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Evaluation of Laterite Soils for Sustainable Land Use Planning of Dryland Agricultural Research Station, Chettinad of Sivagangai District, Tamil Nadu

Rajeshwar Malavath[1], S. Mani and P. Kannan**
[1]Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore- 641 003 **Dryland Agricultural Research Station, Chettinad, Sivagangai- 630 102

Detailed soil survey was conducted at Dryland Agricultural Research Station, Chettinad in Sivagangai District of Tamil Nadu. In this study, field wise morphological, physical, physico-chemical characteristics and nutrients status of soils were studied by collecting the surface (0-15cm) and subsurface (15-30cm) soil samples. The soils were moderately deep to deep, dark red to light reddish brown moderately acidic to slightly acidic in reaction and non-saline in nature, low to medium in organic carbon and low in cation exchange capacity with textural variations. The available nutrient status of surface soil samples indicated that the soils were low in N, low to medium in available P and medium to high in available K, deficient to sufficient in available Zn, Cu and B and high in available Fe and Mn. Based on Nutrient Index Values, the soil fertility ratings of the samples were found to be low on N and P, very low in Zn and B in both the surface and subsurface soils respectively. The land evaluation for soil suitability indicated that the soils were moderately suitable for the cultivation of groundnut, redgram, greengram, blackgram, pearlmillet and vegetables such as tomato under irrigated conditions. Similarly under rainfed situations, the soils were moderate to marginally suitable for the cultivation of groundnut, redgram, greengram, blackgram and pearlmillet and moderate to highly suitable for the cultivation of horsegram. Soil productivity can be improved by maintenance of enhanced soil fertility, addition of organic matter, reduced surface crusting and erosion control practices.

Key words: Soil properties, Laterite soils, Available nutrients, Soil site suitability and crop plan

Soil is a valuable resource and a critical component in many of the environmental and economic issues facing today’s society. Understanding soils and interpreting soil data is especially relevant for many environmental and land management issues. These issues include urban development, control of salinity, clearing of native vegetation, prevention of land degradation, control of water and wind erosion, irrigation development, the management of effluent disposal and the management of acid sulfate soils. The soil fertility status exhibits the status of different soils with regard to amount and availability of nutrients essential for plant growth. The crop growth and yield largely depend upon potential of soil resources and their characteristic provides water, nutrients and anchorage for the growth and yield of crops. The detailed field wise study of morphological, physical, physico- chemical characteristics and available nutrients status in the surface and sub surface soils aid in determining the potential of soils which are essential for better scientific utilization of crop growth. In order to provide a base line data and information, the detailed field wise study was taken up to evaluate the land by identifying the potentials and limitations and to suggest suitable crop plan and management options for increasing the soil productivity.

Materials and Methods

Location and site characteristic of study area

Dryland Agricultural Research Station at Chettinad, DARS Sivagangai district extends over an area of 317 acres and boundary is surrounded between 10°.166’ to 10°.179’ N latitude and 78 °.785’ to 78 °.805’E longitudes and is situated at an altitude of 108 m above Mean Sea Level. Nearly three fourth of the land is under pedi plains and characterized by nearly level to gently slopy in nature.

The climate of the study area is hot and dry and temperature is low during the month of January and the lowest mean daily temperature is 19.8°C**.** The temperature soars after March and the hottest month is July during which period the maximum temperature is 36.8°C. Mean humidity varies from 65 per cent in July to 80 per cent in December. The mean annual rainfall of the study area is 1080 mm**.** The north east monsoon contributes 45% of the annual rainfall from October to December. South west monsoon also contribute 37 % of rainfall from July to October. The soil moisture content section is dry for more than 90 cumulative days or 45 consecutive days in the months of summer solstice. So it qualifies for Ustic soil moisture regime. The natural vegetation

*Corresponding author email: rajeshoct31naik@gmail.com

existing in the study area were grasses, shrubs, thorny bushes such as *Cynodon dactylon, Cyprus rotundus*, *Azardirachta indica, Prosopis juliflora, Cassia sp*,. *Tamarindus indica,* toddy palm, broad leaf weeds such as *Celosia, Parthenium, Euphorbia* sp,. etc. In order to delineate the detailed field wise morphological, physico-chemical characteristics, available nutrients status in the surface and sub surface soils, 72 surface (0-15 cm) and 72 sub-surface (15-30 cm) soil samples were collected from five different blocks of Research Station. The soil samples were air-dried in shade, processed and screened through 2.0mm sieve for analysis.

Methods used for soil analysis

The detailed morphological description of surface and subsurface soils was made as per the procedure outlined in Soil Survey Manual (Anon., 1951). The soil samples representing each of the fields were characterized for physical, physico-chemical and nutrient status using standard procedures. The Soil pH, EC (1:2.5 soil water suspension); exchangeable cations cation exchange capacity organic carbon and free $CaCO_3$. The available nitrogen was determined by kjeldal method available phosphorus, potassium by flame emission method available sulphur The available micronutrients hot water soluble boron was determined by using azomethine method Nutrient index value was calculated from the proportion of soils under low, medium and high available nutrient categories.

Results and Discussion

Soil Morphology

Morphological characteristics of the surface and sub surface soils are described in Table 1. The soil colour varied from red to light reddish brown (2.5 YR5/6 to 5YR7/6) when it was in dry condition and red to yellowish red (2.5 YR4/6 to 5YR5/6) in moist condition in surface soils and in sub surface soil color vary from red to reddish yellow (2.5 YR4/6 to 5YR6/6) in dry condition and dark red to reddish brown (2.5 YR3/6 to 5YR5/4) in moist condition. All the blocks had shown granular to sub angular blocky structure. The texture of the blocks ranged from coarse textured gravelly sandy loam to sandy clay loam. The consistency varied from non-sticky and non-plastic to slightly sticky, coarse and fine roots and fine pores abundant in surface and subsurface soils. The intensity of the colour increased in subsurface soils. The differences in colour might be due to various pedological process and also variation in organic matter content, quality of iron, diffusion of iron oxides in mineral matters of soil, the degree of oxidation and imperfect hydration as reported by Yadav *et al.* (1977) and Gangopadhyay *et al* (1990).

Soil Characteristics

Physical characteristics

The clay, silt and sand contents in the soils varied from 17.9 to 31.7, 3.5 to 10.5 and 60.6 to 76.8% in surface soils and 18.1 to 33.0, 4.2 to 11.5 and 59.1 to 74.4% in sub surface soil respectively.(Table 2) The clay content was more in subsurface soils than surface soils which might be due to the mobilization and translocation of clay.

The bulk density ranged from 1.27 to 1.39 Mgm^{-3} in surface soils and in subsurface soils the values varied from 1.32 to 1.41 Mgm^{-3}. The bulk density of surface soil was low when compared to subsurface soils. Lower bulk density values of surface soil might be due to loose, porous and organic matter content (Walia and Rao, 1997). All the subsurface soils showed increasing trend which might be due to more compaction of finer particles in deeper layers caused by over head weight of surface soils (Jewitt *et al.,* 1979). The maximum water holding capacity of surface and subsurface soils ranged from 9.35 to 32.85 percent and 11.98 to 36.35 percent respectively. These differences were due to the variation in clay, silt and organic carbon content (Rajeshwar *et al*., 2009).

The red laterite soils being dominated by kaolinite clay with lesser surface area, retained lower amount of water at different soil water suctions. The data in Table 2 showed that the water retention at 33 kpa

Table 1. Morphological characteristics of surface and subsurface soils of DARS, Chettinad

Block	No. of soil samples	Depth (cm)	Colour		Texture	Structure	Consistency			Efferve-scence	Pores	Roots
			Dry	Moist			Dry	Moist	Wet			
A	22	0-15	5YR6/4 to 5YR7/6	5YR4/4 to 5YR5/6	sl	f1gr	l	fr	ss	-	f f	c f
	22	15-30	5YR5/6 to 5YR6/6	5YR4/3 to 5YR5/4	scl	f2gr	l	fr	ss	-	f f	f f
B	8	0-15	5YR6/4 to 5YR6/6	5YR5/6 to 5YR5/4	sl	f1gr	l	fr	ss	-	f f	c f
	8	15-30	5YR5/6 to 5YR6/4	5YR4/4 to 5YR5/4	scl	f2gr	l	fr	ss	-	f f	f f
C	20	0-15	2.5YR5/6 to 5YR6/6	2.5YR4/6 to 5YR5/6	scl	m1gr-m1sbk	l	fr	ss	-	f f	c f
	20	15-30	2.5YR4/6 to 5YR5/6	2.5YR3/6 to 5YR4/6	scl	m1sbk	sh	fr	ss	-	f f	f f
D	14	0-15	2.5YR5/6 to 5YR6/6	2.5YR4/6 to 5YR5/6	sl-scl	m1sbk	l	fr	ss	-	f f	c f
	14	15-30	2.5YR4/6 to 5YR5/6	2.5YR4/6 to 5YR4/6	scl	m2sbk	sh	fr	ss	-	f f	f f
E	8	0-15	2.5YR5/8 to 5YR6/6	2.5YR4/6 to 5YR5/6	scl	m2gr-m1sbk	l	fr	ss	-	f f	c f
	8	15-30	2.5YR4/6 to 5YR5/6	2.5YR4/4 to 5YR5/4	sl-scl	m1sbk-m2sbk	sh	fr	ss	-	f f	f f

Soil texture	:	Ls – loamy sand ,Scl –Sandy clay loam, Sc- Sandy clay, Cl- clay loam and C- clay
Soil Structure	:	C-Coarse, M- medium , F- fine , 1- weak, 2- moderate,3 - strong, gr- granular ,abk- angular blocky, sbk- sub-angular blocky
Soil Consistence	:	l- loose, sh- slightly hard, h- hard ,vh- very hard ,vfr-very friable ,fr- friable , fi- firm, vf- very firm, so – non sticky, ss –slightly sticky, s- sticky,vs- very sticky, po- non plastic, ps – slightly plastic, p-plastic, vp- very plastic
Pores	:	Size f-fine, m-medium, c-coarse; Quantity f-few, c-common, m-many
Roots	:	Size f-fine, m-medium, c-coarse; Quantity f-few, c-common, m-many
Effervescence	:	m-mild ,ms-moderately strong s-strong vs-very strong

and 1500 kpa. The moisture content at field capacity (33kpa) varied from 13.2 to 20.5 and 13.8 to 22.5 per cent and at permanent wilting capacity (1500kpa) varied from 5.4 to 10.9 and 4.9 to 11.6 per cent respectively in both surface and subsurface soils. This variation is attributed to the textural changes in the soils. The soils of 'C' block showed higher water retention as it contained more amount of clay. Soils of B block revealed the low content of water retention at field capacity due to considerable amount of sand content in it.

Table 2. Physical characteristics of surface and subsurface soils of DARS, Chettinad

Block	No. of samples	Depth (cm)	Gravel (%)	Particle size distribution (%)					B.D (Mg m^{-3})	Pore space (%)	Water retention (kg kg^{-1})		AWC	WHC (%)
				Coarse and (0.2-2mm)	Fine sand ((0.02-0.2mm)	Total Sand (<2.0 mm)	Silt (0.002-0.02 mm)	Clay (<0.002 mm)			33 kpa	1500 kpa		
A	22	0-15	15.1-39.0	54.9-61.5	11.6-20.5	71.5-76.8	3.5-7.9	18.0-21.9	1.32-1.38	45.4-51.3	13.8-17.4	5.4-8.8	5.7-9.5	11.35-21.36
			(17.6)	(57.9)	(16.6)	(74.5)	(5.5)	(20.0)	(1.34)	(48.2)	(15.1)	(7.37)	(7.7)	(16.4)
	22	15-30	8.4-50.5	50.2-60.1	10.5-16.6	63.8-73.0	4.2-8.1	21.2-28.5	1.33-1.41	43.5-47.9	14.2-17.8	4.9-9.2	5.8-10.7	11.98-23.81
			(20.61)	(55.5)	(13.6)	(69.1)	(5.8)	(25.1)	(1.35)	(45.6)	(15.9)	(7.6)	(8.3)	(17.8)
B	8	0-15	11.0-14.6	57.1-60.5	14.5-18.9	73.2-76.2	4.2-7.1	18.4-19.9	1.36-1.39	45.9-51.4	13.3-16.6	6.4-8.8	4.3-8.8	9.35-19.1
			(12.5)	(58.6)	(16.1)	(74.7)	(6.1)	(19.2)	(1.37)	(48.5)	(14.8)	(7.4)	(7.4)	(15.0)
	8	15-30	6.51-34.0	52.8-61.5	9.6-17.7	68.6-71.6	5.4-7.7	20.0-23.9	1.38-1.42	43.2-49.1	13.8-17.1	6.6-9.8	4.9-9.1	13.35-20.35
			(18.46)	(57.5)	(13.6)	(71.1)	(6.6)	(22.3)	(1.39)	(46.4)	(15.2)	(8.3)	(6.9)	(16.6)
C	20	0-15	2.84-28.7	43.8-61.0	6.8-19.6	60.6-72.1	4.3-9.5	24.0-31.7	1.27-1.35	42.2-49.3	13.9-20.5	5.9-9.4	7.2-13.3	15.1-32.85
			(12.75)	(52.1)	(14.2)	(66.3)	(6.34)	(27.3)	(1.32)	(44.9)	(17.8)	(8.0)	(10.1)	(26.8)
	20	15-30	7.0-25.6	43.6-57.8	7.6-18.2	59.1-68.7	4.5-8.2	27.9-33.0	1.32-1.36	40.1-44.9	17.4-22.5	7.6-9.9	9.2-13.7	25.1-36.35
			(14.56)	(51.1)	(12.6)	(63.8)	(6.6)	(29.6)	(1.34)	(42.5)	(20.1)	(8.8)	(11.3)	(30.3)
D	14	0-15	2.31-26.2	47.9-60.8	8.4-17.5	65.4-73.2	4.3-10.5	17.9-28.5	1.31-1.35	45.3-49.3	13.2-15.5	7.4-10.9	5.5-10.0	14.35-27.1
			(12.43)	(56.2)	(14.2)	(70.3)	(7.0)	(22.6)	(1.32)	(47.7)	(15.2)	(8.0)	(7.0)	(19.5)
	14	15-30	2.91-20.4	45.2-63.9	7.9-16.9	62.1-71.8	5.5-11.5	18.6-30.3	1.33-1.37	42.2-47.6	15.2-19.1	6.5-11.6	7.2-12.8	20.1-34.1
			(13.1)	(53.8)	(13.8)	(67.6)	(8.0)	(24.7)	(1.34)	(44.6)	(16.8)	(8.5)	(8.8)	(24.2)
E	8	0-15	10.1-63.2	57.6-63.4	10.1-16.6	71.1-75.3	4.9-9.1	17.8-22.4	1.31-1.35	44.7-51.3	13.3-15.5	7.8-10.4	5.1-7.1	12.85-19.78
			(33.9)	(60.4)	(13.41)	(73.8)	(6.3)	(19.8)	(1.32)	(47.1)	(14.7)	(8.4)	(6.3)	(16.9)
	8	15-30	19.1-91.2	51.3-62.5	6.8-16.6	63.3-74.4	5.2-9.5	18.1-30.4	1.33-1.37	40.8-48.3	15.8-17.4	7.6-9.6	7.0-9.4	19.6-25.6
			(54.4)	(56.3)	(11.8)	(68.1)	(6.9)	(25.0)	(1.34)	(43.9)	(17.0)	(8.7)	(8.3)	(22.0)
Ovearall range		0-15	2.31-63.2	43.8-63.4	6.8-20.5	60.6-76.8	3.5-10.5	17.9-31.7	1.27-1.39	42.2-51.4	13.2-20.5	5.4-10.9	4.3-13.3	9.35-32.85
Mean			(17.8)	(57.0)	(14.9)	(71.9)	(6.2)	(21.8)	(1.33)	(47.3)	(15.5)	(7.8)	(7.7)	(18.9)
		15-30	2.91-91.2	43.6-63.4	6.8-18.2	59.1-74.4	4.2-11.5	18.1-33.0	1.32-1.41	40.1-49.1	13.8-22.5	4.9-11.6	4.9-13.7	11.98-36.35
			(24.2)	(54.8)	(13.1)	(67.9)	(6.8)	(25.3)	(1.35)	(44.6)	(17.0)	(8.4)	(8.7)	(22.2)

The data in parenthesis indicate average values

Physico-chemical characteristics

The pH of the soils was low and ranged from 4.5 to 6.5 in surface soil and 4.5 to 6.1 in sub-surface soil. Majority of these soils were moderately acidic in soil reaction and appeared to be related with acidic parent materials and leaching of bases such as Calcium, Magnesium, Potassium and Sodium from the soil leading to high hydrogen ion concentration caused by heavy precipitation during rainy season **(**Nayak *et al.*, 2002). The decreasing trend in pH of the subsurface soils due to the chemical weathering lead to accumulation of exchangeable H^+, Al^{3+}, Fe and Al oxides and clay minerals (Bipul Deka *et al.,* 2009). The EC values varied from 0.09 to 0.41 and 0.09 to 0.27 dS m^{-1}, suggesting low amount of soluble salts which could be attributed to loss of bases (Sidhu *et al.,* 1994) due to heavy rainfall during monsoon. The organic carbon content ranged from low to medium in surface and subsurface soils (3.0 to 6.8 and 1.2 to 5.4 g kg^{-1}) respectively. Higher organic carbon content was recorded in surface samples as compared to subsurface samples (Table 3).

The CEC values ranged from 5.1 to 7.1 and 5.4 to 7.4 cmol (p+) kg^{-1} in surface and subsurface soils respectively which corresponds to clay content in the respective depths of soil sampling. The exchangeable bases in all the pedons were in the order of Ca^{++}>Mg^{++}>K^+ >Na^+ on the exchangeable complex. The base saturation of the soils were low to moderate in range and varied from 35.0 to 48.6% in surface soils and 35.6 to 49.2% in subsurface soils. The variation in difference of CEC, base saturation and water holding capacity between soils may ascribe largely due to the varied type or content of soil colloids and soil pH values. The soils were non calcareous and $CaCO_3$ content ranged from 2.0 to 5.0 g kg^{-1}.

Soil fertility status

The soil fertility status exhibits the status of different soils with regard to amount and availability of nutrients essential for plant growth (Table 4). The available nitrogen status of all the soils were low ranging from 123 to 209 kg ha^{-1} in surface soils and in subsurface soils varied from 65 to 141 kg ha^{-1}. However, available N status was found to be relatively higher in surface soils as compared to subsurface soils, which might possibly be due to decreasing trend of organic carbon with depth. These observations are in accordance with the findings of Prasuna Rani *et al.* (1992). The available P (Bray's P) status of soils was low to medium and varied from 14.0 to 28.0 kg ha^{-1} in surface soils and was low varied from 7.0 to 19.0 kg ha-1 in the subsurface soils. In majority of the surface soils, the available P was low due to the fixation of released P by clay minerals and oxides of $Fe^{2+}$and Al^{3+} (Rajeshwar *et al*., 2009). The availability of K status of soils was medium to high and varied from 126 to 319 kg ha-1- in surface soils and 85.0 to 164.0 kg ha-1 in subsurface soils. The high available K in surface soils could be attributed to more intensive weathering, release of labile-K from organic residues of cultivated crop plants and upward translocation of K from lower depths along with capillary rise of ground water. Similar results were reported by Pal and Mukhopadyay (1992).

Table 3. Physico-chemical characteristics surface and subsurface of soils of DARS, Chettinad

Block	No. of samples	Depth (cm)	pH (1:2.5)	EC (dSm-1)	OC (g kg-1)	Exchangeable cations (c mol (p+) kg-1)				Total Exchangeable Bases	Base saturation (%)	CEC (c mol (p+) kg-1)	$CaCO_3$ (g kg-1)
						Ca	Mg	Na	K				
A	22	0-15	4.8-6.4	0.10-0.41	3.6-6.0	1.25-1.57	0.51-0.98	0.04-0.11	0.11-0.25	2.19-2.57	35.0-40.9	6.1-7.1	1-2
			(5.5)	(0.15)	(5.2)	(1.43)	(0.70)	(0.06)	(0.19)	(2.39)	(36.9)	(6.5)	(1.7)
	22	15-30	4.7-6.0	0.10-0.27	1.8-4.7	1.43-1.68	0.76-1.14	0.04-0.09	0.08-0.19	2.42-2.85	35.7-41.3	6.2-6.8	2-3
			(5.3)	(0.13)	(3.3)	(1.53)	(0.87)	(0.07)	(0.12)	(2.60)	(38.7)	(6.712)	(2.3)
B	8	0-15	4.5-5.1	0.10-0.16	4.2-5.7	1.29-1.51	0.61-0.79	0.05-0.09	0.14-0.24	2.21-2.53	36.2-40.8	5.7-6.4	2-5
			(4.8)	(0.12)	(4.9)	(1.36)	(0.72)	(0.07)	(0.18)	(2.34)	(38.6)	(6.1)	(3.0)
	8	15-30	4.6-5.0	0.11-0.16	2.4-3.9	1.48-1.64	0.79-0.93	0.05-0.09	0.09-0.14	2.47-2.73	37.4-42.6	6.2-6.8	2-5
			(4.7)	(0.12)	(3.1)	(1.55)	(0.85)	(0.07)	(0.11)	(2.58)	(40.3)	(6.4)	(3.1)
C	20	0-15	4.7-6.5	0.10-0.13	4.3-6.7	1.34-1.68	0.51-0.79	0.05-0.09	0.18-0.26	2.25-2.56	35.4-38.2	6.3-6.8	0
			(5.4)	(0.10)	(5.7)	(1.41)	(0.66)	(0.07)	(0.22)	(2.37)	(36.4)	(6.5)	0
	20	15-30	4.6-6.1	0.09-0.16	2.8-4.6	1.42-1.76	0.65-0.91	0.04-0.09	0.09-0.19	2.41-2.65	35.6-39.2	6.5-7.1	-
			(5.3)	(0.11)	(3.9)	(1.50)	(0.81)	(0.07)	(0.13)	(2.51)	(37.1)	(6.7)	0
D	14	0-15	4.5-5.7	0.09-0.14	3.0-6.0	1.37-1.59	0.45-0.91	0.04-0.09	0.19-0.28	2.33-2.70	36.0-40.4	6.3-6.8	0
			(5.0)	(0.11)	(5.0)	(1.50)	(0.68)	(0.06)	(0.23)	(2.48)	(37.9)	(6.5)	-
	14	15-30	4.5-5.6	0.09-0.14	1.2-4.6	1.49-1.81	0.74-1.14	0.04-0.09	0.09-0.18	2.59-2.93	37.5-41.6	6.5-7.1	0
			(5.0)	(0.11)	(2.6)	(1.67)	(0.84)	(0.06)	(0.13)	(2.70)	(39.8)	(6.8)	-
E	8	0-15	4.6-5.6	0.09-0.15	4.5-6.8	1.39-1.61	0.65-0.79	0.04-0.09	0.19-0.31	2.45-2.67	36.5-48.62	5.1-7.1	0-2
			(4.8)	(0.12)	(5.5)	(1.50)	(0.73)	(0.07)	(0.23)	(2.54)	(39.9)	(6.4)	(2.0)
	8	15-30	4.5-5.1	0.10-0.23	1.6-5.4	1.46-1.85	0.71-1.01	0.05-0.09	0.08-0.19	2.45-3.02	37.1-49.2	5.4-7.3	2-3
			(4.7)	(0.12)	(3.6)	(1.71)	(0.84)	(0.07)	(0.11)	(2.74)	(40.7)	(6.77)	(2.2)
Overall range		0-15	4.5-6.5	0.09-0.41	3.0-6.8	1.25-1.68	0.45-0.98	0.04-0.11	0.11-0.31	2.19-2.70	35.0-48.62	5.1-7.1	2.0-4.0
Overall Mean			(5.2)	(0.12)	(5.26)	(1.44)	(0.70)	(0.06)	(0.21)	(2.42)	(37.9)	(6.4)	(1.3)
		15-30	4.5-6.1	0.09-0.27	1.2-5.4	1.42-1.85	0.65-1.14	0.04-0.09	0.08-0.19	2.41-3.02	35.6-49.2	5.4-7.3	2.0-5.0
			(5.0)	(0.11)	(3.3)	(1.59)	(0.84)	(0.07)	(0.12)	(2.6)	(39. 3)	(6.7)	(1.6)

The data in parenthesis indicate average values

The available S status of soils was low to high varied from 9.13 to 18.85 mg kg-1 and 5.13 to 13.92 mg kg-1 in surface and sub surface soil respectively which might be due to soil sulphur is continuously cycled between inorganic and organic forms of sulphur (Pasricha and Fox, 1993). Similarly, the organic sulphur was also in equilibrium with inorganic SO_4-S level by means of crop uptake or leaching loss, it will be adequately replenished by the organic fraction (Ghosh *et al.,* 2012).

The DTPA Zn status varied from 0.10 to 3.52 mg kg-1 and 0.29 to 1.92 mg kg-1 in surface and subsurface soils (Table 2). Considering 1.2 mg kg-1 as critical level (Anonymous, 1984), it was found that 70 percent of the surface soils were deficient in availability. The availability was low in subsurface soils than surface soils which might be due to accumulation of comparatively more amount of organic matter as reported by Jalali *et al.,* (1989) and Nayak *et al.,* (2000).

The DTPA Cu status varied from 0.85 to 3.63 mg kg-1 and 0.72 to 2.84 mg kg-1 in surface and subsurface soils respectively. Considering 1.2 mg kg-1 as critical level (Anonymous, 1984), it was found that 90 percent of the surface soils are sufficient. The available Cu was more in surface soils than subsurface soils which might be due to its association with organic carbon affecting its availability in surface layers (Rajeshwar and Ariff khan, 2007).

The available Mn status of these soils varied from 24.0 to 49.2 and 20.2 to 40.2 mg kg-1 in the surface and subsurface soils respectively. Considering 2.0 mg kg-1 as critical level (Anonymous, 1984), it was found that all the surface and subsurface soils were high in availability which might be due to its presence in the reduced forms, higher biological activity and organic carbon in the surface soils. These observations were in agreement with the findings of Murthy *et al*., (1997) and Nayak *et al.,(*2000).

The DTPA Fe content varied from 8.9 to 22.3 mg kg-1 and 7.5 to 18.0 mg kg-1 in the surface and sub surface soils respectively. Based on the critical limit of 3.7 mg kg-1 for non-calcareous soils (Anon., 1984), the soils were sufficient in available Fe. It was relatively high in the surface soils when compared to the subsurface soils might be due to accumulation of humic material in the surface soils besides prevalence of reduced conditions in subsurface soils. The findings were in agreement with the findings of Prasad and Sakal (1991). The sufficiency status of Fe may be attributed to the non calcareous nature of soils of the study area.

The hot water soluble boron status varied from 0.36 to 0.64 mg kg^{-1} and 0.14 to 0.44 mg kg^{-1} soil in the surface and subsurface soils respectively. Based on critical limit of 0.46 mg kg^{-1} (Anon., 1984), it was found that 76 percent of the surface soils are deficient in availability. The availability was low in subsurface soils than surface soils which might be due to accumulation of organic matter and well drained condition in the surface soils.

The nutrient index values (NIV) was worked out to know the fertility rating of available macro and micronutrients in the surface soils of different blocks of Research Station (Table 7). Based on NIV and soil fertility ratings the soils were found to be low in N (1.00) and P (1.4), very low in Zn (1.39) and B (1.23); medium in the availability of K (2.15), high (2.47) in availability of S and high in availability of Cu (2.91), very high in Mn (3.00) and Fe (3.00) in surface soils respectively.

Table 4. Available nutrient status surface and subsurface soils of DARS, Chettinad

Block	No. of samples	Depth (cm)	Available Macronutrients (kg ha^{-1})			Available S (mg kg^{-1})	Available Micronutrients (mg kg^{-1})				
			N	P	K		Zn	Cu	Mn	Fe	B
A	22	0-15	129-174	20-28	126-201	10.53-18.61	0.59-3.52	0.85-3.62	24.98-49.21	8.92-22.38	0.36-0.56
			(157.0)	(24.0)	(177.0)	(14.90)	(1.33)	(2.29)	(33.67)	(13.88)	(0.45)
	22	15-30	77.0-141	8.0-19	101-171	5.43-13.92	0.1-1.92	0.84-2.84	21.03-35.23	8.42-17.79	0.14-0.44
			(113.0)	(13.0)	(132.0)	(9.70)	(0.71)	(1.49)	(30.6)	(11.94)	(0.28)
B	8	0-15	123-173	14-21	184-211	9.13-17.53	0.29-1.29	1.51-2.91	26.18-36.89	11.72-17.42	0.42-0.47
			(153.0)	(18.0)	(201.0)	(13.31)	(0.81)	(1.88)	(31.12)	(13.72)	(0.45)
	8	15-30	65-126	7.0-13	98-164	7.25-11.51	0.16-1.88	0.79-1.43	25.1-35.75	9.63-15.33	0.14-0.39
			(101.0)	(10.0)	(136.0)	(9.0)	(0.69)	(1.15)	(30.67)	(12.54)	(0.25)
C	20	0-15	131-195	18-27	153-284	11.36-18.85	0.31-1.29	1.25-3.63	24.02-38.0	9.29-13.6	0.37-0.58
			(171.0)	(23.0)	(236.0)	(15.33)	(0.81)	(1.82)	(28.19)	(11.37)	(0.47)
	20	15-30	74-128	9-18	101-186	5.13-12.63	0.15-1.06	0.77-1.76	20.2-33.71	7.56-12.67	0.15-0.39
			(104.0)	(14.0)	(156. 0)	(9.54)	(0.59)	(1.24)	(26.75)	(9.99)	(0.25)
D	14	0-15	176-209.0	16-27	186-319	10.45-18.41	0.50-2.29	0.94-3.48	30.14-48.28	11.08-21.95	0.40-0.64
			(195.0)	(24.0)	(270.0)	(14.88)	(1.307)	(2.25)	(35.93)	(14.61)	(0.46)
	14	15-30	89-124	11-19	107-191	5.63-13.03	0.21-1.92	0.72-2.82	23.08-40.28	9.21-18.07	0.14-0.39
			(119.0)	(15.0)	(148.0)	(9.48)	(0.79)	(1.69)	(32.21)	(12.55)	(0.23)
E	8	0-15	138-208	21-26	185-283	10.85-17.16	0.45-1.76	0.92-1.91	27.95-31.65	9.03-16.98	0.42-0.62
			(191.0)	(23.0)	(247.0)	(14.10)	(0.96)	(1.46)	(29.67)	(11.2)	(0.49)
	8	15-30	97-141	13-18	85-167	8.12-12.78	0.17-0.49	0.76-1.26	20.2-28.55	7.77-15.78	0.15-0.26
			(117.0)	(15.0)	(130.6)	(10.33)	(0.34)	(0.99)	(24.8)	(9.89)	(0.22)
Overal range		0-15	123.0-209.0	14.0-28.0	126.0-319.0	9.13-18.85	0.10-3.52	0.85-3.63	24.02-49.21	8.9-22.38	0.36-0.64
Mean			(173.0)	(22.0)	(226.0)	(14.50)	(1.04)	(1.94)	(31.71)	(12.95)	(0.46)
		15-30	65.0-141.0	7.0-19.0	85.0-164.0	5.13-13.92	0.29-1.92	0.72-2.84	20.2-40.28	7.56-18.07	0.14-0.44
			(111.0)	(13.4)	(109.0)	(9.61)	(0.62)	(1.31)	(29.06)	(11.38)	(0.25)

The data in parenthesis indicate average values

Very high Fe fertility in the soils might be attributed to acidic soil reaction (Sood *et al.,* 2009). Very high fertility rating of Mn in the soils could be attributed to the oxidation of divalent Mn^{++} to trivalent Mn^{+++} by certain fungi and by the organic compounds synthesized by micro- organisms and plants (Vijayakumar *et al.,* 2011).

The low nutrient index values of N, P, Zn and B in surface and subsurface soils may be attributed to several factors. Among these some of the factors causing low availability and deficiency in the red lateritic soils are inherent soil properties such as low native nutrients status, coarse texture, low organic matter content and soil conditions that favour leaching losses.

Correlation studies

The relationship between various soil physical, physico-chemical properties and nutrient availability was tested using the statistical tool "SPSS".

Interaction between soil physical properties and organic carbon

Correlation coefficients between physical properties and organic carbon of surface soils showed that (Table 5) the sand was negatively correlated with silt, clay, organic carbon, water retention at field capacity, available water content and maximum water holding capacity (r=-0.382**, -0.933**,-0.253*-0.648*,-0.621* and -0.792** respectively) and it was positively correlated with bulk density and pore space (r = 0.384** and 0.662** respectively). The silt was negatively correlated with bulk density (r = -0.276*). The clay content positively correlated with organic carbon, water retention at field capacity, available water content and maximum water holding capacity (r = 0.291*, 0.729**, 0.682** and 0.823** respectively) and it was negatively correlated with bulk density and porespace (r = -0.309**and- 0.704**). The bulk density significantly positively influenced by porespace(r=0.304**) and it was negatively correlated with wilting point and maximum water holding capacity (r= - 0.250* and 0.284* respectively). The porosity was negatively correlated with water retention at field capacity, available water content and maximum water holding capacity (r= -0.556**,-0.549** and -0.681** respectively). The water retention at field capacity is positively correlated with wilting point, available water content and maximum water holding capacity (r = 0.336**, 0.814**and 0.838** respectively).

Interaction between soil physico-chemical properties and nutrients availability

Correlation coefficients between soil physico-chemical properties and nutrient availability of surface soils revealed that the pH of the surface soils had positive correlation with EC (r = 0.239*) and organic carbon (r =0.293*) (Table 6). The EC was negatively correlated with available K (r =-0.269*). The availability of S and Cu was significant and positively correlated with soil pH (r = 0.241* and 0.233* respectively) Similar relationship was reported by Kumar and Babel (2011). The exchangeable Ca was negatively correlated with Mg (r = -0.307**) and positively correlated with exchangeable K and CEC (r = 0.248*, and 0.379** respectively). Nitrogen availability in the soils was significantly influenced by exchangeable Ca, K and CEC (r= 0.286*, 0.256* and 0.258* respectively) and the availability of P was positively correlated with CEC (r = 0.273*). The availability of K positively correlated with exchangeable Ca, K, CEC and with available nitrogen (r = 0.263*, 0.352**, 0.259* and 0.671* respectively). The Zn availability was significant and positively correlated with availability of P (r= 0.280*). The availability of Cu was positive and significantly correlated with soil pH, CEC and Zn and negatively correlated with exchangeable K (r= 0.233*, 0.241* and 0.390** and -0.252 respectively). The availability of Mn was negatively correlated with Mg (r= -0.300*). The availability of Fe was significant and positively correlated with available Zn and Mn (r= 0.269* and 0.723**) and negatively correlated with exchangeable Mg and CEC (r= -0.279*, 0.242* respectively). The B availability was significant and negatively correlated with Zn (r = -0.280*).

Table 5. Correlation between soil physical properties of surface soils and organic carbon

	Sand	Silt	Clay	OC	BD	Pore space	33 kpa	1500 kpa	AWC	MW.H.C
Sand	1.00	-0.382**	-0.933**	-0.253*	0.384**	0.662**	-0.648**	-0.159	-0.621**	-0.792**
Silt		1.00	0.030	-0.035	-0.276*	-0.019	-0.042	-0.036	-0.006	0.115
Clay			100	0.291*	-0.309**	-0.704**	0.729**	0.180	0.682**	0.823**
Organic Carbon				1.00	-0.051	-0.189	0.216	0.031	0.177	0.255*
Bulk Density					1.00	0.304**	-0.191	-0.250*	-0.081	-0.284*
Pore space						1.00	-0.556**	-0.126	-0.549**	-0.681**
33 kpa							1.00	0.336**	0.814**	0.838**
1500 kpa								1.00	-0.170	0.041
AWC									1.00	0.879**
MW.H.C										1.00

AWC-Available water capacity; MWHC-Maximum water holding capacity *. Significant at 0.05 level (2-tailed). **. Significant at 0.01 level (2-tailed).

Soil site suitability for major crops

The red laterite soils of the Research Station, in general, have low to medium productivity potential. The annual crops like pulses, pearlmillet and horticultural crops, like mango, cashew and tapioca thrive well in these soils. Intensive leaching causes nutrient losses and release of free iron and aluminum oxides. The free iron and aluminum cause toxicity and nutrient imbalances in terms of N, K, P and Zn (Sehgal *et al*., 1993). Due to low pH of these soils, acidification causes P fixation with Fe or Al ions and hydroxides resulting in deficiency of phosphorus in the form of insoluble compound of $Al_2(H_2PO_4)_3$ and FeH_2PO_4; reduced availability of K, Ca, Mg and toxicity due to high availability of Mn, Fe, B and Mo.

The five blocks of the Research Station were evaluated for their suitability to different crops *viz*., groundnut, blackgram, greengram, redgram, pearlmillet and horticultural and forest crops such as tomato, tapioca, cashew, sapota, teak and Eucalyptus

Table 6. Correlation between soil physico-chemical properties and available nutrients of surface soils

	pH	EC	OC	Ca	Mg	Na	K	CEC	N	P	K	S	Zn	Cu	Mn	Fe	B
pH	1.00	0.239*	0.293*	-0.128	-0.196	-0.098	-0.174	0.131	-0.127	0.201	-0.128	0.241*	0.114	0.233*	0.021	-0.022	-0.118
EC		1.00	-0.153	0.013	0.153	0.110	-0.269*	0.103	-0.152	0.078	-0.190	0.090	0.092	0.228	-0.001	-0.114	-0.142
OC			1.00	-0.001	-0.187	0.024	0.073	0.071	0.051	0.115	0.069	0.000	-0.108	0.024	-0.060	-0.111	0.115
Ca				1.00	-0.307**	-0.173	0.248*	0.379**	0.286*	0.060	0.263*	0.121	-0.060	0.111	0.166	-0.018	0.181
Mg					1.00	0.027	-0.202	0.115	-0.051	0.206	-0.161	-0.142	0.044	0.170	-0.300*	-0.279*	-0.198
Na						1	-.0.291*	0.103	0.043	0-.103	-0.037	0.119	-0.163	-0.083	-0.146	-0.137	0.022
K							1.00	0.071	0.256*	0.056	0.352**	-0.150	-0.031	-0.252*	0.016	-0.104	0.187
CEC								1.00	0.258*	0.273*	0.259*	-0.073	-0.002	0.241*	-0.023	-0.242*	-0.055
N									1.00	0.184	0.671**	0.073	-0.024	-0.031	0.146	-0.135	0.046
P										1.00	0.024	0.131	0.280*	0.192	0.056	0.018	-0.070
K											1.00	0.067	-0.033	0.014	0.035	-0.119	-0.021
S												1.00	0.001	0.045	0.086	0.162	0.078
Zn													1.00	0.390**	0.220	0.269*	-0.280*
Cu														1.00	0.103	0.052	-0.194
Mn															1.00	0.723**	0.030
Fe																1.00	0.092
B																	1.00

. Significant at 0.01 level (2-tailed).. Significant at 0.05 level (2-tailed).

(Table 8 & 9) following the criteria outlined by Sys *et al*. (1993). The major soil limiting factors are coarse texture, low pH, poor organic carbon status and low CEC. The different blocks of the Research Station such as A, B, C and D were moderate to marginally suitable for cultivation of groundnut, horsegram, redgram, greengram, blackgram, and pearlmillet and vegetables such as tomato. The soils were marginally suitable to moderately suitable for the cultivation of groundnut, redgram, greengram, blackgram, pearlmillet and tomato under irrigated conditions. Similarly under rainfed situations, the soils were moderate to marginally suitable for the cultivation of groundnut, redgram, greengram, blackgram and pearlmillet and moderate to highly suitable for the cultivation of horsegram. These observations are in accordance with the findings of Kannan *et al.* (2011).

The 'E' block of the Research Station soils are red to reddish yellow with gravelly nature. Topography was very gently sloping to gently sloping with 3-5% slope and are well drained. They had fine weak granular to subangular blocky structure surface horizon and subangular blocky structure in sub surface horizons. The surface horizons varied from gravelly sandy loam to sandy clay loam and sub surface soils vary from gravelly sandy clay loam to sandy clay. The soils were acidic with low cation exchange capacity and organic matter content. The maximum water holding capacity of these soils varied from 12.8 to 25.6 percent. Water erosion was largely responsible for rendering soils shallow, gravelly and coarse textured resulting in low water holding capacity causing moisture stress besides droughtiness. No crop was growing in this block and it was dominated by the natural vegetation includes grasses *Cynodon dactylon, Cyprus rotundus*, *Azardirachta indica, Prosopis juliflora, cassia sp*,. toddypalm, broad leaf weeds, local plant species and thorny bushes. This block was not suitable for cultivation of dryland agricultural crops both under irrigated and rainfed situation. The horticultural and forest crops such as cashew, sapota, teak and Eucalyptus were highly suitable under rainfed condition with one or two supplement irrigation at the time of planting. It is estimated that 33 percent of the area of the research station is suitable for raising dryland agricultural crops and the remaining area suitable for horticultural and forest crops.

Table 7. Nutrient index values (NIV) of available nutrients status in surface soils of DARS, Chettinad

Blocks	Nutrient Index values and fertility ratings								
	N	P	K	S	Zn	Cu	Mn	Fe	B
A	1.00	1.5	2.00	2.50	1.59	2.95	3.00	3.00	1.18
B	1.00	1.00	2.00	2.12	1.25	3.00	3.00	3.00	1.00
C	1.00	1.50	2.15	2.60	1.15	3.00	3.00	3.00	1.30
D	1.26	1.75	2.91	3.00	1.83	3.33	3.50	3.50	1.50
E	1.00	1.12	2.12	2.25	1.25	2.62	3.00	3.00	1.37
Overall NIV	1.00	1.40	2.15	2.47	1.39	2.91	3.00	3.00	1.23
A	Low	Low	Medium	High	Low	Very high	Very high	Very high	Very low
B	Low	Low	Medium	Adequate	Very low	High	Very high	Very high	Very low
C	Low	Low	Medium	High	Very low	Very low	Very high	Very high	Very low
D	Low	Medium	High	Very high	Marginal	High	Very high	Very high	Low
E	Low	Low	Medium	Adequate	High	High	Very high	Very high	Low
Overall Fertility Ratings	Low	Low	Medium	High	Low	Very high	Very high	Very high	Very low

Soil fertility ratings (Macronutrients):< 1.66 Low; 1.67 –2.33 Medium; High >2.33

Soil fertility ratings (S and micronutrients) : < 1.33 – Very Low; 1.33 – 1.66 – Low, 1.67 – 2.00 – Marginal, 2.0 – 2.33 – Adequate ; 2.33 – 2.67 – High; >2.67 – Very high.

Table 8. Soil suitability classes selected for rainfed crops of DARS, Chettinad

Blocks	Groundnut		Horsegram		Greengram		Redgram		Tomato		Pearl millet		Tapioca		Cashew		Sapota		Teak		Eucalyptus	
	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS
A	S3	S2	S2	S1	S3	S2	S3	S2	S3	S2	S3	S2	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1
B	S3	S2	S2	S1	S3	S2	S3	S2	S3	S2	S3	S2	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1
C	S3	S2	S2	S1	S3	S2	S3	S2	S3	S2	S3	S2	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1
D	S3	S2	S2	S1	S3	S2	S3	S2	S3	S1	S3	S2	S2	S1	S2	S1	S3	S2	S2	S1	S2	S2
E	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	S2	S2	N2	N2	S3	S2	S2	S2	S2	S2

Constraints and management

In general, soils had light surface texture, moderately deep to deep rooting depth and gravelliness with kaolinite clay mineralogy resulting in poor water holding capacity. Surface crusting was common problem in this soil. The low water holding capacity did not permit post-rainy season cropping without irrigation. They were denuded and subject to serious erosion problems. Laterite soils had moderate acidity and were low in availability of phosphorus. They are low in nitrogen and deficient in calcium, magnesium, zinc and boron. Improved management practices have good potential to enhance productivity on these soils.

Suggestions for soil

management Application of Lime

Spreading lime remains the most effective remedy for soil acidity. It is the only cost-effective option for acidic agricultural soils. Liming may result in substantial crop yield responses for several years, as well as allowing or improving crop production.

Application of enriched rockphosphate

Recommended quantity of FYM enriched rockphosphate and zinc sulphate to be applied for crops to enhance the phosphorous and zinc use efficiency and maintain soil quality.

Green manuring

Pre monsoon sowing of green manures and incorporation at flowering stage will enhance the nitrogen availability and reduce surface crusting problem by creating favourable soil physical environment.

Application of organic manures

Farmyard manure, composted coirpith or pressmud at 25 t ha^{-1} per year conserves soil moisture, adds micronutrients, enhances aeration and improves the physical properties of the soil, Therefore 15-20 tonnes of well decomposed farmyard manure is added while preparing the land a month before sowing the seed. Maintenance of surface pH above 5.5 to allow movement of lime into the subsurface. More than one application of 1.0-1.5 t/ha of lime is likely to be required over a number of years or application of higher rates of lime (2-5 t/ha) to reach the desired surface pH. Using higher rates of lime may expose crops to nutrient deficiencies, particularly manganese and zinc. Raising of soil pH decreases the level of available aluminum and manganese in the soil and at the same time increases the availability of phosphorus, magnesium, calcium and molybdenum. Improves plant establishment and vigour. Improves nodulation in legumes and improves the persistence of different crops.

Reduce leaching of nitrogen

Use of split application of nitrogen fertilizers along with phosphorus and Zn for maximizing the crop yield; Use of lower rates of less acidifying fertilizers; and avoiding acidifying fertilizers such as mono ammonium phosphate or sulphate of ammonia.

Table 9. Soil suitability classes selected for irrigated crops of DARS Chettinad

Blocks	Groundnut		Horsegram		Greengram		Redgram		Tomato		Pearl millet		Tapioca		Cashew		Sapota		Teak		Eucalyptus	
	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS	AS	PS
A	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S1	S1	S2	S1	S2	S1	S1	S1	S1	S1
B	S2	S1	S2	S1	S2	S1	S1	S1	S2	S1	S2	S1	S1	S1	S2	S1	S2	S1	S1	S1	S1	S1
C	S2	S1	S2	S1	S2	S1	S1	S1	S2	S1	S2	S1	S1	S1	S2	S1	S2	S1	S1	S1	S1	S1
D	S2	S1	S2	S1	S2	S1	S1	S1	S2	S1	S2	S1	S1	S1	S2	S1	S2	S2	S3	S2	S2	S2
E	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	S2	S2	N2	N2	S3	S2	S2	S2

Suitable class : S_1 - Highly suitable; S_2 - Moderately suitable; S_3 - Marginally suitable Not suitable class : N_1- Temporarily not suitable N_2 - Permanently not suitable AS - Actual Suitability PS - Potential Suitability

Crop rotation with legume crops tend to take up more cations in proportion to anions. As a consequence, H+ ions are excreted from their roots to maintain the electrochemical balance within their tissues. This leads to a rise in soil acidification. Hence crop rotation with cereals crop is mandatory.

The soils are moderately deep to deep and ideal for cultivation of short duration agricultural crops and deep rooted horticultural and perennial crops. The soils are well drained both internally and externally. They don't possess the problems of alkalinity, calcareousness and salinity. These soils are low in organic carbon, available N, P and deficient in S, Zn and boron. Surface crusting and surface droughtiness are the major problems that are associated with these soils because of the low organic matter content, low exchangeable bases and the coarse texture of the soils. High soil productivity could be achieved by improving enhanced soil fertility, enrichment of organic matter, reduced surface sealing and crusting and erosion control practices, development and use of high-yielding varieties and hybrids.

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