussion, but also helps in monitoring the soil health from time to time.

5.2. Materials and methods

Thrissur district of Kerala was selected for carrying out the study to prepare GIS based thematic soil fertility maps. The data on various properties of 600 geo-referred soil samples obtained in previous chapter (chapter – III) were used for this study also. Soil samples were representing different agro ecological zones of Thrissur district and geo referencing was done using a hand held GPS.

5.2.1. Generation of thematic maps

Thematic maps were generated for each of the soil nutrients using inverse distance weighted (IDW) interpolation using Arc GIS 10 software (CWRDM, Kozhikode). Base map of the Thrissur district was digitized and Geo-referenced. Polygons were superimposed on the geo referred map. Latitude, longitude and analyzed data were entered in to attribute table and linked to Arc GIS10 software for making thematic maps.

5.2.1.1. Soil fertility index map

The soil fertility index integrate the soil parameters into a single parameter that could be used as an indicator of overall soil quality. In this study, the soil fertility index that integrated the 11 parameters of soil chemical properties into a single number that can be used to monitor changes in soils of different agro ecological zones, and thematic map was prepared. Three soil properties such as EC, Fe and Mn were excluded from this study. This is because EC was normal and the deficiency of Fe and Mn were negligible.

Total soil quality index = ∑ individual soil property index values

The maximum value of the total soil fertility index was 18. Missing properties do not contribute to the index (Amacher *et al.*, 2007).

Table 24. Soil fertility index values of basic soil properties and primary nutrients

Parameter	Level	Limits	Index
pH	Extremely acid	3.5 - 4.4	0
	Very strongly acid	4.5 – 5.0	1
	Strongly acidic	5.1-5.5	1
	Moderately acidic	5.6-6.0	2
	Slightly acidic	6.1 -6.5	2
	Neutral	6.6-7.3	1
	Slightly alkaline	7.4-7.8	0
Organic carbon	Low	<0.76 %	0
	Optimum	0.76-1.5 %	1
	Above optimum	>1.5 %	2
Nitrogen	Low	<0.01 %	0
	Optimum	0.01-0.02 %	1
	Above optimum	>0.02 %	2
Phosphorous	Low	<10 kg ha^{-1}	0
	Optimum	10-24 kg ha^{-1}	2
	Above optimum	>24 kg ha^{-1}	0
Potassium	Low	<115 kg ha^{-1}	0

Table 25. Soil fertility index values of secondary and micronutrients

Parameter	Level	Limits	Index
	Optimum	115-275 kg ha^{-1}	1
	Above optimum	>275 kg ha^{-1}	2
Calcium	Very low	<150 mg kg^{-1}	0
	Low	151-300 mg kg^{-1}	0
	Optimum	>300 mg kg^{-1}	2
Magnesium	Very low	<60 mg kg^{-1}	0
	Low	61-120 mg kg^{-1}	0
	Optimum	> 120 mg kg^{-1}	2
Sulphur	Low	<5 mg kg^{-1}	0
	Optimum	5-10 mg kg^{-1}	1
	Above optimum	>10 mg kg^{-1}	0
Copper	Low	<1ppm	0
	Optimum	1-20 mg kg^{-1}	1
	Above optimum	>20 mg kg^{-1}	0
Zinc	Low	<1 mg kg^{-1}	0
	Optimum	1-40 mg kg^{-1}	1
	Above optimum	>40 mg kg^{-1}	0
Boron	Low	<0.5 mg kg^{-1}	0
	Optimum	0.5-2 mg kg^{-1}	1
	Above optimum	>2 mg kg^{-1}	0

5.3. Results and discussion

The soil fertility and soil index maps were drawn based on basic properties, primary nutrients, secondary nutrients and micronutrients. The results obtained are given in the following paragraphs.

5.3.1. Basic properties (pH, EC and OC)

The data on the extent of area under different classes of pH (Table 26) revealed that, the moderately acidic soils were distributed in larger area (37.9 %) extending to about 1146.6 km^2. This was followed by strongly acidic (858.12 km^2), slightly acidic (441.29

km^2), very strongly acidic (430.44 km^2), extremely acidic (91.91 km^2), neutral (61.27 km^2) and slightly alkaline (0.37 km^2) (Table 26). Elevated levels of soil acidity is due to intensive rainfall that could leach soluble nutrients such as Ca and Mg, and with subsequent replacement by aluminum and hydrogen ions. Soils of the central laterite and high hills were strongly to moderately acidic. Continuous use of acid forming inorganic fertilizers on acid soils also aggravate soil acidity. In order to tackle the problem with high acidity, liming of soils in accordance with soil test results is recommended.

Table 26. Extent of area under different classes of pH

Range	Status	Area (km^2)	% Area
3.5 – 4.4	Extremely Acidic	91.91	3.0
4.5 – 5.0	Very Strongly Acidic	430.44	14.2
5.1 – 5.5	Strongly Acidic	858.12	28.3
5.6 – 6.0	Moderately Acidic	1146.6	37.8
6.1 – 6.5	Slightly Acidic	441.29	14.6
6.6 – 7.3	Neutral	61.27	2.0
7.4 – 7.8	Slightly Alkaline	0.37	0.01
Total		3030	100.0

The data on the extent of soils under different classes of EC (Table 27) revealed that the major area of the district was non saline (2901.08 km^2). Medium saline soils were spread over 110.85 km^2 and high saline soils confined only to 18.07 km^2. The accumulation of high soluble salts is not expected in areas of high rainfall and the same is evidently proved in this study.

Table 27. Extent of area under different classes of EC

Range (dS/m)	Status	Area (km^2)	Area (%)
< 1	Low	2901.08	95.8
1 – 3	Medium	110.85	3.7
> 3	High	18.07	0.6
Total		3030	100.0

With regard to OC, data given in Table 28 revealed that the soils with higher status of OC were distributed in larger area (1544.39 km^2) followed by those with optimum levels (1133.11 km^2). The soils with low content of OC was distributed only in smaller area extending to about 352.5 km^2. The high OC status in high hills might be due to the reduced rate of decomposition of OM at higher elevation. But the high OC in special AEUs such as pokkali and kole lands is attributed due to the peat deposit prevalent in that area.

Table 28. Extent of area under different classes of OC

Range (%)	Condition	Area (km^2)	Area (%)
< 0.76	Low	352.5	11.63
0.76 – 1.50	Optimum	1133.11	37.40
> 1.50	Above optimum	1544.39	50.97
Total		3030	100.00

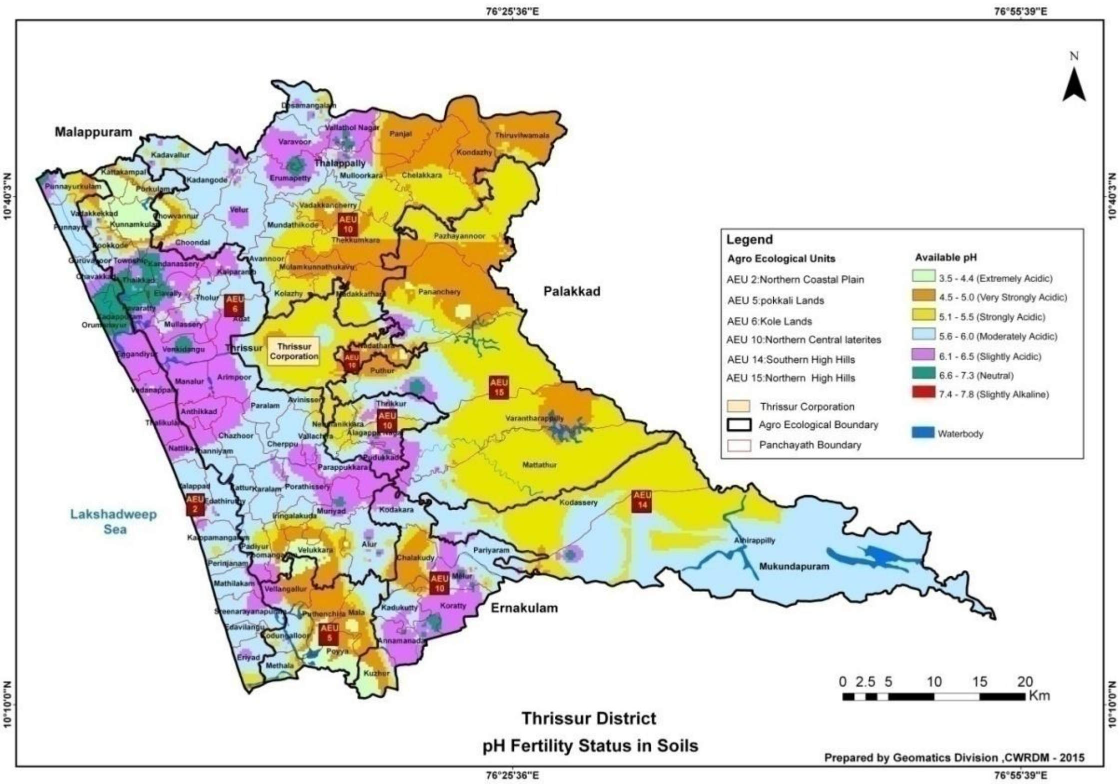

Fig.58. Status of soil pH in Thrissur district

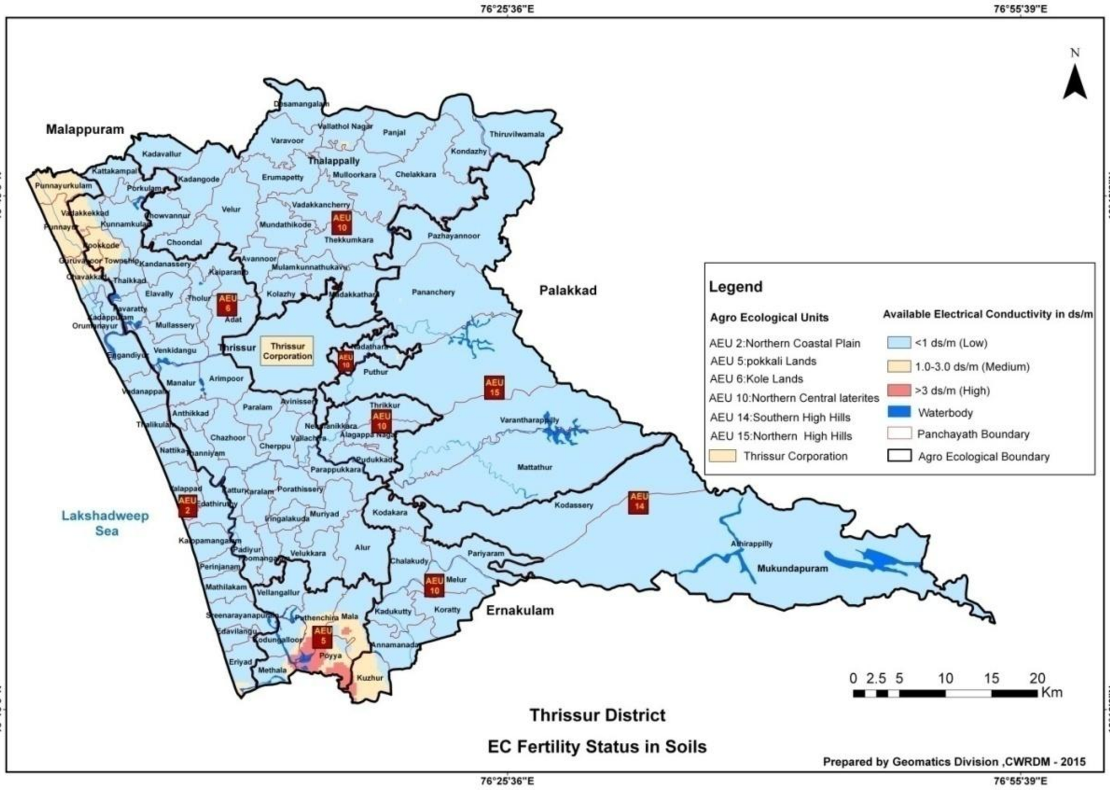

Fig.59. Status of EC in the soils of Thrissur district

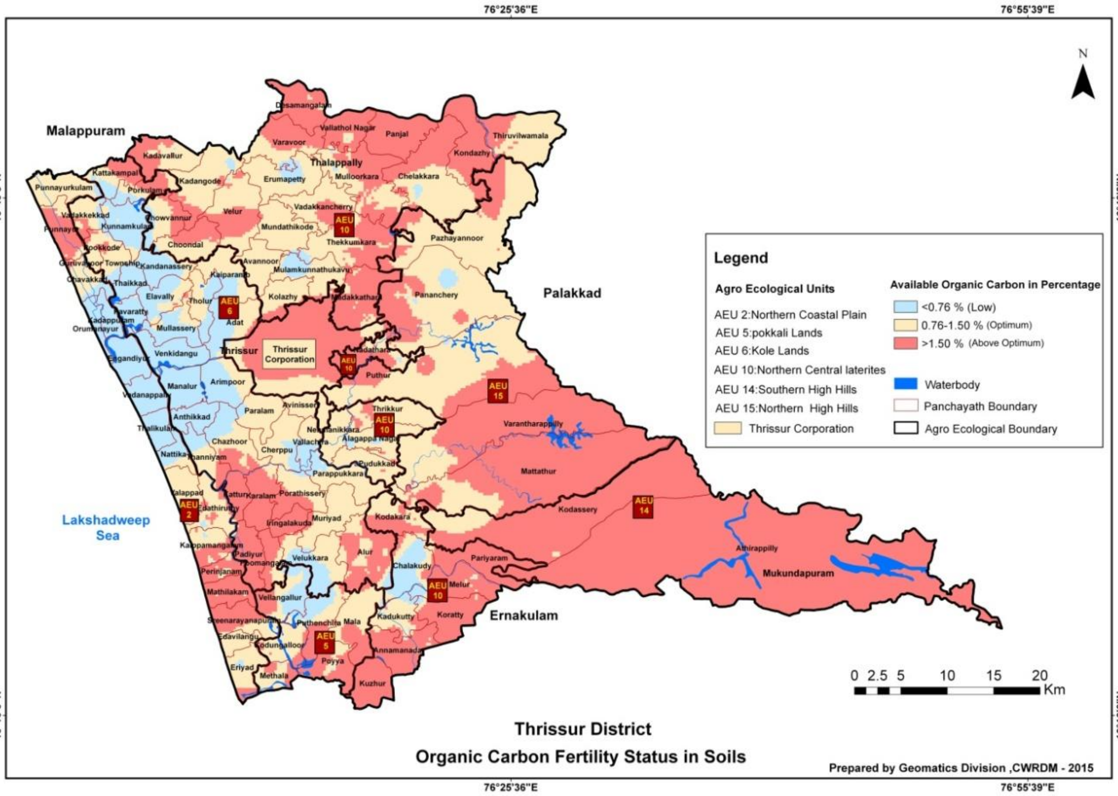

Fig.60. Status of OC in the soils of Thrissur district

5.3.2. Primary soil nutrients (N, P and K)

About 42.96% of the area, extending to about 1301.56 km^2 are optimum in the content of N in the soils of the district, 34.37 % (1041.44 km^2) above optimum and 22.7 % (687 km^2) low (Table 29). High status of N was mainly located in high hills, might be due to the decomposition of OM and further release of N, and accumulated over the years.

Table 29. Extent of area under different classes of N

Range (%)	Status	Area (km^2)	Area (%)
< 0.01	Low	687	22.7
0.01 – 0.02	Optimum	1301.56	43.0
> 0.02	Above optimum	1041.44	34.4
Total		3030	100.0

The data on extent of area under different classes of P (Table 30) pointed out that 97.0 % of the area in the district (2940 km^2) were with high levels of P, while those with low and optimum status of P confined only to 1.1 % (34.5 km^2) and 1.8 % (55.18 km^2) respectively. High content of P in the soil not only impairs the availability and uptake of essential nutrients by plants but also leads to soil and water pollution.

Table 30. Extent of area under different classes of P

Range (kg/ha)	Status	Area (km^2)	Area (%)
< 10	Low	34.5	1.1
10 – 24	Optimum	55.18	1.8
> 24	Above optimum	2940.32	97.0
Total		3030	100.0

The extent of area under different classes of K (Table 31) revealed that, optimum status of K was distributed in larger area extending to about 1369.78 km^2 (45.2%). This was followed by above optimum (39.5 %) and low (15.28 %) fertility status. Above optimum level of K was less prominent in the study area might be due to the high leaching of this nutrient from the soils.

Table 31. Extent of area under different classes of K

Range (kg/ha)	Status	Area (km^2)	Area (%)
< 115	Low	463.01	15.3
115 – 275	Optimum	1369.78	45.2
> 275	Above optimum	1197.21	39.5
Total		3030	100.0

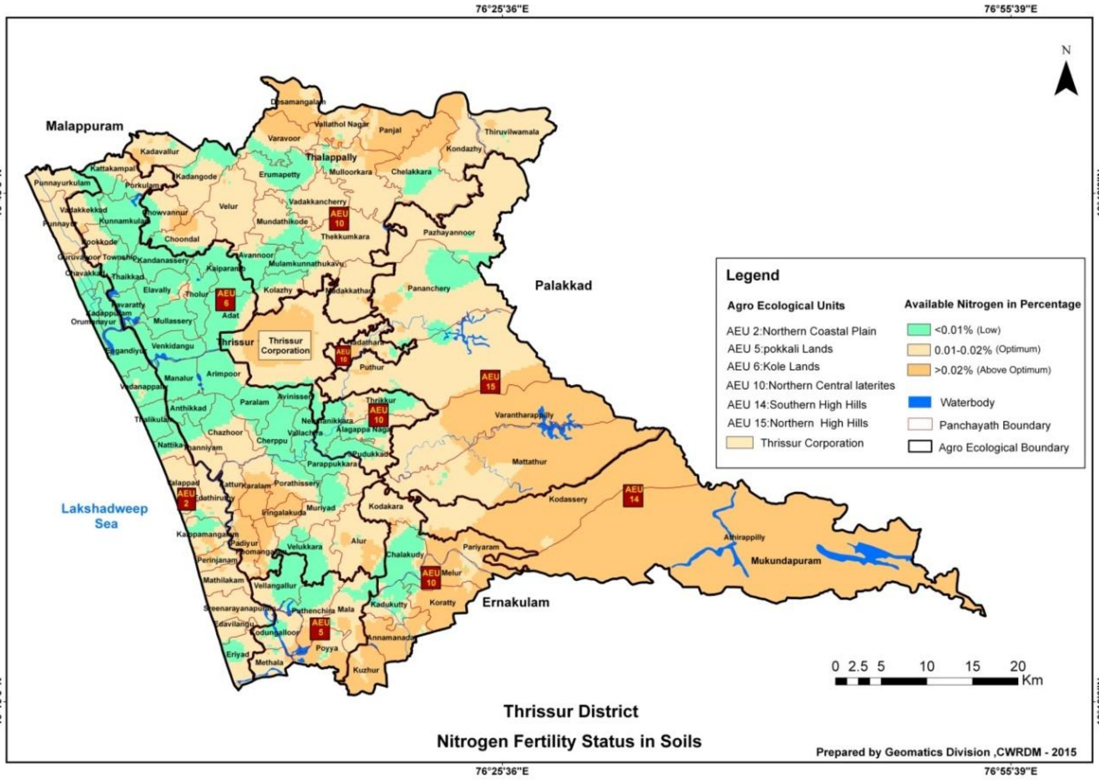

Fig.61. Status of N in the soils of Thrissur district

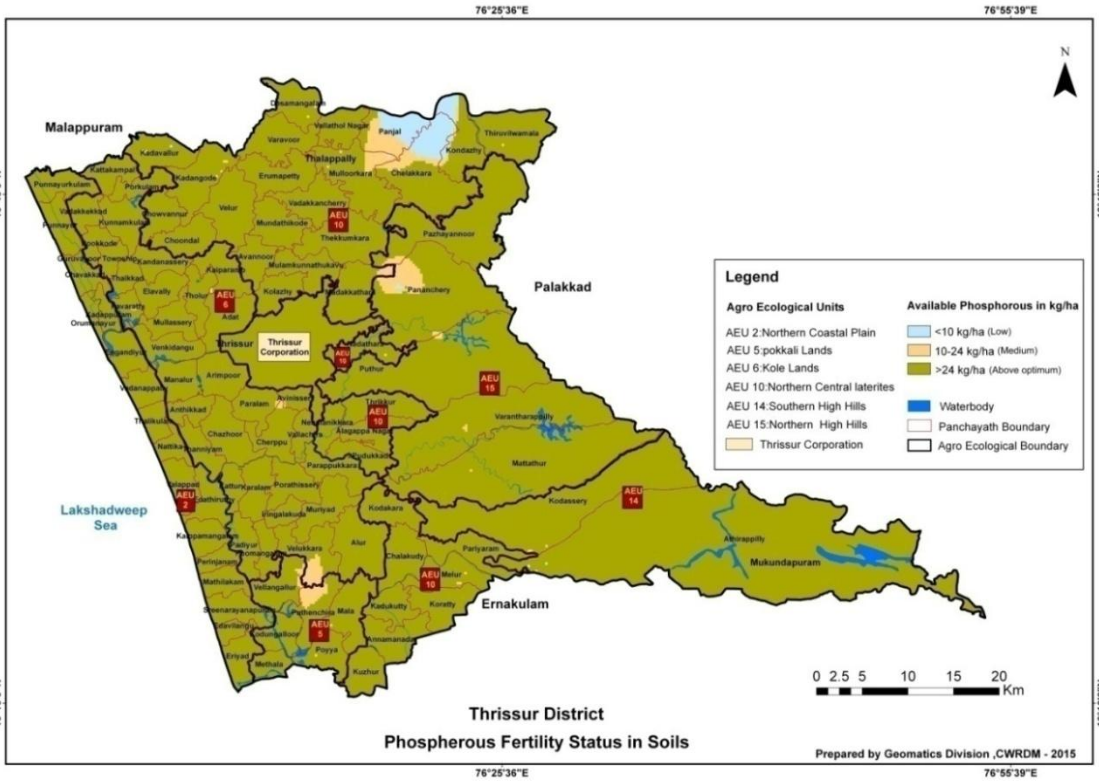

Fig.62. Status of P in the soils of Thrissur district

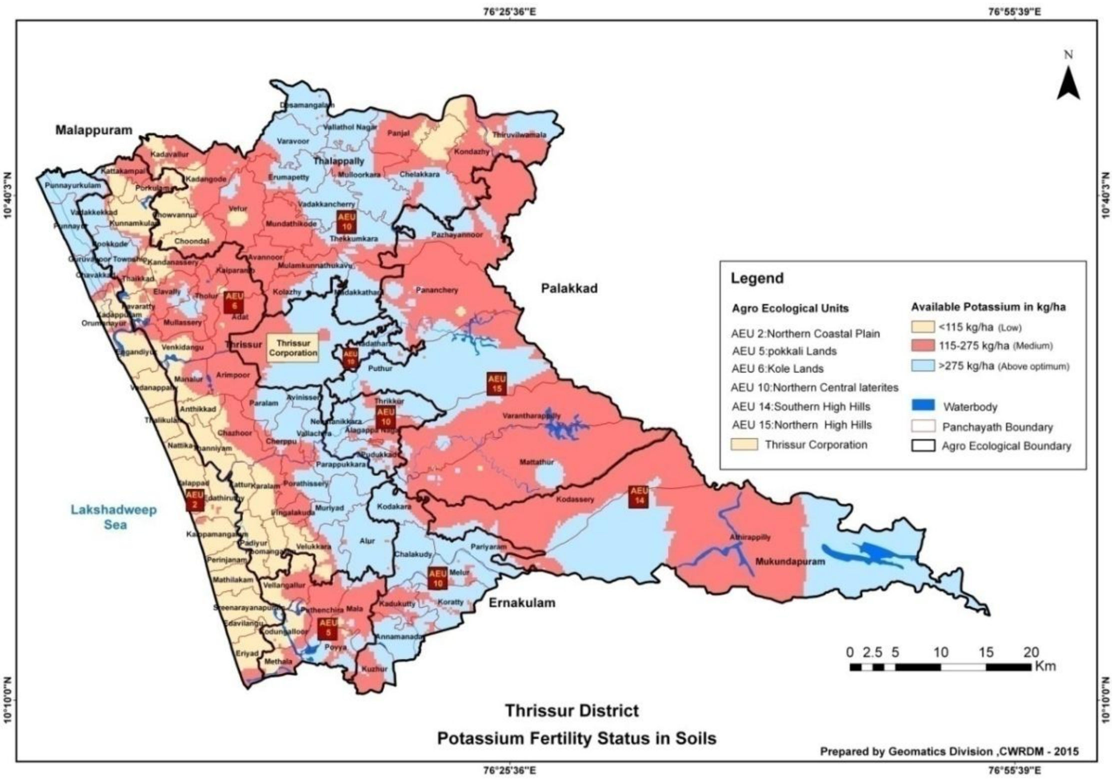

Fig.63. Status of K in the soils of Thrissur district

5.3.3. Secondary nutrients (Ca, Mg and S)

The data on extent of area under different classes of Ca (Table 32) revealed that the optimum status was distributed in larger area extending to about 2763.8 km^2 (91.2 %) followed by low (8.8 %) status. Deficiency of Ca was well pronounced in pokkali, kole lands and in northern coastal plain and this is attributed to various factors such as low pH, high exchangeable and extractable Al and Mn, intensive cultivation and use of inorganic fertilizers (Saikh *et al*., 1998 and Aitken *et al*., 1999).

Table 32. Extent of area under different classes of Ca

Range (ppm)	Status	Area (Km^2)	Area (%)
< 150	Very Low	67.37	2.2
151 – 300	Low	198.83	6.6
> 300	Optimum	2763.8	91.2
	Total	3030	100.0

But in the case of Mg (Table 33), it was seen that larger area was under low status extending to about 2540.1 km^2 (83.8 %) followed by optimum (16.2 %). This indicated that deficiency of Mg was well pronounced in the district, and its severity was more in northern coastal plain, pokkali and kole lands. Application of high dose of NPK fertilizers, inherent high soil acidity, lack of application of Mg containing amendments and heavy leaching are considered as various reasons attributed to the deficiency of this nutrient.

Table 33. Extent of area under different classes of Mg

Range (ppm)	Status	Area (km^2)	Area (%)
< 60	Very Low	698.09	23.0
60 – 120	Low	1842.01	60.8
> 120	Optimum	489.9	16.6
	Total	3030	100.0

With respect to S (Table 34), optimum status was seen distributed in larger area extending to about 1242.5 km^2 (41.0 %) followed by high (40.0 %) and low (19.0 %) status. Most of the phosphatic fertilizers contain S as an additional constituent and this was responsible for optimum levels, especially in intensively managed areas. High reserves of iron pyrites act as a major source of S in pokkali and kole lands.

Table 34. Extent of area under different classes of S

Range (ppm)	Status	Area (km^2)	Area (%)
< 5	Low	574.93	19.0
5 – 10	Optimum	1242.51	41.0
> 10	Above optimum	1212.56	40.0
	Total	3030	100.0

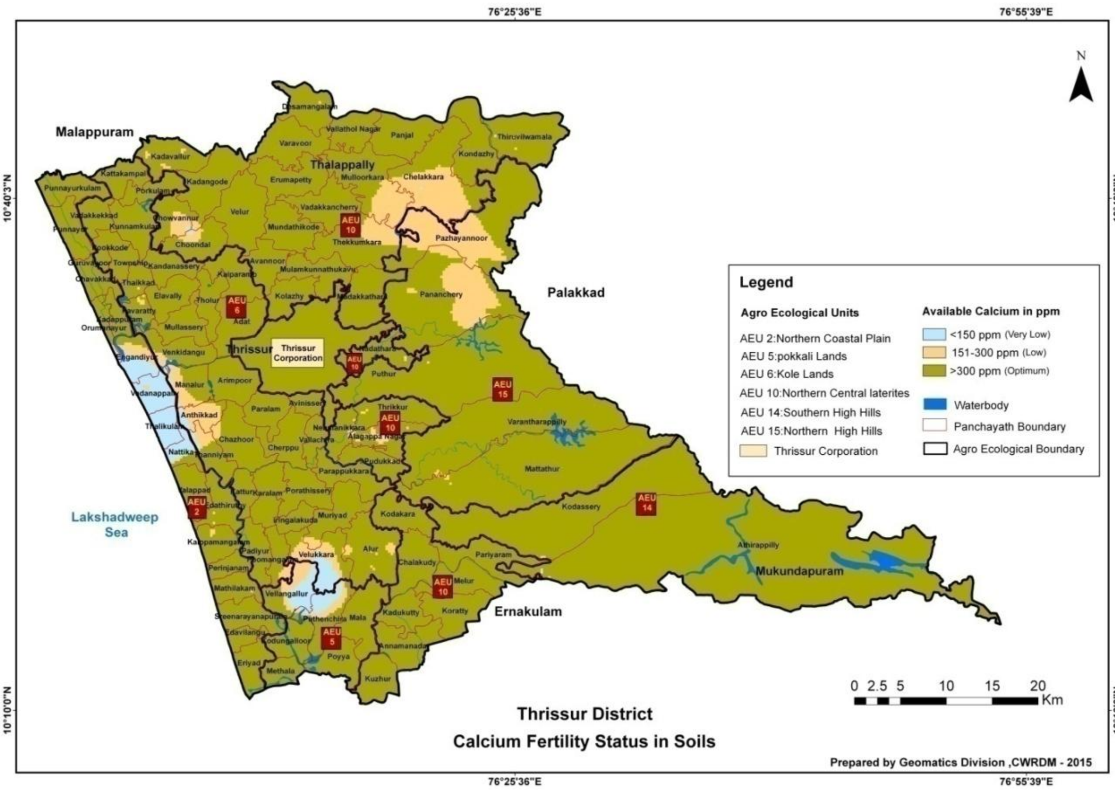

Fig.64. Status of Ca in the soils of Thrissur district

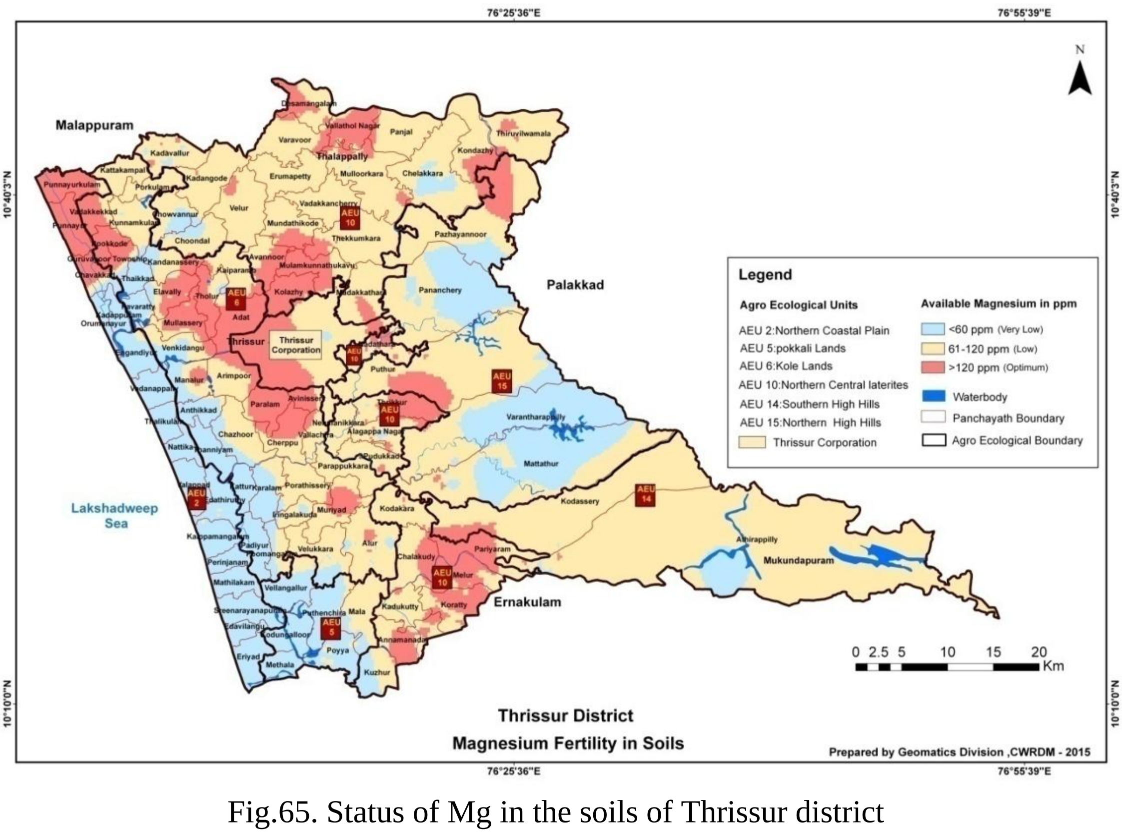

Fig.65. Status of Mg in the soils of Thrissur district

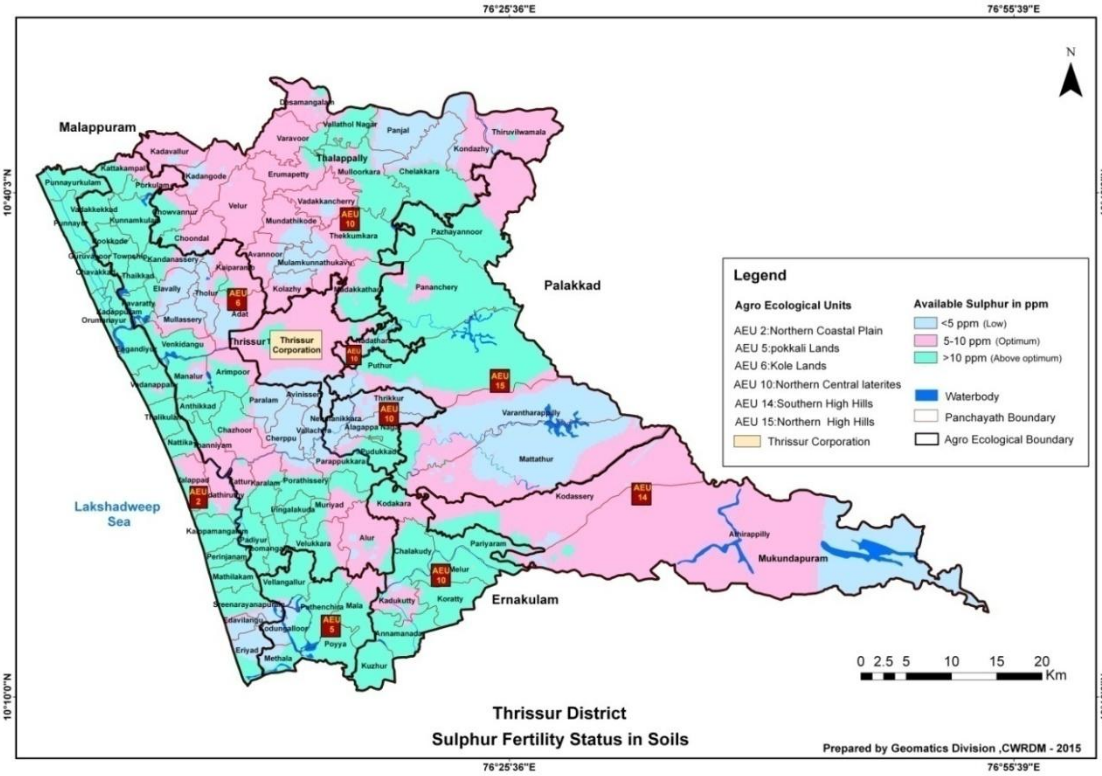

Fig.66. Status of S in the soils of Thrissur district

5.3.4. Micronutrients (Fe, Cu, Zn, Mn and B)

The data on extent of area under different classes of Fe (Table 35) revealed that the soils with adequate status were distributed in larger area (99.96 %) extending to about 3028.84 km^2. Deficiency of Fe was negligible in the study area extending to about 1.16 km^2 (0.04%).

Table 35. Extent of area under different classes of Fe

Range (mg/kg)	Status	Area (km^2)	Area (%)
< 5	Deficient	1.16	0.04
> 5	Adequate	3028.84	99.96
Total		3030	100.0

In the case of Cu, soils with optimum status were distributed in larger area (85.2 %) extending to about 2580.41 km^2. The deficiency of Cu was less prominent and confined to about 449.59 km^2 (14.8 %) (Table 36). Cu was an important ingredient of common fungicides used to combat many fungal born diseases of crops. Cu input from fungicides and the retention of the element in soil organic matter might be the reason for its optimum status in the study area.

Table 36. Extent of area under different classes of Cu

Range (mg/kg)	Status	Area (km^2)	Area (%)
< 1	Low	449.59	14.84
1 – 20	Optimum	2580.41	85.16
> 20	Above Optimum	-	
	Total	3030	100.00

With regard to Zn (Table 37), the soils with optimum status was distributed in larger area extending to about 2884.13 km^2 (95.2 %). The deficiency of Zn was negligible in the district covering an area of 145.87 km^2 only. Usually, this element occurs as a contaminant in phosphatic fertilizers and high input of phosphatic fertilizers might have ensured adequate levels of Zn in the soils of the district.

Table 37. Extent of area under different classes of Zn

Range (ppm)	Status	Area (km^2)	Area
< 1	Low	145.87	4.8
1 – 40	Optimum	2884.13	95.2
> 40	Above Optimum	-	
	Total	3030	100.0

With regard to Mn (Table 38), soils with adequate status were prominent in larger area (93.98%) extending to about 2847.54 km^2. The deficiency level of this nutrient was negligible in the district extending to an area of 182.46 km^2 (6.0 %).

Table 38. Extent of area under different classes of Mn

Range (mg/kg)	Condition	Area (km^2)	Area (%)
< 1	Deficient	182.46	6.0
> 1	Adequate	2847.54	94.0
	Total	3030	100.0

The data on the extent of area under different classes of B (Table 39) showed that, deficiency level was prominent in larger area (99.21%) extending to about 3006.16 km^2 followed by optimum level 23.84 km^2 (0.79%). B, being water soluble, is lost quickly from the system through run off water and leave the soil at deficient level.

Table 39. Extent of area under different classes of B

Range (mg/kg)	Status	Area (km^2)	Area (%)
< 0.5	Deficient	3006.16	99.2
0.5 – 2	Optimum	23.84	0.8
> 2	Above Optimum	-	
	Total	3030	100.00

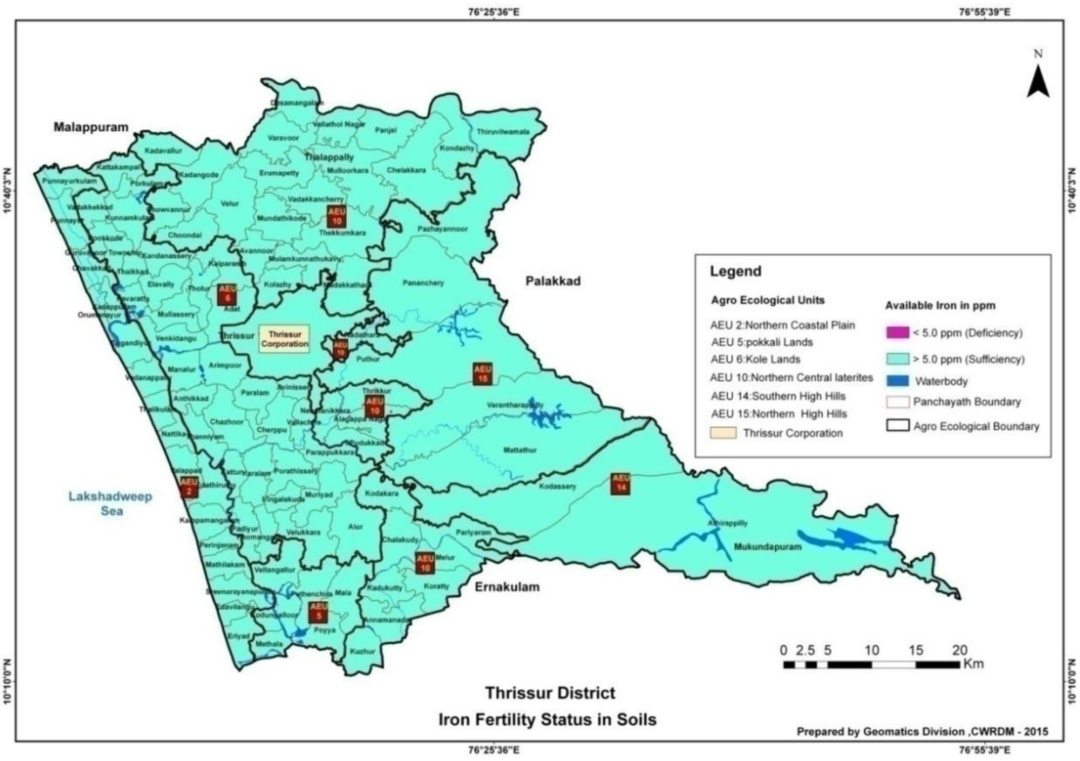

Fig.67. Status of Fe in the soils of Thrissur district

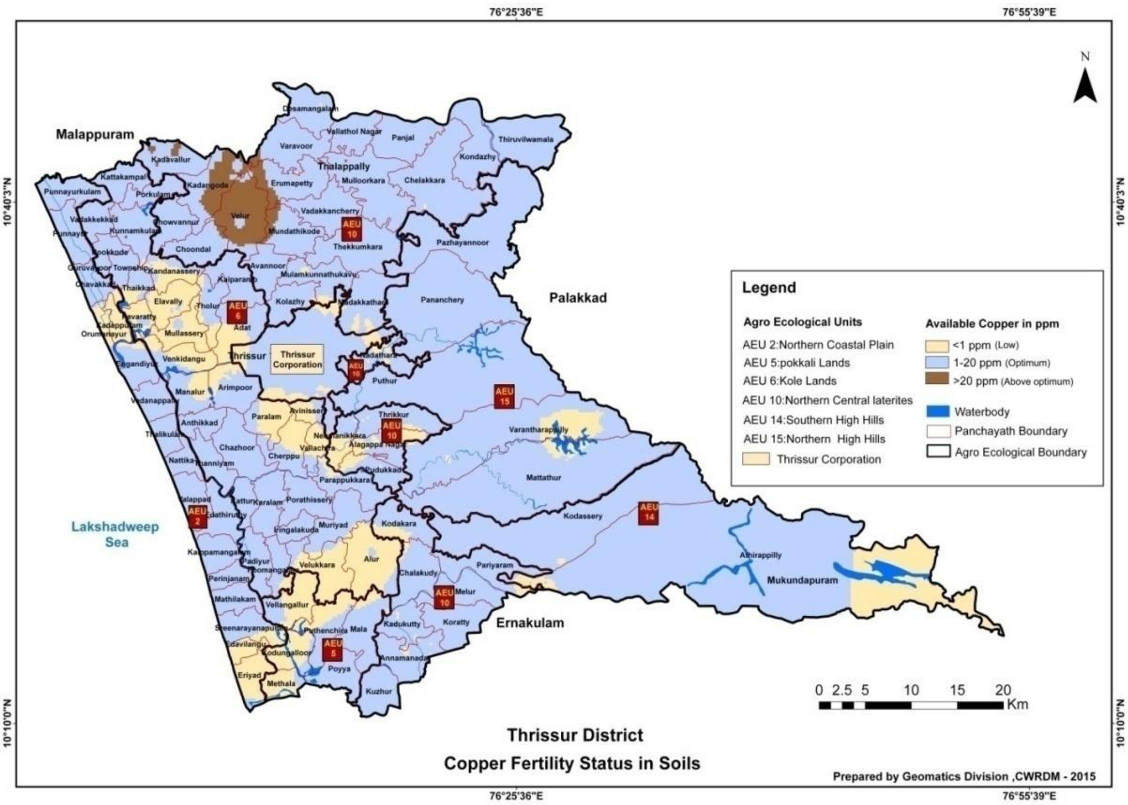

Fig.68. Status of Cu in the soils of Thrissur district

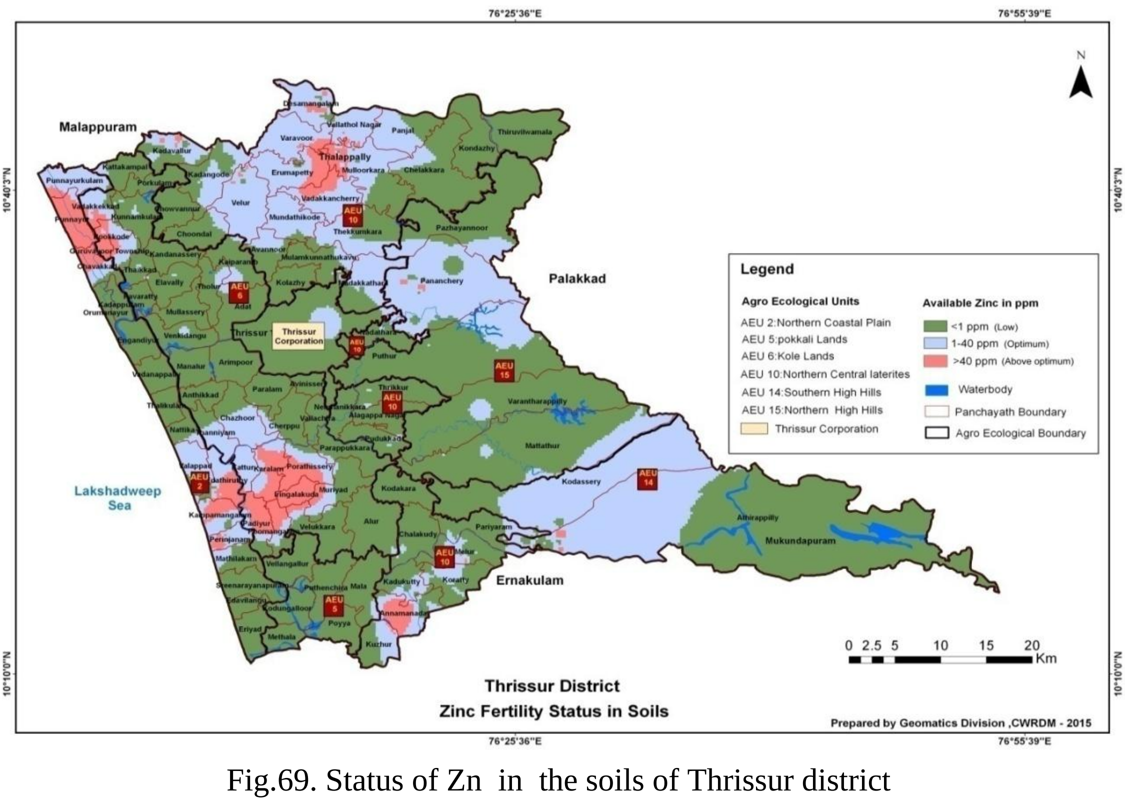

Fig.69. Status of Zn in the soils of Thrissur district

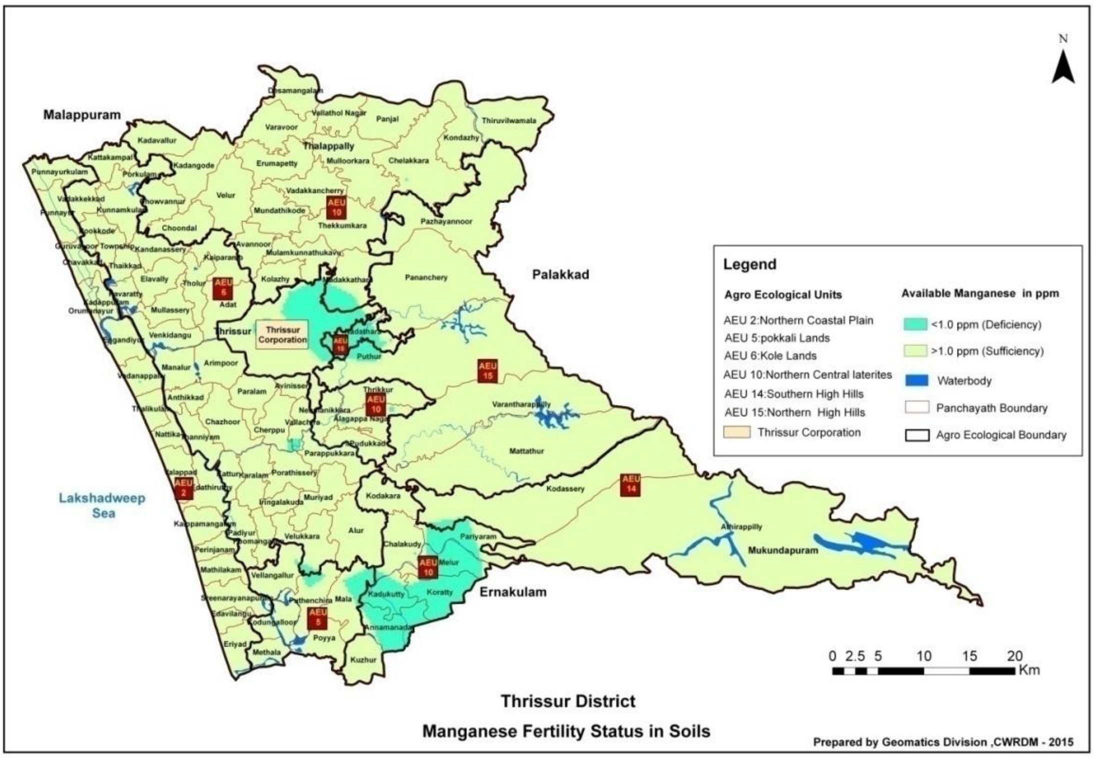

Fig.70. Status of Mn in the soils of Thrissur district

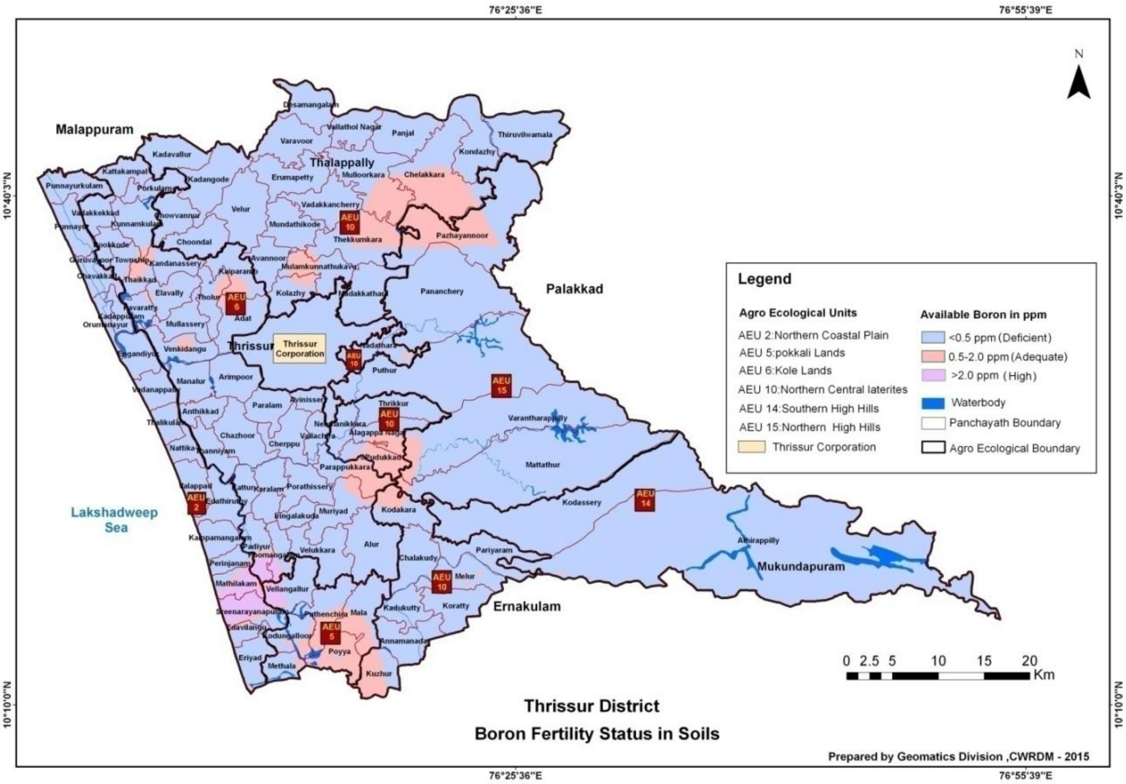

Fig.71. Status of B in the soils of Thrissur district

5.3.5. Soil fertility index

The data on the extent of area under different classes of soil fertility (Table 40) in Thrissur district revealed that, optimum level of fertility extended to about 1243.9 km^2 (41.1%). This was followed by above optimum (1551.9 km^2) and low fertility (234.18 km^2) of the study area. The above optimum status of soil might be negatively affect the nutrient availability of soil, there was no need of any nutrient management and need only OM management in the district. 41% of the area in the district showed optimum soil fertility (Table 40), which was most suitable for farming practices. 44.9 % of optimum area of highly suitable for agricultural practices was also reported by Adornado and Yoshida (2008) in Philippines and created optimum soil fertility maps to provide information regarding the current soil condition and crop suitability.

Table 40. Extent of area under different classes of soil fertility

Range	Status	Area (km^2)	Area (%)
0 - 5	Low	234.18	7.7
6 - 10	Above Optimum	1551.93	51.2
11 - 18	Optimum	1243.89	41.0
		3030	100.0

5.3.5.1. *Soil fertility index in various agro ecosystems*

The map (Fig.73) on the fertility index of various agro ecosystems revealed that, soils with low fertility was mainly concentrated in the coconut prominent areas of the northern coastal plain. The coconut based cropping systems in the map were indicated by the red colour. The areas within the yellow band indicated low fertility and blue band optimum fertility. The coconut based cropping systems in northern coastal plain were more prominent within the yellow band. The agro ecosystems belonging to optimum fertility were paddy, banana, coconut and rubber. The ecosystems in the areas without any band were above optimum fertility.

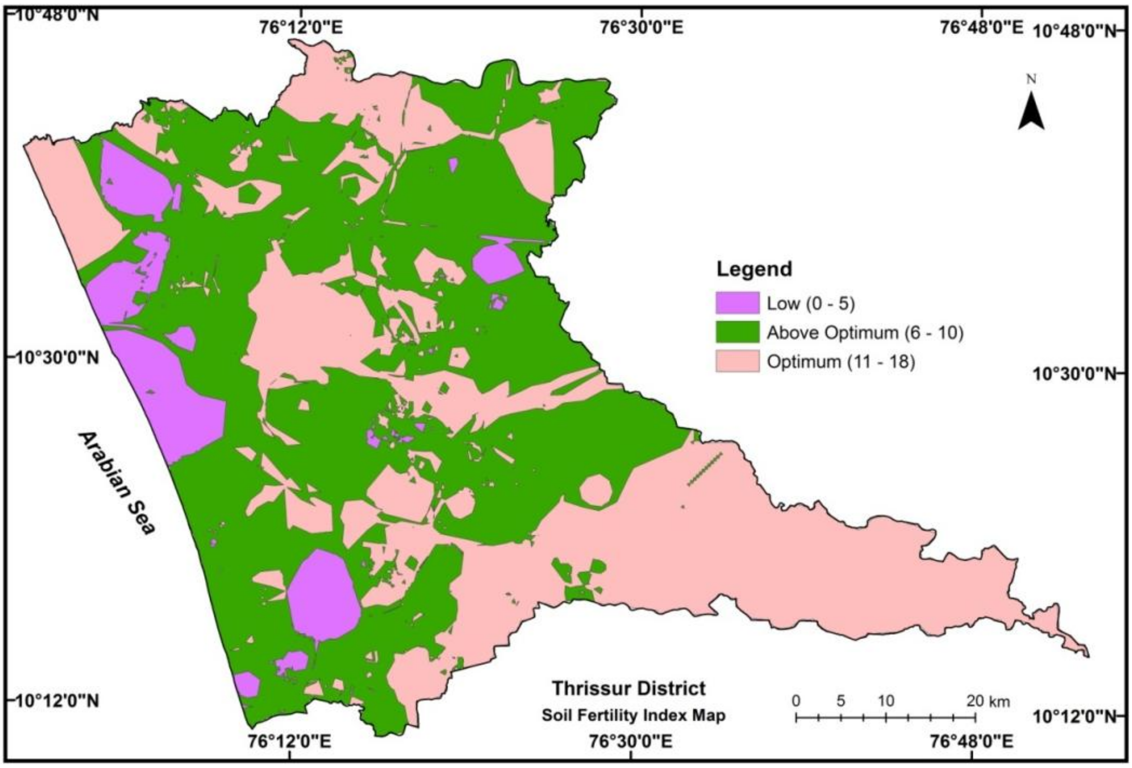

Fig.72. Soil fertility index map of Thrissur district

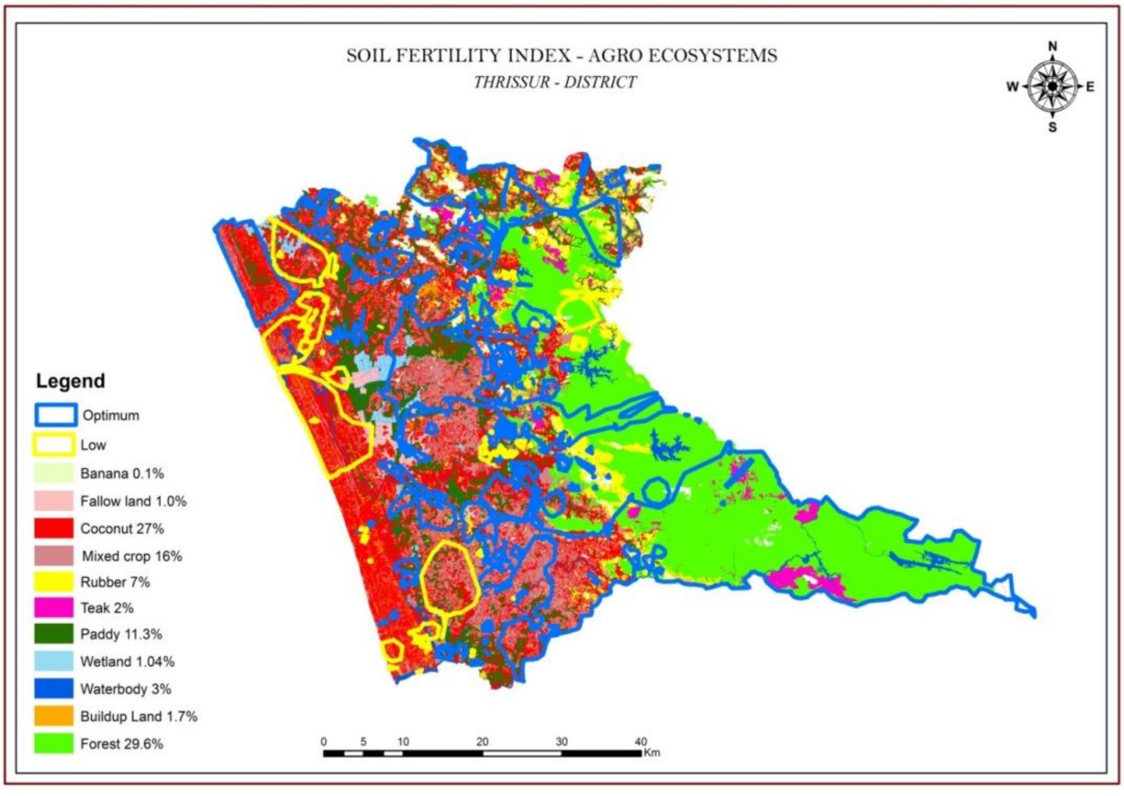

Fig.73. Soil fertility index map of various agro ecosystems in Thrissur district

In recent years increasing attention is being paid on soil test based fertilization for sustaining the productivity of agricultural soils leading to better efficiency and economics of nutrient use with off farm advantage of environmental security. A district wide soil fertility map developed to provide the information regarding the current soil condition for efficient management of soil. The level of soil nutrient must be known for maintaining soil in good condition. The information generated in this study could be used for temporal study of the soil fertility to compare the fertility status in future. For soil fertility monitoring it may be ideal to identify some bench mark sites in the study area.