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Evaluation of soil fertility status in various agro ecosystems of Thrissur District, Kerala, India

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ABSTRACT: This study was conducted to evaluate soil fertility status in the eight major agro ecosystems viz., coconut, banana, rubber, paddy, arecanut, nutmeg, pepper and vegetables in Thrissur District, Kerala. For this, a total of 30 panchayats out of 92 were selected representing 6 agro ecological zones in the district. Surface soil samples (0-15 cm) @ one sample/ ha. were collected from dominant agro ecosystems along with the details regarding farmer's name, soil type, fertilizer details, irrigation etc. There were a total of 5120 samples. The collected samples were air dried, sieved and analyzed for various soil fertility parameters such as pH, EC, organic carbon, macro and micro nutrients etc. The data on various parameters were categorized into low, medium and high classes based on soil fertility ratings and nutrient index was calculated. Results revealed that soil reaction in the study area varied from strongly acidic to slightly alkaline with pH values varying from 2.9 to 7.7 Among the eight agro ecosystems studied, soil fertility with respect to organic carbon and nitrogen were high in rubber and medium in all others. In all the agro ecosystems, status of P was high. Status of K was low in arecanut and high in rubber. Sulphur was low in rubber, vegetables and pepper. All the micronutrients except boron were high in all the agro ecosystems. But the status of boron was low in all the eight agro ecosystems studied. .

Key words: Agro ecosystem, macronutrients, micronutrients, nutrient index, soil fertility status

INTRODUCTION

Soil, the source of infinite life is the most vital and precious natural resource, and not renewable in short time. Soil fertility is a dynamic natural property and it can change under the influence of natural and human induced factors. As human population continue to increase, human disturbance on the earth's ecosystem to produce food and fiber will place greater demand on soils to supply essential nutrients. Continuous cropping for enhanced yield removes substantial amounts of nutrients from soil. Imbalanced and inadequate use of chemical fertilizers, improper irrigation and various cultural practices also deplete the soil quality rapidly (Medhe *et al.,* 2012). Soil fertility fluctuates throughout the growing season each year due to alteration in the quantity and availability of mineral nutrients by the addition of fertilizers, manure, compost, mulch, and lime in addition to leaching. Hence, evaluation of fertility status of the soils of an area or a region is an important aspect in the context of sustainable agriculture (Singh and Misra, 2012). Soil testing assess the current fertility status and provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for maximizing crop yields and to maintain the optimum fertility in soil year after year.

The site specific nutrient management practices reduce the cost of cultivation and environmental pollution due to the imbalanced application of chemical fertilizers. For proper soil management, the farmer should know what amendments are necessary to optimize the productivity of soil for specific crops. At present, crop specific and site specific informations on fertility status of soils in Thrissur district of Kerala are not available. Hence this study mainly focused on the soil fertility evaluation of various agro ecosystems prevalent in Thrissur district of Kerala.

MATERIALS AND METHODS

Description of the Study Area

Thrissur district is situated in the central part of Kerala. Lying between north latitudes 10° 31' and 10° 52' and east longitudes 76° 13' and 76° 21', the district is bound on the north by Malappuram and Palakkad districts, east by Palakkad district, south by Ernakulam district and west by Lakshadweep Sea. Administratively, the district is divided into 5 taluks, one corporation, 6 municipalities, 254 villages, 17 block panchayats and 92 grama panchayats covering a geographical area of 3032 km^2. Descending from the heights of Western Ghats

in the east, the land slopes towards the west forming three distinct natural divisions, the highland, the mid land and sea board. The district has a tropical humid climate with an oppressive hot season and plentiful seasonal rainfall. Annual rainfall is about 3000 mm. The hot season is from March to May. South-west monsoon is received during the period June to September and north-east monsoon during October and November. The maximum temperature ranges from 29.3 °C to 36.2 °C and the minimum temperature ranges from 22.1 °C to 24.9 °C. Archaean crystalline formation (gneiss, schist and charnockite), tertiary formation, sub-recent laterite and recent riverine alluvium are the major geological formations of the district. Five rivers and their tributaries drain the district: Periyar, Chalakkudy, Karuvannur, Karumali and Bharathapuzha. They all take their origin from the mountains in the east, flow westward and discharge into the Kole lands or sea. Major soil types in the district include laterite soil, brown hydromorphic soils, hydromorphic saline soils, coastal alluvium, riverine alluvium and forest loamy soil. Sandy loam soil is found in the part of Mukundapuram, Thrissur and Chavakkad taluks. Laterite soil is common in eastern part of Thrissur and western part of Thalappally taluks. Clayey soil is found in Mukundapuram taluk and portions of Chavakkad taluk. Hydromorphic saline soil is seen in coastal tracts of Thrissur, where during rainy season the fields are flooded leaving the area almost free of salt.

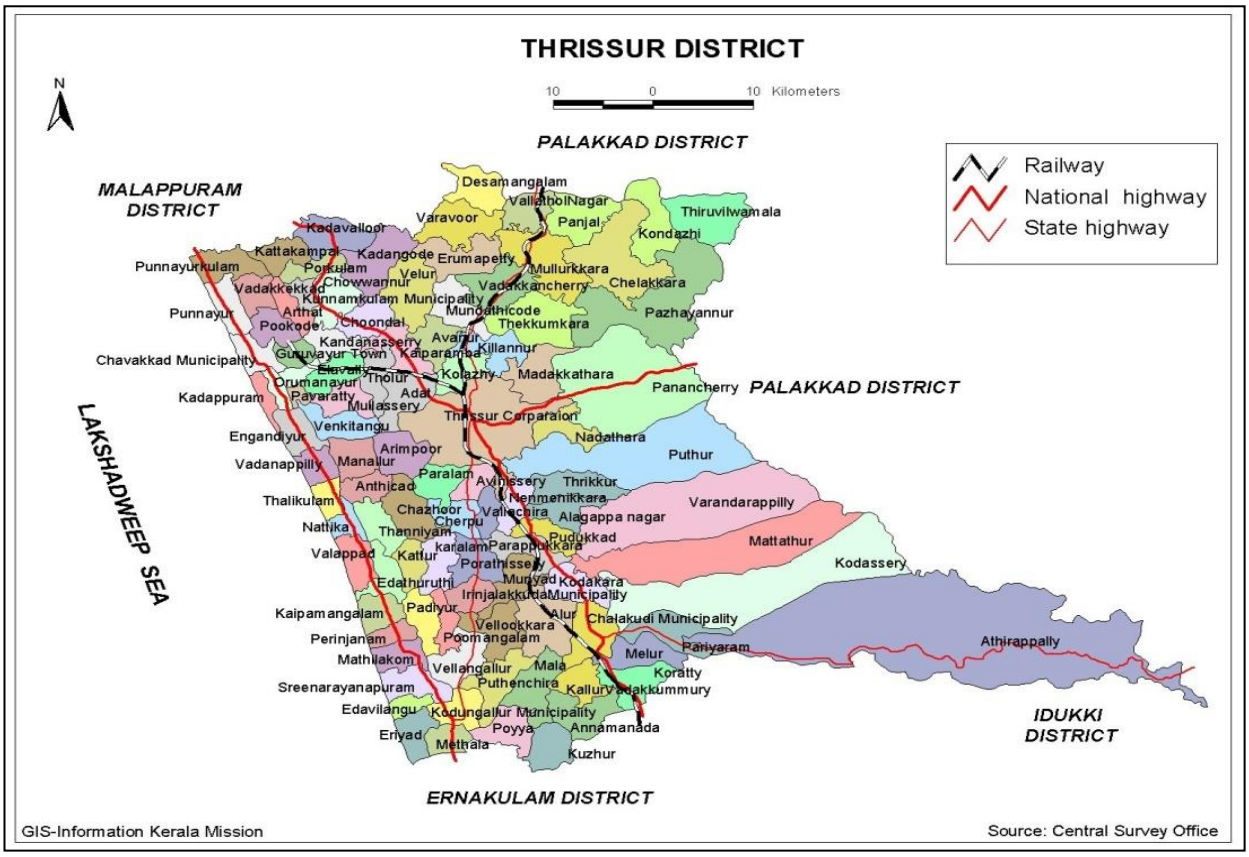

Figure 1. Map of the study area

Soil Sampling and Analysis

Agriculture is an important livelihood activity among the people in Thrissur Dt. Major Agro ecosystems in Thrissur district are paddy fields, rubber plantations, mono and poly cultures of coconut, banana, arecanut, vegetables etc. Thirty Panchayaths were selected from different agro ecological zones. 600 Georeferenced surface soil samples (0-15 cm) were collected from the dominant agro ecosystems along with the details regarding farmer's name, soil type, fertilizer details, irrigation etc. Altogether 5120 **s**oil samples (0-15 cm depth) were collected from the district. The collected samples were then air dried and sieved through 2mm sieve. The processed soil samples were analyzed for pH (2:5 soil water suspension), electrical conductivity (conductivity meter), organic carbon (Walkley and Black, 1934), available phosphorous by spectrophotometer (Bray and Kurtz, 1945), available potassium using flame photometer, available calcium, magnesium, micronutrients such as copper, iron, manganese and zinc (DTPA Extractable), sulphur ($Cacl_2$ Extraction) and boron(hot water extraction) using AAS (AA 240). Extractable potassium by using flame photometer (CL 378). Nutrient index value was calculated using the following equation.

Nutrient Index Value = (per cent samples testing low x 1 + per cent samples testing medium x 2 + per cent samples testing high x 3) /100 (Shetty *et al*., 2008; Pathak, 2010 and Kumar *et al*., 2013).

Statistical Analysis

The data were analyzed using descriptive statistics and analysis of variance using (SPSS 17. 0) Duncan's multiple range was also employed to test the significance difference between locations. Correlation analysis was also performed in order to determine the relationship between the selected soil properties.

RESULTS AND DISCUSSION

The soil fertility status of various agro ecosystems in the study area was evaluated with respect to pH, EC, organic carbon (OC), primary nutrients, secondary nutrients and micronutrients such as Cu, Fe, Mn, Zn, and B and the results obtained are presented and discussed in the following paragraphs.

pH, Electrical conductivity and Organic carbon

The pH of the soils of various agro ecosystems varied from 2.9 to 7.7 indicating extremely acidic to slightly alkaline in reaction (Table 1). pH was significantly high in pepper (6.0) and low in paddy (4.9) growing areas. The cropping systems viz., vegetables, coconut, rubber and banana were on par with pH 5.4 and strongly acidic in reaction. (Table 3). On assessing the soil acidity in relation to major crops, it was found that 60% of samples were accounted for optimum range of soil reaction in arecanut, 10% in paddy, 50% in coconut, 35% in vegetables and 50% in rubber (Fig 2). Most of the rice growing areas of the district were extremely to strongly acid soils (Pokkali and kole lands). The low proportion of strongly acid soils under arecanut and rubber production systems may be due to low input of chemical fertilizers. The soils of Thrissur district in general were acid in reaction brought out by the intense rainfall and consequence leaching of bases. The acidity of the study area is aggravated by heavy input of acidic fertilizers and lack of inputs to neutralize acidity. Soil pH affects the plant nutrient availability by controlling the chemical forms of the nutrients and the optimum range of pH was 5.5-6.5 in which all the nutrients were moderately available to plants.

The electrical conductivity of the soils of various agro ecosystems of the study area varied from 0.01-5.8 dS/m. The agro ecosystems such as arecanut, paddy, rubber and pepper were on par with respect to the mean content of soluble salts (Table 3). Even though the mean value of electrical conductivity was significantly high in banana and in nutmeg (0.3 dS/m) (Table 3), in all the cropping systems, above 90% of the samples were low in EC. This may be due to leaching of soluble salts by irrigation water and high rain fall. The low EC of soils indicate the conditions prevailed was not favorable for accumulation of salts (Roy *et al*., 1962).

The organic carbon content of the soils of various agro ecosystems varied from 0.04-7.6 %. The mean value was significantly high in rubber (1.8%) and low in coconut (1.1%, Table.1). The cropping systems; banana, nutmeg and vegetables were on par with respect to the content of organic carbon (1.6%). Low level of organic carbon was more in coconut (30%) followed by arecanut (25%), vegetables and nutmeg (20%) (Fig. 3). Continuous and intensive cultivation leading to high crop removal was the reason for high shortage of organic carbon. Soils of Thrissur district being rich in low activity clays, it is essential to maintain high levels of organic matter in the soils. High levels of organic matter not only provides part of the N requirement of crop plants, but also enhance nutrient and water retention capacity of soils and create favourable physical, chemical and biological environment.

Primary nutrients (N, P and K)

The nitrogen content of the soils of the various agro ecosystems varied from 0.003-0.63 %. Among the eight agro ecosystems; arecanut, paddy, pepper and banana were on par with respect to the mean content of N (0.13%) (Table 3). Nitrogen was significantly high in rubber (0.15%) and low in coconut (0.09%) (Table 1). On considering each crop separately, coconut growing areas were more deficient in nitrogen (30%) followed by arecanut (25%), vegetables (20%) and nutmeg (20%) (Fig 4). Continuous and intensive cultivation leading to high crop removal together with insufficient replenishment might be the reason for high degree of nitrogen deficiency. Soils with higher levels of nitrogen (60%) were more in rubber, might be the contribution from the leguminous cover crops for the crops and very little tillage.

The phosphorous level of the soils of various agro ecosystems varied from 0.1-847.7 ppm. Its mean content was significantly high in arecanut (274 kg/ha) and low in paddy (61.8 kg/ha) (Table 3). A very high proportion of soil samples (80%) were with excess levels of P, which may be due to the high input of phosphatic fertilizers over a period of time (Fig. 5). There was no significant variation between the cropping systems with respect to available P. High level 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.

A significant positive correlation was observed between soil available P and soil pH in vegetables (r= .294**), nutmeg (r= .319**), rubber (r=.152**), coconut (r=.849**) and in banana (r= .192**). Another significant positive correlation was found between available P and OC in coconut (r= .982**), rubber (r= .141**), banana (r= .172**) and in arecanut (r= .144**) (Table. 6). The significant and positive correlation indicates that availability of

P in these soils regulated by the content of organic carbon and high soil pH. According to Tisdale *et al.* (1997) decomposition of organic matter produces humus, which protects P fixation.

The content of potassium in the soils of various agro ecosystems varied from 1.0 – 2914 kg/ha. Its mean content was significantly high in banana (433 kg/ha) and low in paddy (166.1kg/ha) (Table 3). The potassium deficiency was low in rubber (10%) and in banana (25%), might be due to intense use of potassium fertilizers. The deficiency level was high in arecanut (60%), paddy (50%) and in coconut (45%) (Fig 6), the probable reason might be the leaching condition brought in by irrigation coupled with strong acidity which does not permit retention of potassium on the soil exchangeable complex. The same trend was observed in samples drawn from nutmeg, pepper, and vegetables. A significant positive correlation was found between K and EC in arecanut (r= .241**), paddy (r= .335**), nutmeg (r= .139**), coconut (r= .991**) and in rubber (r= .437**) (Table. 6). Similarly there was a significant positive relation between potassium and organic carbon in soil. It was also supported by Chauhan (2001) in Rajasthan. Hassan (2002) could n't find high deposits of K in any of the districts in Kerala, but in the present study 32.5 % of soil samples were high in K.

Secondary nutrients (Ca, Mg and S)

The content of calcium in the soils of various agro ecosystems varied from 20.6 – 3515 ppm (Table 3). It was significantly high in banana (600.2 ppm) and low in paddy (413.6 ppm). The agro ecosystems; arecanut, banana, vegetables and pepper were with almost similar content of this nutrient (Table 3). Usually content of calcium in the soils are affected by drainage, soil type, pH and liming practices. The deficiency level of calcium was high in paddy (40%), coconut (30%) and vegetables (30%) and low in arecanut (17%) pepper (17%) (Fig 7). The low levels of Ca might be due to continuous addition of acidifying chemical fertilizers. The correlation studies revealed a significant and positive correlation between pH and Ca in all the agro ecosystems (Table. 6). This is supported by the findings of Mahapatra and Sahu (1966) and Methe *et al*. (2012)

Table 1. Descriptive statistics of macronutrients in various agro ecosystems in Thrissur

Agro ecosystems	Soil properties	Mean	Std. Deviation	Std. Error	Coefficient of variation	Minimum	Maximum
Arecanut	p^H	5.8	0.7	0.02	11.4	2.9	7.7
	EC(ds/m)	0.1	0.3	0.01	216.9	0.01	4.8
	OC(%)	1.4	0.8	0.02	61.8	0.3	7.6
	N(%)	0.117	0.067	0.002	57.3	0.025	0.633
	P(%)	297.5	873.7	23.73	293.7	0.1	315.8
	K(%)	166.1	195.7	5.31	117.8	4.7	2280.3
	Ca(ppm)	579.6	324.5	8.82	56	55	3515
	Mg(ppm)	67.7	58.7	1.59	86.7	3	711
	S(ppm)	13.3	28.7	0.78	216.4	0.06	575
Banana	p^H	5.4	0.7	0.05	12.6	3.9	7.1
	EC(ds/m)	0.3	0.7	0.05	263.5	0.01	4.8
	OC(%)	1.6	0.8	0.06	52.7	0.1	5.7
	N(%)	0.13	0.07	0.01	53.80	0.01	0.48
	P(%)	110.7	95.9	6.92	86.6	1.0	713.9
	K(%)	433	943.6	68.1	217.9	28	1275.7
	Ca(ppm)	600.2	411.5	29.7	68.6	37.7	1631.9
	Mg(ppm)	103.1	70.3	5.07	68.2	11.7	323.7
	S(ppm)	23	49.5	3.58	215.1	0.03	321.7
Coconut	p^H	5.4	0.8	0.03	15.5	3.3	7.4
	EC(ds/m)	0.2	0.6	0.02	270.9	0.01	5.8
	OC(%)	1.1	0.8	0.03	68.3	0.04	4.3
	N(%)	0.09	0.07	0.003	77.70	0.003	0.36
	P(%)	92.6	97.6	3.59	105.4	0.2	777.1
	K(%)	277.5	373.3	13.74	134.5	4.0	2914
	Ca(ppm)	462.1	364.8	13.43	78.9	20.6	1888.5
	Mg(ppm)	83.3	55.9	2.06	67.1	9.8	518.4
	S(ppm)	22	37.7	1.39	171.6	0.1	337.5
Nutmeg	p^H	5.5	0.8	0.06	14.2	3.7	7.7
	EC(ds/m)	0.3	0.9	0.07	290.2	0.01	5.6
	OC(%)	1.6	0.8	0.06	49.9	0.04	4.6
	N(%)	0.133	0.067	0.005	50	0.003	0.38
	P(%)	95.4	90.9	7.32	95.3	3.1	562.2
	K(%)	274.9	241.2	19.44	87.7	16	1926
	Ca(ppm)	481.2	260.6	21	54.2	101.3	1409.5
	Mg(ppm)	77.7	44	3.54	56.6	3	206.5
	S(ppm)	32.4	66.6	5.36	205.3	0.2	526.3

Where, EC= electrical conductivity; OC = organic carbon; N= nitrogen; P = phosphorous; K=potassium; Ca = calcium; Mg = magnesium; S= sulphur

The magnesium content of the soils of various agro ecosystems varied from 3.0 – 524.0 ppm. It was significantly high in banana (103.1ppm) and low in paddy (80. ppm) (Table 2). Deficiency of magnesium was well pronounced in arecanut (37%) followed by coconut (25%) (Fig 8). Almost same percentages of samples were deficient in the cropping systems such as banana, paddy and nutmeg (17%). A significant positive correlation was observed between soil pH and magnesium in paddy (r= .138**), nutmeg (r= .271**), rubber (r= .309**), coconut (r= .966**) and banana (r= .238**) (Table. 6). But Methe *et al.* (2012) reported a significant negative correlation between pH and magnesium in Maharashtra..

The content of sulphur in the soils of various agro ecosystems varied from 0.03 – 575.0 ppm. It was significantly high in nutmeg (32.4 ppm) and low in vegetables (9.4) (Table 3). The cropping systems such as arecanut, paddy, rubber, vegetables and pepper were with similar content of this nutrient (Table. 3). Among the various cropping systems deficiency of sulphur was well observed in the samples drawn from rubber (50%), pepper (45%), vegetables (40%), banana (43%) and paddy (40%) (Fig 9). According to Sahrawat *et al*. (2007) 66% samples were deficient in available S in Rajasthan 46% in Gujarath. Correlation results revealed a significant negative correlation with pH and positive correlation with organic carbon (Table. 6). These results were also supported by Singh *et al*. (2012) in Varanasi.

Table 2. Descriptive statistics of macronutrients in various agro ecosystems in Thrissur district

Agro ecosystems	Soil properties	Mean	Std. Deviation	Std. Error	Coefficient of variation	Minimum	Maximum
Paddy	p^H	4.9	0.6	0.02	12.6	3.6	8.4
	EC(ds/m)	0.1	0.2	0.01	179.8	0.01	2.6
	OC(%)	1.4	0.7	0.03	52.5	0.04	4.1
	N(%)	0.12	0.06	0.002	50.0	0.003	0.3
	P(%)	61.8	69.5	2.48	112.4	1	501
	K(%)	181.9	170.4	6.09	93.7	1	1474
	Ca(ppm)	413.6	248.3	8.87	60	45.2	1930
	Mg(ppm)	80.1	50.7	1.81	63.3	7.2	315.7
	S(ppm)	11.1	23.1	0.83	207.4	0.09	400
Rubber	p^H	5.4	0.7	0.04	12.6	3.1	7.5
	EC(ds/m)	0.1	0.2	0.01	167.8	0.01	1.5
	OC(%)	1.8	0.8	0.05	42.9	0.2	4.3
	N(%)	0.15	0.06	0.004	40.0	0.013	0.4
	P(%)	107.3	107.3	6.58	100	0.3	803
	K(%)	310	224.5	13.76	72.4	14	1941
	Ca(ppm)	528.3	319.8	19.61	60.5	21.4	2230
	Mg(ppm)	84.6	62.3	3.82	73.6	5.9	524
	S(ppm)	7.9	11.7	0.71	147.4	0.1	150.4
Vegetables	p^H	5.4	0.8	0.07	14.4	3.7	7.4
	EC(ds/m)	0.2	0.5	0.04	264.7	0.01	4.5
	OC(%)	1.6	0.9	0.08	59.2	0.1	4.5
	N(%)	0.13	0.08	0.007	61.5	0.010	0.4
	P(%)	197	208.1	17.59	105.7	1.1	756.9
	K(%)	221.7	175.8	14.86	79.3	28	1294
	Ca(ppm)	552	330.3	27.91	59.8	35.2	1390.4
	Mg(ppm)	84.2	55.5	4.69	65.9	14.7	247.8
	S(ppm)	9.4	14.9	1.26	158.7	0.2	142.5
Pepper	p^H	6	0.6	0.06	9.8	4.5	7.1
	EC(ds/m)	0.1	0.1	0.01	84.2	0.02	0.5
	OC(%)	1.4	0.7	0.07	51.8	0.1	3.6
	N(%)	0.12	0.06	0.006	50.0	0.010	0.3
	P(%)	215.7	166.5	15.87	77.2	1.2	847.7
	K(%)	248.1	193.1	18.41	77.8	20	1217.4
	Ca(ppm)	572.1	274.9	26.21	48.1	94.2	1730
	Mg(ppm)	95.1	68.3	6.51	71.8	7.1	431
	S(ppm)	9.8	15.2	1.45	155.1	0.06	134.4

Where, EC= electrical conductivity; OC = organic carbon; N= nitrogen; P = phosphorous; K= potassium; Ca = calcium; Mg = magnesium; S= sulphur

Table 3. Analysis of variance of various agro ecosystems in Thrissur district.

Agro ecosystem	pH	EC(ds/m)	OC (%)	N(%)	P(kg/ha)	K(kg/ha)	Ca(mg/kg)	mg(mg/kg)	S(mg/kg)
Arecanut	5.8^{d}	0.1^{ab}	1.4^{b}	0.11^{b}	297.5^{d}	166.1^{a}	579.6^{de}	67.7^{a}	13.3^{a}
Banana	5.4^{bc}	0.3^{cd}	1.6^{cd}	0.13^{cd}	110.7^{bc}	433.0^{d}	600.2^{d}	103.1^{d}	23.0^{b}
Coconut	5.4^{b}	0.2^{c}	1.1^{a}	0.09^{a}	92.6^{ab}	277.5^{bc}	462.1^{ab}	83.3^{b}	22.0^{b}
Nutmeg	5.5^{c}	0.3^{d}	1.6^{d}	0.13^{d}	95.4^{ab}	274.9^{bc}	481.2^{bc}	77.7^{ab}	32.4^{c}
Paddy	4.9^{a}	0.1^{ab}	1.4^{b}	0.11^{b}	61.8^{a}	181.9^{a}	413.6^{a}	80.1^{b}	11.1^{a}
Rubber	5.4^{bc}	0.1^{a}	1.8^{e}	0.15^{e}	107.3^{ab}	310.0^{c}	528.3^{cd}	84.6^{bc}	7.9^{a}
Vegetables	5.4^{bc}	0.2^{bc}	1.6^{cd}	0.13^{cd}	197.0^{bc}	221.7^{ab}	552.0^{de}	84.2^{bc}	9.4^{a}
Pepper	6.0^{e}	0.1^{ab}	1.4^{bc}	0.12^{bc}	215.7^{c}	248.1^{bc}	572.1^{de}	95.1^{cd}	9.8^{a}

Means in the same column followed by the same letters are not significantly different at 0.05 level of significance; *significant at P= 0.05; EC= electrical conductivity; OC = organic carbon; N= nitrogen; P = phosphorous; K= potassium; Ca = calcium; Mg = magnesium; S= sulphur

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

The content of zinc in the soils of various agro ecosystems varied from 0.01 – 100.2 ppm. Deficiency of Zn was negligible in the study area as well as among various agro ecosystems. There was no significant variation between various agro ecosystems such as banana, coconut, nutmeg, paddy, rubber, vegetables and pepper with respect to this nutrient (Table 5). This element occurs as a contaminant in phosphatic fertilizers. So continuous addition of chemical fertilizers might have increased the adequate levels of zinc in these soils. Correlation studies revealed a strong negative correlation between soil pH and zinc (Table. 6). The studies of Sahrawat *et al*. (2007) revealed that in Rajasthan 15% of soil samples were deficient in zinc and 82% in Gujarath.

The boron content of the soils of various agro ecosystems varied from 0.001- 1.23 ppm. Deficiency of B was well pronounced in the district (98%) as well as among various cropping systems. There was no significant variation between the cropping systems; nutmeg, banana, paddy, rubber and pepper with respect to this nutrient (Table. 5). According to Sahrawat *et al*., 2007, in Rajasthan, 38 % of soil samples were deficient in B and100 % in Gujarat. Among the micronutrients, deficiency of boron was severe in the study area, might be due to leaching by high rainfall coupled with low levels of organic carbon. In general, management of B in the soil is difficult because of its high mobility and fixations at high pH (Saleem *et al*., 2010). Correlation studies also revealed a significant positive correlation between boron and soil pH (Table. 6). But a contradictory result was obtained in paddy fields of Malasia (Saleem *et al*., 2010).

The copper content of the soils in various cropping systems varied from 0.01 – 54.1 ppm. There was no significant variation between the cropping systems; banana, nutmeg, paddy, rubber and pepper in its content (Table 5). The deficiency level of this nutrient was less prominent in the district and also among the various cropping systems. Copper is an ingredient in common fungicide and their frequent application either to soil or in crops might increase the level. Copper has a strong negative correlation with pH (Table 6).

The lateritic soils of Kerala in general contain high content of Fe and Mn. Even though, the content of iron in the soils of various agro ecosystems varied from 0.1 – 675.4 ppm, there was no significant variation between the cropping systems such as arecanut, coconut, nutmeg and paddy. Significantly high content of this nutrient (73.4 ppm) was noted in nutmeg (Table5). Manganese content of these soils varied from 0.1 – 280.2 ppm. It was significantly high in vegetables (51. ppm) and significantly low in rubber (25.0 ppm) and arecanut (27.5 ppm) (Table. 5). Deficiency levels of manganese and iron were prominently less in the district as well as among the various cropping systems. A strong negative correlation between these nutrients and pH was also observed (Table 6)

However, based on the results of this study, it is revealed that the severity of macronutrient deficiency in the study area occur in the order S > K > Ca > Mg > N > P and micronutrient deficiency in the order B > Cu > Zn > Fe > Mn. But the order of micronutrient deficiency in Rajasthan were Zn > Fe > Cu > Mn (Sharma *et al*., 2006). The study also revealed a significant negative correlation of micronutrients with pH and a positive correlation with soil organic carbon. This is in support with the findings of Kumar *et al*., 2013.

Table 4. Descriptive statistics of micronutrients in various agro ecosystems in Thrissur district.

Agro ecosystems	Soil properties (ppm)	Mean	Std. Deviation	Std. Error	Coefficient of variation	Minimum	Maximum
Arecanut	Zn	4.4	6.5	0.2	150.1	0.02	100.2
	B	0.06	0.08	0.002	134.5	0.004	1.23
	Fe	66	71.7	1.9	108.7	0.1	675.4
	Cu	3.5	5.7	0.2	164.1	0.01	54.1
	Mn	27.5	36.9	1.0	134.2	0.1	240.8
Banana	Zn	3.6	3.4	0.2	94.6	0.02	18.9
	B	0.04	0.03	0.002	76.8	0.01	0.16
	Fe	51.2	40.3	2.9	78.7	2.2	220.9
	Cu	2.7	4.5	0.3	170.4	0.08	43.6
	Mn	39	39.3	2.8	100.8	0.5	184
Coconut	Zn	3.4	4.2	0.2	123.8	0.03	56.1
	B	0.06	0.06	0.002	90.3	0.003	0.3
	Fe	61.2	57	2.1	93.2	0.1	546.9
	Cu	4.6	6.5	0.2	140	0.01	41.5
	Mn	35.9	48	1.8	133.5	0.1	243.4
Nutmeg	Zn	3.2	3.8	0.3	120.6	0.04	33.1
	B	0.05	0.03	0.002	56.9	0.01	0.18
	Fe	73.4	97.4	7.8	132.7	1.22	552.3
	Cu	2.1	2.3	0.2	110.2	0.01	15.5
	Mn	35.3	38	3.1	107.7	0.1	254.3
Paddy	Zn	3.4	3.4	0.1	101	0.01	31.5
	B	0.05	0.05	0.002	102.1	0.02	0.4
	Fe	63.5	53.1	1.9	83.6	0.7	475.6
	Cu	2.7	2.3	0.1	83	0.05	28.1
	Mn	28.8	26.4	0.9	91.8	0.1	152.2
Rubber	Zn	3.0	4.3	0.3	142.9	0.03	51.1
	B	0.04	0.03	0.002	77.3	0.01	0.16
	Fe	43.9	30.9	1.9	70.3	0.2	160.9
	Cu	1.7	2.1	0.1	120.3	0.01	20.4
	Mn	25	27.1	1.7	108.5	0.5	175.3
Vegetables	Zn	3.2	4.3	0.4	135.4	0.01	31.3
	B	0.07	0.11	0.009	165.5	0.001	1.18
	Fe	58.4	73.4	6.2	125.7	1.6	484
	Cu	4.3	6	0.5	140.7	0.04	24.7
	Mn	51.6	60.2	5.1	116.6	0.6	280.2
Pepper	Zn	3.7	4.9	0.5	133.3	0.03	33
	B	0.05	0.04	0.004	83.9	0.001	0.22
	Fe	41.1	28	2.7	68	3.1	133.6
	Cu	2.4	2.7	0.3	110.7	0.1	19.7
	Mn	30.4	45.1	4.3	148.5	1.1	249.5

Where, Zn = zinc; B = boron; Fe = iron; Cu = copper; Mn = manganese

Table 5**.** Analysis of variance of micronutrients in different agro ecosystems in Thrissur district.

Agro ecosystem	Zn(ppm)	B(ppm)	Fe(ppm)	Cu(ppm)	Mn(ppm)
Arecanut	4.4 ± 6.5^{b}	0.06 ± 0.08^{bcd}	66.0 ± 71.7^{cd}	3.5 ± 5.7^{bc}	27.5 ± 36.9^{a}
Banana	3.6 ± 3.4^{ab}	0.04 ± 0.03^{a}	51.2 ± 40.3^{ab}	2.7 ± 4.5^{ab}	39.0 ± 39.3^{c}
Coconut	3.4 ± 4.2^{ab}	0.06 ± 0.06^{cd}	61.2 ± 57.0^{bcd}	4.6 ± 6.5^{d}	35.9 ± 48.0^{bc}
Nutmeg	3.2 ± 3.8^{a}	0.05 ± 0.03^{abc}	73.4 ± 97.4^{d}	2.1 ± 2.3^{a}	35.3 ± 38.0^{bc}
Paddy	3.4 ± 3.4^{ab}	0.05 ± 0.05^{abc}	63.5 ± 53.1^{bcd}	2.7 ± 2.3^{ab}	28.8 ± 26.4^{ab}
Rubber	3.0 ± 4.3^{a}	0.04 ± 0.03^{a}	43.9 ± 30.9^{a}	1.7 ± 2.1^{a}	25.0 ± 27.1^{a}
Vegetables	3.2 ± 4.3^{a}	0.07 ± 0.11^{d}	58.4 ± 73.4^{bc}	4.3 ± 6.0^{cd}	51.6 ± 60.2^{d}
Pepper	3.7 ± 4.9^{ab}	0.05 ± 0.04^{ab}	41.1 ± 28.0^{a}	2.4 ± 2.7^{a}	30.4 ± 45.1^{ab}

Means in the same column followed by the same letters are not significantly different at 0.05 level of significance; *significant at P= 0.05; Zn = zinc; B = boron; Fe = iron; Cu = copper; Mn = manganese

Table 6. Pearson' correlation matrix for the selected soil fertility parameters in various agro ecosystems in Thrissur district

Arecanut	PH	EC	OC	Paddy	PH	EC	OC
Potassium		.241**	.144**	Potassium	.288**	.335**	
Calcium	.269**		.178**	Calcium	.288**		
Magnesium		.072**	.117**	Magnesium	.138**		
Sulphur	-.117**	.283**		Sulphur		.497**	
Copper	-.127**		.105**	Boron	.156**	.096**	
Iron	-.118**			Iron	-.110**		
Manganese	-.252**		.135**	Copper	-.170**		.129**
Zinc		.085**	.084**	Manganese			.105**
Boron			.200**				
Vegetables	**PH**	**EC**	**OC**	**Nutmeg**	**PH**	**EC**	**OC**
Phosphorous	.294**			Phosphorous	.319**		
Potassium	.191**		.295**	Potassium	.238**	.139**	.238**
Calcium	.309**			Calcium	.350**	-.101**	
Sulphur	-.187**	.809**		Magnesium	.271**	-.089**	
Boron			.236**	Sulphur		.571**	.143**
Manganese			.301**	Boron	.157**		
Zinc	.304**			Iron	-.185**		.125**
Rubber	**PH**	**EC**	**OC**	**Coconut**	**PH**	**EC**	**OC**
Phosphorous	.152**	.293**	.141**	Phosphorous	.849**	.941**	.982**
Potassium	.400**	.437**	.183**	Potassium	.984**	.991**	.951**
Calcium	.390**	.265**		Calcium	.968**	.997**	.978**
Magnesium	.309**			Magnesium	.966**	.966**	.970**
Sulphur	.408**			Sulphur	.943**	.992**	.994**
Boron	.259**	.140**		Boron	.930**		
Manganese		.317**		Manganese	-934**	.998**	
Banana	**PH**	**EC**	**OC**	Zinc	-.943**	.990**	
Phosphorous	.192**		.172**	Iron	-.961**	.998**	.998**
Calcium	.235**						
Magnesium	.238**						
Sulphur	-.172*	.591**	.158*				
Iron		-.144**					

Significant at P=0.05; ** Significant at P = 0.01; EC= electrical conductivity; OC = organic carbon; N= nitrogen; P = phosphorous; K= potassium; Ca = calcium; Mg = magnesium; S= sulphur; Zn = zinc; B = boron; Fe = iron; Cu = copper; Mn = manganese

Soil nutrient indices of different ago ecosystems

Soil nutrient index was calculated from low, medium and high ratings of soil nutrients. If the index value was less than 1.67, the fertility status was low and the value between 1.67-2.33 then the status was medium. If the value greater than 2.33, the fertility status was high. Among the major cropping systems, status of N was high in rubber and medium in other cropping systems. In all the cropping systems, levels of P and micronutrients except B were high. S was low in rubber, vegetables and pepper and medium in all others. On the other hand potassium fertility status was high in rubber, low in arecanut and medium in all the others. In all the cropping systems magnesium was medium and boron was low (Table 7). In this work the P status was high in Thrissur but Tiwari (2001) reported a wide spread deficiency of P in 98% of districts in India. According to Pathak (2010) in Kerala in 1967 NPK fertility status was 2.11, 1.11 and 1.0 (M-L-L) in 1977 it was 1.7, 1.7 and 2.0 (M-M-M), in 1997 it was 1.66, 2.35 and 1.98 (L-H-M), and in this work it was 2.1, 2.7 and 1.9 (M-H-M). So the result revealed that there was increasing the fertility status of N and P and inverse in the case of K in Thrissur District. According to Ravikumar & Somashekar (2014) the NPK status of Karnataka was L-L-H. In Uttar Pradesh the NPK status was L-M-M and the micronutrients were in sufficient amount (Kumar *et al*., 2013).

Table 7. Nutrient indices for macro and micronutrients in general

Soil nutrients	Nutrient index	Fertility rating
Nitrogen (%)	2.1	M
Phosphorous(kg/ha)	2.7	H
Potassium (kg/ha)	1.9	M
Magnesium(ppm)	2.1	M
Sulphur(ppm)	1.8	M
Zinc(ppm)	2.6	H
Boron(ppm)	1.0	L
Iron(ppm)	3.0	H
Copper(ppm)	2.5	H
Manganese(ppm)	2.9	H

Index Value, Low (L) < 1.67, Medium (M) 1.67 – 2.33, High (H) > 2.33; N= nitrogen; P = phosphorous; K= potassium; Mg = magnesium; S= sulphur; Zn = zinc; B = boron; Fe = iron; Cu = copper; Mn = manganese

Table 8. Soil fertility status of each agro ecosystems with respect to soil nutrient indices

Agro ecosystems	N(%)	P(Kg/ha)	K(Kg/ha)	Mg(ppm)	S(ppm)	Zn(ppm)	B(ppm)	Fe(ppm)	Cu(ppm)	Mn (ppm)
Arecanut	M	H	L	M	M	H	L	H	H	H
Banana	M	H	M	M	M	H	L	H	H	H
Coconut	M	H	M	M	M	H	L	H	H	H
Nutmeg	M	H	M	M	M	H	L	H	H	H
Paddy	M	H	M	M	M	H	L	H	H	H
Rubber	H	H	H	M	L	H	L	H	H	H
Vegetables	M	H	M	M	L	H	L	H	H	H
Pepper	M	H	M	M	L	H	L	H	H	H

Where, L – Low; m – Medium; H – High; Index Value Low (L) < 1.67; Medium (M) 1.67 – 2.33; High (H) > 2.33; N= nitrogen; P = phosphorous; K= potassium; Mg = magnesium; S= sulphur; Zn = zinc; B = boron; Fe = iron; Cu = copper; Mn = manganese

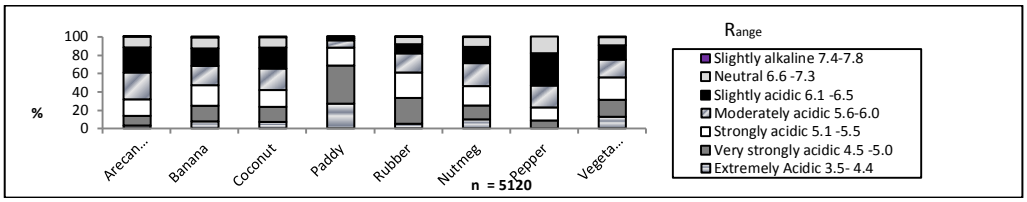

Figure 2. Frequency of soil reaction classes (pH)

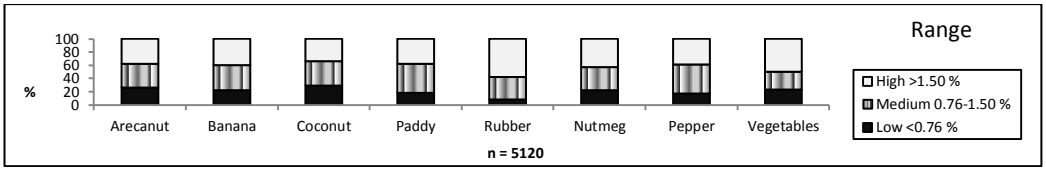

Figure 3. Frequency of carbon classes

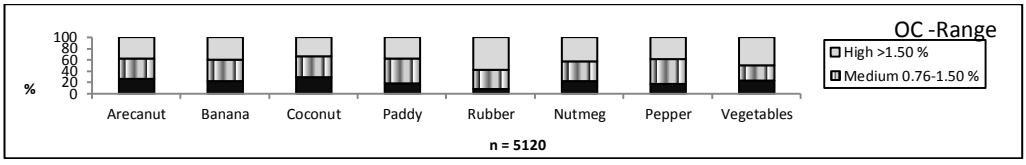

Figure 4. Frequency of nitrogen classes

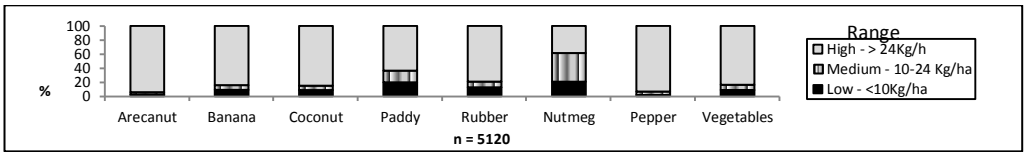

Figure 5. Frequency of phosphorous classes

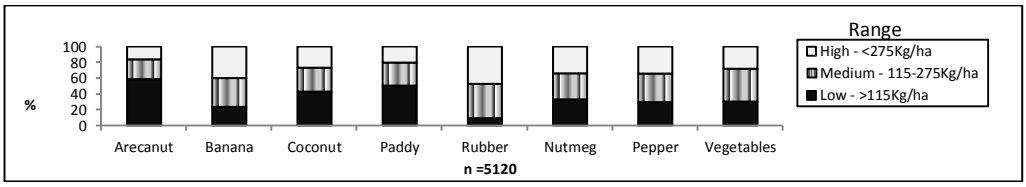

Figure 6. Frequency of potassium classes

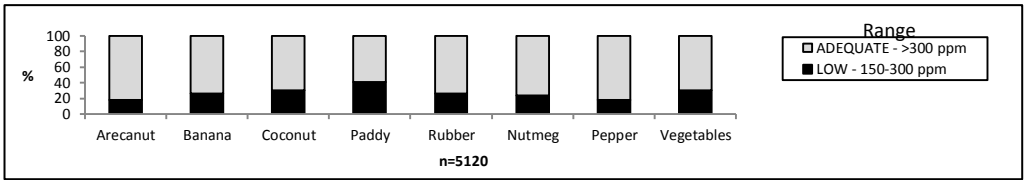

Figure 7. Frequency of calcium classes

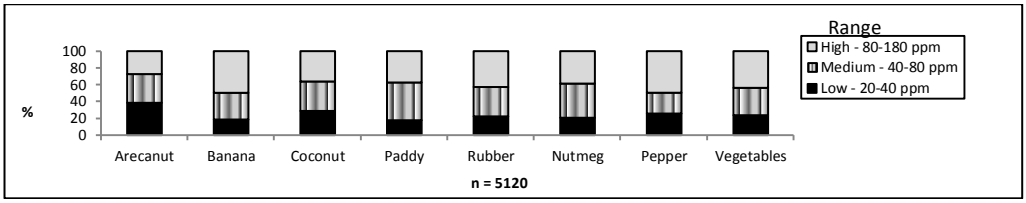

Figure 8. Frequency of magnesium classes

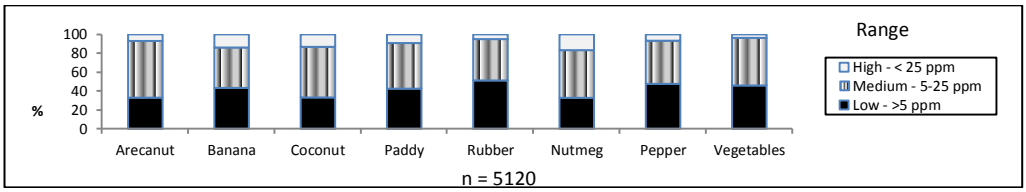

Figure 9. Frequency of sulphur classes

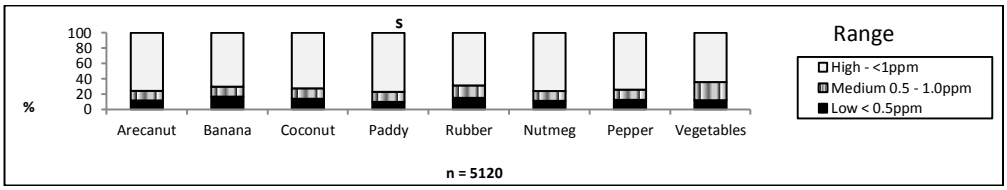

Figure 10. Frequency of zinc classes

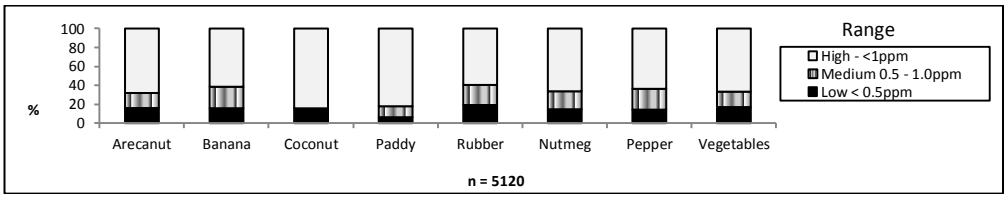

Figure 11. Frequency of copper classes

Frequency classes of soil macro and micro nutrients

CONCLUSIONS

Based on the above study it is concluded that soil fertility status of Thrissur District varied between various agro ecosystems. Among the cropping systems, status of N, P and K was high in rubber. Acute deficiency of K was observed in arecanut plantations while the deficiency of S was noted in rubber, vegetables and pepper. High accumulation of P, acute deficiency of B and relatively higher levels of Fe, Cu, Zn and Mn were observed in all the agro ecosystems. However, site and crop specific amendments/ nutrient inputs are suggested for enhanced productivity in all the agro ecosystems.

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