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Soil Fertility Evaluation under Different Land Use System in Tropical Humid Region of Kerala, India

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Authors' contributions

This work was carried out in collaboration between all authors. Author MC designed the study, performed the statistical analysis, wrote the protocol and wrote the manuscript. Author MR prepared the base maps for soil sampling. Author KS prepared the study area and surface soil sampling location map. Author RH managed the literature searches. Author SKS approved the project and sanctioned the fund for study. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To know the fertility status of soils of the Elamdesam block.
Place and Duration of Study: Soil samples were brought from Elamdesam block, Idukki district, Kerala, India in the year 2016 and laboratory characterization was done in *National Bureau of Soil Survey and Land Use Planning, Regional Centre, Hebbal, Bangalore.*
Methodology: Based on the different land use type, composite soil samples were collected randomly from 0 to 20 cm depth. Soils were processed and analyzed for soil reaction, electrical conductivity, organic carbon, available major (Available NPK), secondary (Ca, Mg and S) and micronutrients (Fe, Mn, Zn and Cu, B). Mean values for all the nutrients under different land uses were calculated for comparison. Soil testing rating chart was further used to separate soils for interpretation under various categories.

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Results: Results revealed that soils are very strongly acidic in reaction. Organic carbon content is high in all samples. Phosphorus content varied from low to medium and potassium content was very low to medium. Available calcium and magnesium were very low and sulphur was medium. The copper content was adequate and zinc and boron were a deficit. Among land uses, pineapple land uses recorded highest EC (0.10 dS m^{-1}), available P (82.19 kg ha^{-1}), K (196.32 kg ha^{-1}) and S (11.49 ppm) whereas paddy soils recorded highest pH (5.08), Ca (264.33 ppm), Fe (98.70 ppm), Cu (3.95 ppm) and B (0.32 ppm). Similarly, rubber growing soils have the highest Mn (6.92 ppm) whereas oil palm soils have highest organic carbon (2.80%). Banana land uses the highest EC (0.10 dS m^{-1}) and Zn (1.26 ppm) and coconut soils have highest Mg (34.96 ppm).

Conclusion: Soil fertility is one of the important factors controlling the crop yields. There is a need for correcting deficiencies of nutrients for sustained crop production. Thus, evaluating and assessing nutrient status is a must under various land use systems in order to recommend soil and crop specific nutrients.

Keywords: Soil fertility status; evaluation; land use; Elamdesam block.

1. INTRODUCTION

The soil is the source of mineral nutrients for crop production which is not renewable under continuous cultivation due to crop removal as well as leaching and other losses. The dynamic nature of the soil is highly influenced by human-induced as well as natural processes of soil formation [1]. With time, soils undergo changes rapidly in their physical, chemical and biological properties. Addition of inputs such as chemical fertilizers, organic manures, insecticides and pesticides alter the properties of soil. Hence, soil testing to know the status of soil fertility is a necessary step towards sustainable soil management. Soil test status based recommendation of nutrients, manures results in better crop production and productivity apart from maintaining soil health. Thus, soil fertility evaluation is a fundamental aspect to keep the soil nutrient balance, which indicates the quantity of nutrients to be added for higher crop yields, besides reducing the cost of cultivation and environmental pollution. Therefore the study highlights the status of soil fertility in various land use systems in the tropical humid region of Kerala, India.

2. MATERIALS AND METHODS

2.1 Details of the Study Area

Elamdesam block falls under the agro-ecological zone foothills and high hills, the agro ecological units 12 and 14 i.e. southern and central foothills and southern high hills, respectively. These units are subdivided into forests, denudational hills, lateritic terrain and lateritic valley lying between latitudes 9^0 46' 38.2" and 10^0 2' 18.14" north of Equator and longitudes 76^0 42' 59.49" and 76^0 53' 46.99" East of the Meridian. There are seven panchayats namely Vannapuram, Kodikulam, Karimannor, Udumbannoor, Alakode, Velliyamattom and Kudayathoor in the Elamdesam block and eight villages covering a total geographical area of 40,307 ha. Villages are further divided into a number of wards for the purpose of administration. Geology of the area is charnockite and granite gneiss of the Archaen age, elevation ranges from 30 m in low land to 850 m in high hills. Climate is tropical humid monsoon type. Rainfall ranges from 3462 mm to 3602 mm and means annual temperature varies between 22ºC to 27ºC. Length of dry period is two to two and a half months. High hills are covered by mixed forest whereas foothills and midlands have a plantation of rubber, coconut, pepper, banana, pineapple, arecanut, cocoa, nutmeg, cashew. Low land is occupied by paddy and tapioca, banana, coconut, arecanut and rubber were also cultivated in raised beds. Laterites and Ultisols are the major soil type which, are well drained, shallow to very deep and strongly acidic in nature. Study area with soil sampling sites is given in Fig. 1.

2.2 Soil Sampling and Analysis

In Elamdesam block, agriculture is the fundamental livelihood activity among the people. Major land uses are rubber plantations, mixed forest plantations and paddy cultivation. 155 geo-referenced surface (0-15 cm) soil samples were collected from the different land uses. Soils were air dried and, sieved through 2 mm sieve. The processed soil samples were analysed for organic carbon by Walkley and Black [2], available phosphorus by Bray and Kurtz [3], pHs (1:2.5), electrical conductivity, available potassium, available calcium and magnesium by Jackson [4], available sulphur by Black [5], available micronutrients (1N HCl extraction) followed by Lindsay and Norvel [6] and available boron by Wolf [7] method.

Soil analysis data were grouped based on land use. Mean values for all the nutrients under different land use were calculated for comparison. Further, soils were separated using soil test rating chart (Table 1) for interpretations under various classes and data were expressed in the form of a graph.

Fig. 1. Study area and surface soil sampling points

Table 1. Soil test rating chart used for interpretations

Soil parameters	Soil test rating					
PH	Extremely acid (3.5-4.5)	Very strongly acid (4.5-5.0)	Strongly acid (5.1-5.5)	Moderately acid (5.6-6.0)	Slightly acid (6.1-6.5)	-
Organic carbon	Medium (0.8-1.5)	High (1.6-2.5)	Very high (2.6-5.0)	-	-	-
Available phosphorus (kg ha^{-1})	Very low (< 5)	Low (5-10)	Medium (11-24)	High (25-35)	Very high (36-100)	Extremely high (>100)
Available potassium (kg ha^{-1})	Very low (<75)	Low (75-115)	Medium (116-275)	High (276-400)	Very High (400-1000)	-
Available Calcium (ppm)	Very low (<150)	Low (151-300)	Adequate(>300)	-	-	-
Available magnesium (ppm)	Very low (<60)	Low (61-120)	Adequate(>120)	-	-	-
Available sulphur (ppm)	Low (<5)	Medium (5-10)	Adequate(11-25)	High (>8)	-	-
Iron (ppm)	Deficit (<5)	Adequate (>5)				
Manganese (ppm)	Deficit (<1)	Adequate (>1)				
Available copper (ppm)	Deficit (<1)	Adequate (>1)	High (>20)	-	-	-
Available zinc (ppm)	Deficit (<1)	Adequate (>1)	High (>40)	-	-	-
Available boron (ppm)	Deficit (<0.5)	Adequate (>0.5)	-	-	-	-

Table 2. Soil fertility status under different land use (mean and range values) in soils of Elamdesam block, Idukki Ditrict, Kerala

	pHs (1:2)	EC (dS/m)	OC (%)	P (Kg/ha)	K (Kg/ha)	Ca (ppm)	Mg (ppm)	S (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	B (ppm)
Banana	4.90	0.10	2.07	26.84	149.77	213.03	33.59	8.98	33.13	5.33	2.96	1.26	0.30
Coconut	4.83	0.08	2.35	17.77	80.19	155.61	34.96	4.72	34.23	2.80	2.82	0.80	0.30
Oil palm	4.90	0.05	2.80	7.18	95.18	133.32	15.58	7.22	20.50	5.50	0.83	0.70	0.27
Paddy	5.08	0.06	2.56	26.55	62.41	264.33	31.70	6.53	98.70	4.67	3.95	0.98	0.32
Pineapple	4.88	0.10	2.05	82.19	196.32	166.80	19.21	11.49	18.38	4.78	3.34	0.68	0.27
Rubbeer	4.86	0.07	2.30	43.63	130.75	173.72	31.08	8.97	26.32	6.92	3.46	1.20	0.31
Range	4.06-6.48	0.018-0.32	0.89-3.34	1.08-453.20	11.35-494.28	18.44-977.05	3.86-223.67	0.83-28.30	10.40-242.10	0.90-22.00	0.60-20.50	0.30-11.00	0.09-0.60
SD	0.09	0.02	0.29	26.48	49.68	47.05	8.17	2.35	30.16	1.34	1.09	0.25	0.02

3. RESULTS AND DISCUSSION

Data pertaining to soil nutrient status are furnished in Figs. 4 to 11 and the mean and range values of soil nutrients under different land use are given in Table 2.

3.1 pH, Electrical Conductivity and Organic Carbon

The acidification of soils is a serious constraint to crop production in the region. The pH of the soils of Elamdesam block varied from 4.06 to 6.48 (Fig. 2). Among total soils studied 57.42 percent soils are very strongly acidic followed by extremely acidic (18.06 percent) and strongly acidic (18.06 percent). Only a few samples are moderately and slightly acidic. The pH under different land uses did not differ much, highest mean pH was noticed in paddy land use (5.08) followed by oil palm (4.90) and banana (4.90) while the lowest pH (4.83) was noticed in soils of coconut land use. The higher acidity recorded might be due to leaching of bases by irrigation water as well as higher rainfall associated with better drainage condition. Soils of the humid tropics are generally acidic in reaction due to intense leaching condition and the consequent loss of basic cations. Sarvade [8] reported significantly lower soil pH under forest soils of Tehri as compared to other sites. The reduction in pH also might be due to the accumulation of organic matter and release of organic acids through their subsequent slow decomposition rate [9]. Peng [10] stated that the increase in acidity of soil is generally linked with a decrease in decomposition rate of organic matter, although the extent of decrease varies with nature of the organic materials. The intensification of agriculture through high yielding crop varieties and external inputs of acid producing chemical fertilizers aggravated the problem of soil acidity. Strongly acid soils affect plant available nutrients, decomposition of organic matter and also plant roots due to a higher concentration of aluminium ion in the soil solution. Thus the application of lime is must to neutralize the acidity generated [11].

The electrical conductivity of the soils of different land uses varied from 0.018 to 0.32 dS m^{-1}. The mean EC value was highest (0.1 dS m^{-1}) under banana and pineapple growing soils and the lowest EC (0.05 dS m^{-1}) recorded in oil palm land use. Lowest EC recorded due to leaching of soluble salts by irrigation water and also due to high rainfall [12]. The low EC of soils indicated that the prevailing conditions were not favourable for the accumulation of salts [13].

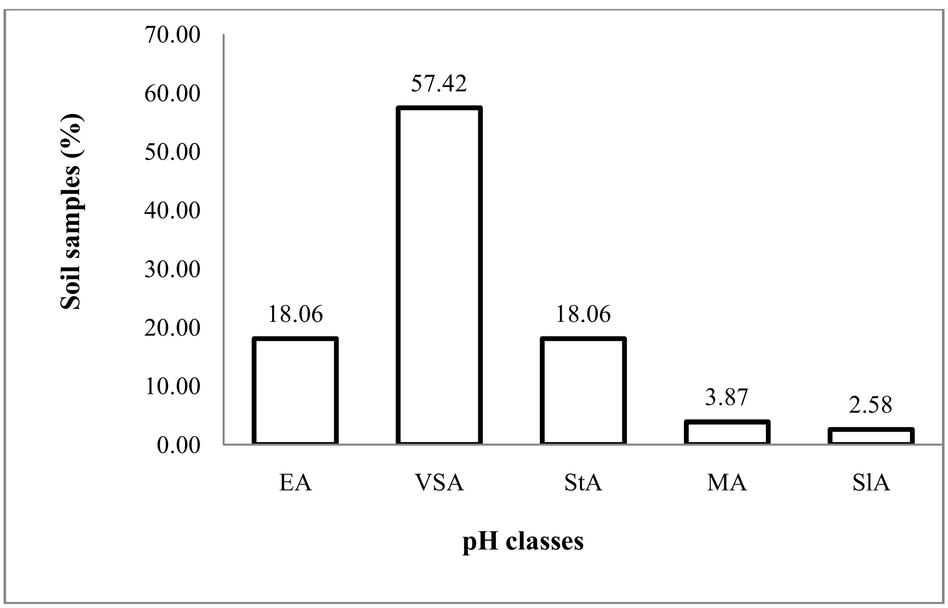

Fig. 2. Status of pH in soils of Elamdesam block

EA-Extremely acidic; VSA-Very strongly acidic; StA-Strongly acidic; MA-Moderately acidic; SlA-Slightly acidic

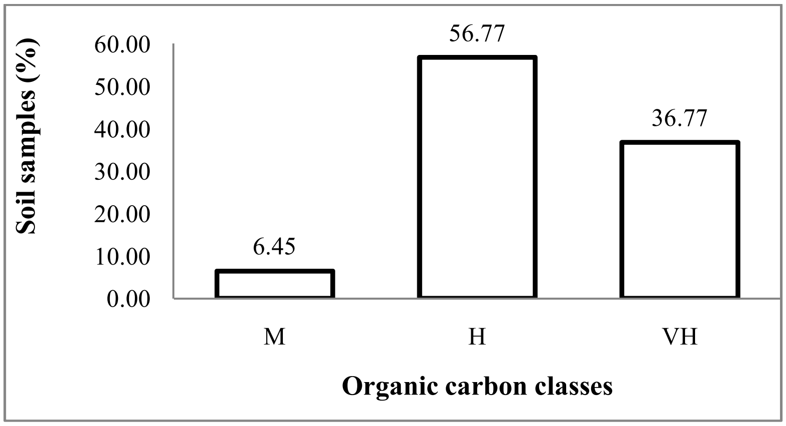

Fig. 3. Status of organic carbon in soils of Elamdesam block
M-Medium; H-High; VH-Very high

The organic carbon content of the soils of the Elamdesam block varied from 0.89 to 3.34 percent (Fig. 3). Among total soils sampled, 56.77% recorded high organic matter and 36.77% recorded very high. Only 10 samples out of 155 samples recorded medium class. The mean organic carbon in various land uses was highest in oil palm land use (2.8 percent) followed by paddy soils (2.56 percent) and the lowest (2.05 percent) was noticed in pineapple land use. Higher organic carbon recorded might be due to continuous addition of organic matter through perennial plantation crops. Soil organic matter generally increases where biomass production is higher and where organic material additions are common [12 and 14]. Mineralization of organic matter is constrained in acid soils. Hence it is necessary to correct soil acidity to benefit from high levels of organic matter. Higher levels of organic carbon not only provide part of nitrogen requirement of the crop plants but also enhance nutrient and water retention capacity of soils and create favourable environment [11]. Thakur [15] also reported higher SOC under plantations in the range of 1.5-1.95%.

3.2 Primary Nutrients

The phosphorus content of Elamdesam soils varied from 0.54 to 226.6 mg kg^{-1} (Fig. 4). Among total soils studied, 27.74 percent soils fell under low, 23.23 percent under medium class and only 15 samples recorded high in available P. The mean available P content under different land uses was highest in pineapple growing soils (41.09 mg kg^{-1}) followed by rubber growing soils (21.82 mg kg^{-1}) and the lowest was recorded in oil palm plantations (3.59 mg kg^{-1}). There is a build up of P in pineapple land use thus, which caused imbalances in the availability and uptake of other essential plant nutrients besides leading to pollution of soil, water and environment. Higher P content was also recorded in Hassan district of Karnataka due to the addition of phosphatic fertilizers specially the DAP for the crops [12]. Phosphorus is often described as the second limiting nutrient for crop production after nitrogen. Thus correction of soil acidity through liming can leads to the release of P fixed by soil constituents into the available pool. Hence, it is recommended to get the soils tested regularly and apply fertilizer accordingly [16].

Potassium levels in soils of Elamdesam block varied from 11.35 to 494.28 kg ha^{-1} (Fig. 5). Among total samples, 33.55 percent fell under medium and 30.32 samples under very low and low category each. Only two samples recorded very high category. In case of land use, pineapple growing soils recorded higher available K (196.32 kg ha^{-1}) followed by banana land use (149.77 kg ha^{-1}) and the lowest mean values of available K recorded in paddy soils (62.41 kg ha^{-1}). In general, the potassium status of Kerala soils is found to be low and the reason can be attributed to the tropical climate and predominance of kaolinitic clay mineral characterized by low K [16]. Kavitha and Sujatha [1] reported that 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. Rajasekharan [1] reported that the highly weathered and leached soils of Kerala developed under humid tropics do not have any significant amount of potassium bearing minerals. Cation exchange capacity of the low activity clay minerals in the soils (mainly kaolinite) does not permit retention of a significant amount of potassium in exchangeable form. Thus the regular application of potassium fertilizer to crop plants in many splits is necessary.

3.3 Secondary Nutrients

The available calcium (Ca) content of the soils of the Elamdesam varied from 18.44 to 977.05 ppm (Fig. 6). Among total samples studied, 67.10 percent of samples recorded very low category followed by adequate category (20.65 per cent) and 19 samples fell under low class. In case of land use, paddy soils recorded the highest available calcium (264.33 ppm) followed by banana growing soils (213.03 ppm) and oil palm land use noticed the lowest value (133.32 ppm). The lower levels of calcium might be due to continuous addition of acidifying chemical fertilizers. There existed a direct relationship between pH and available Ca content of the soil. Medhe [17] reported similar results. Rajasekharan [11] reported that lower availability of calcium was mainly because of lack of mineral bearing this element. Thus the application of liming materials to alleviate soil acidity shall ensure the supply of the nutrient wherever deficient.

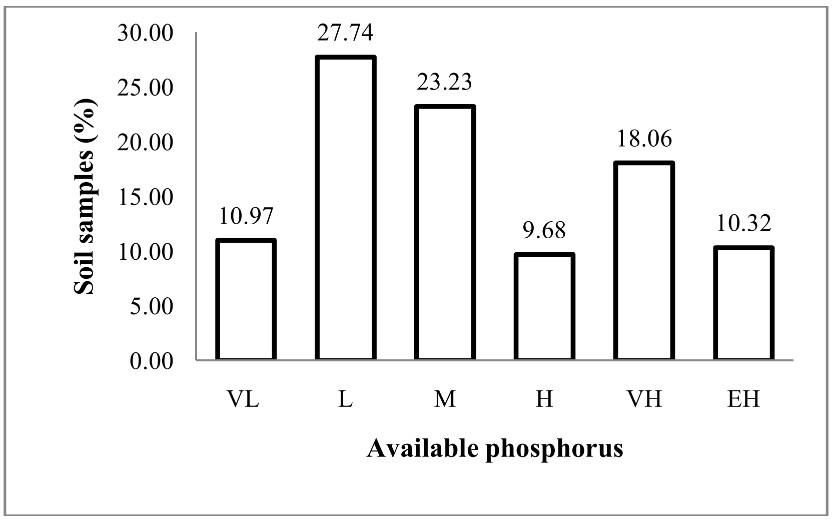

Fig. 4. Status of available phosphorus in soils of Elamdesam block
VL-Very low; L-low; M-medium; H-high; VH-very high; EH-extremely high

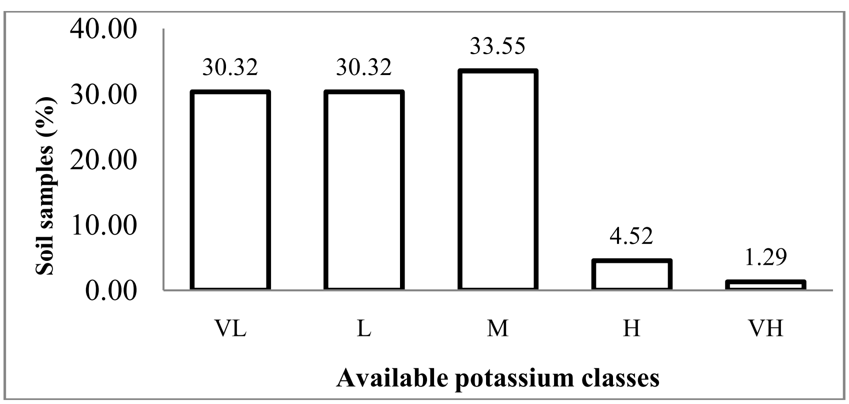

Fig. 5. Status of available potassium in soils of Elamdesam block
VL-very low; L-low; M-medium; H-high; VH-very high

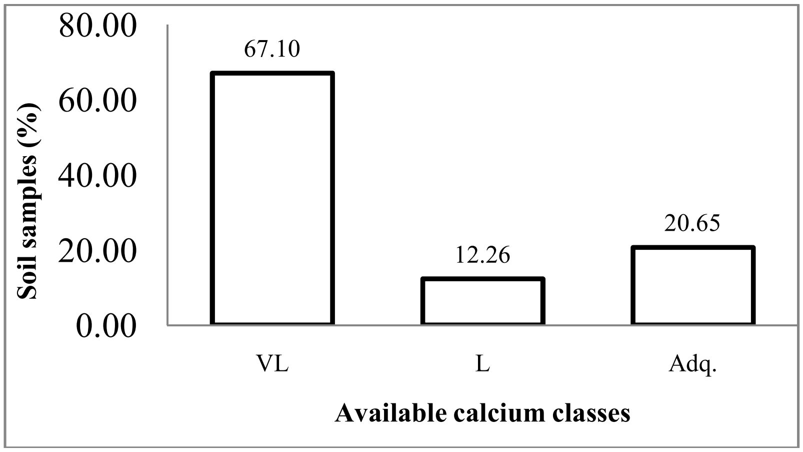

Fig. 6. Status of available Calcium in soils of Elamdesam block
VL-Very low; L-low; Adq-Adequate

The magnesium (Mg) content of the soils varied from 3.86 to 223.67 ppm (Fig. 7). Among total samples, 86.45 percent samples are very low followed by 12.26 percent samples fell under low category. Cultivation of coconut recoded higher mean available Mg (34.96 ppm) followed by banana growing soils (33.59 ppm) and the lowest mean available Mg recorded in oil palm growing soils. Similar results reported by Mini and Usha Mathew [16].

Available sulphur (S) content varied from 0.83 to 28.3 ppm in soils of Elamdesam block (Fig. 8). Among total soils analysed, 49.03 percent samples are medium followed by 27.74 percent samples fell under adequate category and only one sample fell in the high category. In case of land use pineapple growing soils recorded highest mean available S (11.49 ppm) followed by banana growing soils (8.98 ppm) and the lowest S recorded in (4.72 ppm) coconut growing soils. Continuous application of S containing fertilizer like ammonium phosphate might have maintained S level in the medium category. Deveraj [18] also observed that fine texture soils are generally well supplied with sulphur. Thus S deficiency can be managed by applying magnesium sulphate [16].

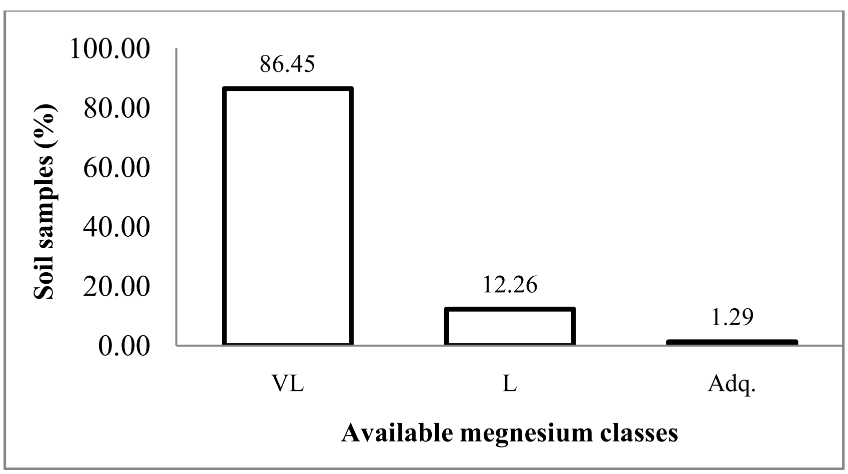

Fig. 7. Status of available magnesium in soils of Elamdesam block
VL-Very low; L-low; Adq-Adequate

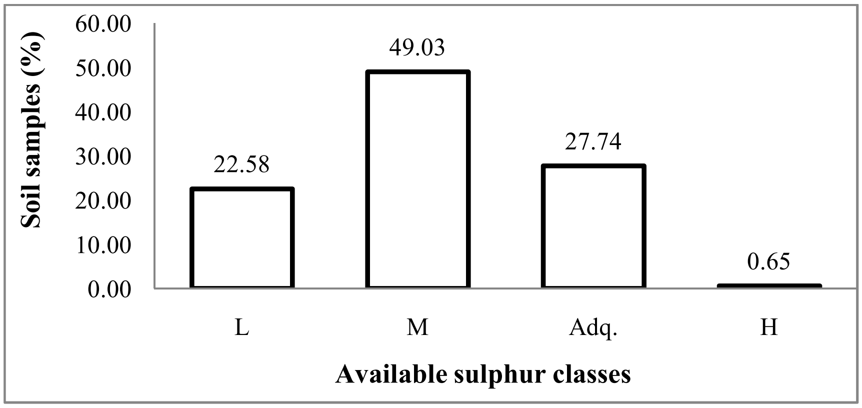

Fig. 8. Status of available sulphur in soils of Elamdesam block
L-low; M- medium; Adq-Adequate; H-high

3.4 Micronutrients Nutrients

Iron (Fe) and manganese (Mn) content of soils of Elamdesam block varied from 10.4 to 242.1 ppm and 0.9 to 22 ppm, respectively. Among the land use, available Fe content was highest in paddy soils (98.70 ppm) followed by coconut and banana growing soils (34.23 and 33.13 ppm, respectively) and the lowest mean value recorded in pineapple land use (18.38 ppm). In case of manganese, highest mean Mn contest recorded in rubber soils (6.92 ppm) followed by oil palm land use (5.50 ppm) and the lowest Mn content noticed in coconut soils (2.8 ppm). Considering critical limits of 5 ppm, the soils are sufficient in iron. It shows that soils have inherent capacity to supply sufficient amount of available iron [19].

Copper (Cu) content of soils of Elamdesam block varied from 0.6 to 20.5 ppm (Fig. 9). Among total soils studied 93.55 percent of samples are adequate in available copper and only one sample noticed higher category. In case of land use, paddy soils recorded higher mean value (3.95 ppm) followed by rubber soils (3.46 ppm) and the lower mean Cu content recorded in oil palm soils (0.83 ppm). The adequate availability of copper in soil might be due to it being an ingredient in common fungicide and their frequent application either to soil or in crops might increase its level and also copper has a strong negative correlation with pH but positively correlated with organic carbon [1].

Zinc (Zn) content of the soils of the Elamdesam block soils varied from 0.3 to 11.00 ppm (Fig. 10). Among total soils studied 72.26 percent of samples are a deficit of Zn and 27.74 percent samples are adequate. In case of land use, banana growing soils recorded highest Zn content (1.26 ppm) followed by rubber growing soils (1.2 ppm) and the lowest mean value noticed in pineapple land use (0.68 ppm). Kavitha and Sujatha [1] reported a strong negative correlation between Zn and pH. Similar results were reported by Nair [20].

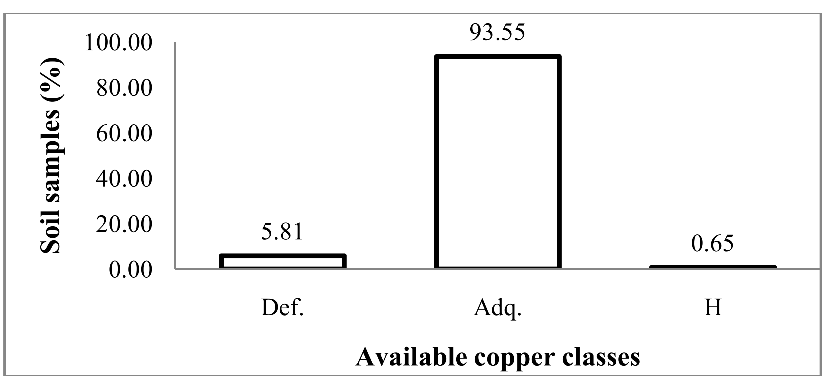

Fig. 9. Status of available copper in soils of Elamdesam block
Def- Deficit; Adq- Adequate; H-high

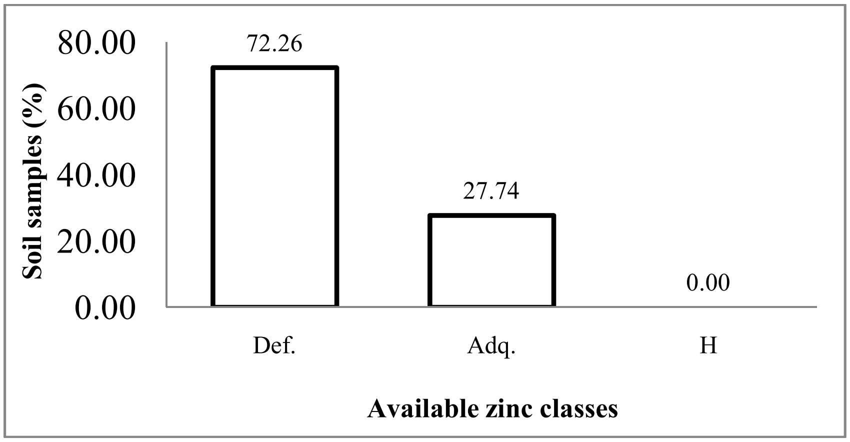

Fig. 10. Status of available zinc in soils of Elamdesam block
Def- Deficit; Adq- Adequate; H-high

Fig. 11. Status of available boron in soils of Elamdesam block
Def- Deficit; Adq- Adequate

Available boron (B) content of soils of Elamdesam block varied from 0.09 to 0.60 ppm (Fig. 11). Out of total soils studied 92.90 percent of soils are deficient and 7.10 percent of soils are adequate in available boron content. Among the land use, paddy growing soils have recorded highest mean boron content (0.32 ppm) followed by rubber soils (0.31 ppm) and the lowest mean B content recorded in pineapple (0.27 ppm) and oil palm (0.27 ppm) soils. The low level of B might be due to leaching by high rainfall. Similar results were reported by Mini and Usha Mathew [16]. Kavitha and Sujatha [1] reported a significant positive correlation between B and pH. However, managing B is also difficult because of its high mobility. Application of borax or foliar spray of borax solution can supply available boron.

4. CONCLUSIONS

Soils of the Elamdesam block are varied in soil fertility status. Soils are high in organic matter and acidic in reaction. Amelioration of soil acidity and external inputs of essential nutrients is necessary for successful crop production. The status of available nutrition provides the basis for soil and crop specific mineral nutrition recommendation in all the land uses in order to maintain soil nutrient balance and also to enhance higher crop production and productivity.

DISCLAIMER

This manuscript was presented at the conference.

"International Conference on "Integrated Land Use Planning for Smart Agriculture –An Agenda for Sustainable Land Management".
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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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