Research Article

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Coconut-growing soils of Kerala: 1. Characteristics and classification

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Abstract

Coconut plantations are the major land use systems in Kerala state. The tropical hot humid climate and soils of the state are considered suitable for the palm, with the exception of highlands occurring 600 m above MSL. However, the productivity of coconut is abysmally low in the state with an average productivity of around 40 nuts per year per palm. To find out whether the highly weathered and leached low activity clay soils developed in tropical hot humid climate is responsible for the low yield, an assessment of soil qualities in the coconut-growing soils of the state was made. Six distinct regions of coconut cultivation in the state were identified and delineated based on the variability of agro-climate and soils, *viz.*, Central and Eastern Palakkad, Northern Kerala, Central Kerala, Southern Kerala, Onattukara sandy plains and coastal sandy plains. Soil profiles were studied at representative sites in each region. Investigated morphological features and sampled horizon-wise for the analysis of physical and chemical properties of the soil. Coconut-growing soils of Kerala state are in general deep and well drained, clayey or sandy having good structure permitting rapid transmission of water. The soils of Palakkad, Southern Kerala and Coastal Sandy Plains have near neutral reaction whereas the extensive areas of laterite soils of Northern and Central Kerala and sandy soils of Onattukara were strongly acid and had high levels of KCl extractable aluminium. The acid soils also analysed for low levels of basic cations, potassium, calcium and magnesium. Soils from all regions except Palakkad have low CEC. Surface and sub-soils base status were extremely low for soils of Northern and Central Kerala and Onattukara sandy plain. The soils of Central and Eastern Palakkad were classified as Typic Haplustalfs, Northern Kerala as Plinthic Humults, Central Kerala as Typic Plinthustults, Southern Kerala as Rhodic Kandiustults and the soils of sandy plains as Ustipsamments, according to soil taxonomy.

Keywords: Coconut-growing soils, Kandiustults, Plinthic Humults, Plinthustults, soils of humid tropics

Introduction

Coconut and coconut based mixed cropping are the major land use systems of Kerala. About twenty one per cent of the state's agricultural GDP is contributed by coconut production. However, the production and productivity of the palm is not encouraging. The current productivity of coconut is abysmally low, just around 40 nuts per palm per year (Jnanadevan, 2013). We have reasons to believe that decline in soil qualities is primarily responsible for the declining health and productivity of coconut palm in the state. Analysis of the soil qualities in south Indian states (Krishnan, *et al*., 1996; Reddy, *et al*., 1996; Natarajan *et al*., 1997; Shivaprasad *et al*., 1998) pointed to poor soil qualities in Kerala, compared to other states, *viz.*, soil acidification, sub-soil aluminium, low level of plant available nutrient cations in soils (K, Ca, Mg) and micronutrient deficiencies (Zn and B). Added to this is the low cation exchange capacity and consequent low retention of plant nutrients. Extensive studies on soil qualities in coconut-growing areas were made in the past, but focused on relating soil qualities to root (wilt) disease affecting the coconut palm (Shankarasubramoney *et al*., 1954; 1955; 1956; Pandalai *et al*., 1958a, 1958b). Recently concluded study on fertility of surface soils, covering the entire

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state, pointed to strong acidification of soils and deficiencies of macro-nutrient potassium, secondary nutrients calcium and magnesium, and micro-nutrients zinc and boron (Rajasekharan *et al*., 2013).

The nature and properties of the coconut-growing soils in major agro-climatic regions of the state are reported in this paper and a companion paper presents fertility of the soils and discusses the soil related constraints to coconut palm health and productivity in Kerala state.

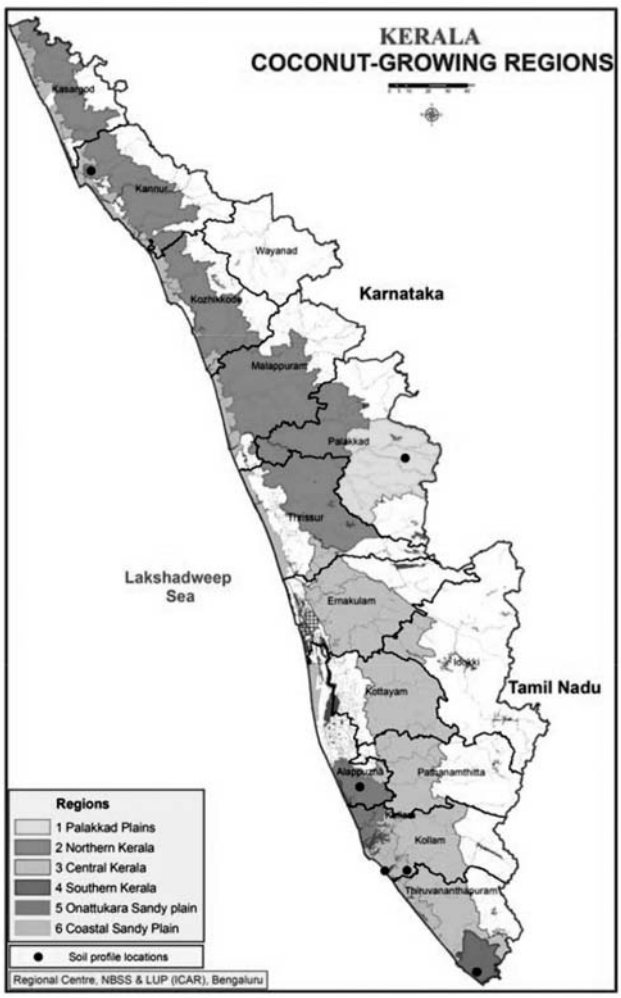


Fig. 1. Coconut-growing areas of Kerala (excluding high lands)

Materials and methods

Study of agro-climate and soil variability across the state (Nair *et al*., 2012; Krishnan *et al*., 1996; NBSS & LUP, 1999) enabled identification of six distinct regions of coconut cultivation in the state (Fig. 1), 1) Central and Eastern Palakkad, 2) Northern Kerala, 3) Central Kerala, 4) Southern Kerala, 5) Onattukara sandy plain and 6) Costal sandy plain.

High lands comprising escarpments and plateaus of Western Ghats with only limited area under the palm were excluded. Representative sites were located in the regions and soils were studied and sampled by exposing soil profiles. External land features and morphology of the soil were recorded in the field. Bulk and core samples were collected horizon-wise from the exposed profile of soil. The physical and chemical properties of the soil samples analyzed by following the methods listed in Table 1. The soil classification was done following USDA soil taxonomy (Soil Survey Staff, 1999).

The following secondary parameters were derived from the above primary soil parameters estimated.

Total exchangeable bases: Exchangeable Ca+Mg+K+Na

ECEC: Summation of total exchangeable bases plus 1.0 N KCl exchangeable Al^{3+}

Base saturation, CEC, pH 7: [Total exchangeable bases /CEC by sum of NH4OAc] × 100

Base saturation, CEC, pH 8.2: [Total exchangeable bases /CEC by sum of cations] × 100

Al saturation percentage: [Extr. Al/(Exch. Ca+Mg+K+Na+ Extr. Al)]*100

Table 1. Methods of soil analysis

Sl. No.	Soil parameter analysed	Method	Reference
1.	Particle size distribution	Robinson Pipette	Piper, 1950
2.	Soil pH, water	1:2.5 soil water ratio	Jackson, 1973
3.	Organic carbon	Wet oxidation method	Walkley and Black, 1934
4.	Cation exchange capacity	1 N Ammonium acetate method	Sarma *et al.*, 1987
5.	Exchangeable cations	Extract from CEC determination and atomic absorption spectrophotometry	Sarma *et al.*, 1987
6.	Exchange acidity	Extraction with 1 N KCl	Sarma *et al*., 1987

Results and discussion

Soils of Central and Eastern Palakkad

The region comprising Alathur, Chittur and Palakkad taluks of Palakkad district represents coconut-growing areas with relatively low rainfall and about 6 months dry period. Mean annual precipitation is 1655 mm. Around 6 per cent of coconut-growing areas in state belong to this region. A soil profile was exposed and studied in a coconut garden on nearly level land in Elapully panchayat (10° 44' 41.0'' N and 76° 4' 17.6'' E).

Morphological description of soil

Ap 0-15 cm	Very dark grey (7.5 YR 2.5/1 M) loamy sand; weak medium sub-angular blocky structure; 5 per cent gravel; friable slightly sticky and slightly plastic; many fine pores; many coarse and medium roots; pH 7.74; clear smooth boundary.
B1 16-30 cm	Dark brown (7.5 YR 4/4 M) sandy loam; moderate medium sub-angular blocky structure; 8 per cent gravel; friable sticky and plastic; many fine pores; many coarse and medium roots; pH 7.84; clear smooth boundary.
Bt1 31-49 cm	Dusky red (2.5 YR 3/2 M) sandy clay loam; moderate medium sub-angular blocky structure; 8 per cent gravel; friable sticky and plastic; many fine pores; many coarse and medium roots; thin patchy cutans on ped faces; pH 7.88; gradual smooth boundary.
Bt2 50-77 cm	Red (2.5Y R 4/6 M) clay; moderate medium sub-angular blocky structure; 5 per cent gravel; friable sticky and plastic; many fine pores; common coarse roots; thick continuous cutans on ped faces; pH 7.84; gradual smooth boundary.
Bt3 78-103 cm	Red (2.5Y R 4/6 M) clay; moderate medium sub-angular blocky structure; friable sticky and plastic; many fine pores; common coarse roots; thick continuous cutans on ped faces; pH 7.72; gradual smooth boundary.
Bt4 104-133 cm	Dark grey (10 YR 4/1 M) clay; moderate medium sub-angular blocky structure; friable sticky and plastic; few fine pores; few coarse roots; thin patchy cutans on ped faces; pH 7.67; gradual smooth boundary.
Bt5 134-160 cm	Dark grey (10 YR 4/1 M) clay; weak medium sub-angular blocky structure; 3 per cent gravel; friable sticky and plastic; few fine pores; few coarse roots; pH 7.54.

Soils of Northern Kerala

The region is delineated to represent land areas with high rainfall, but experience long dry period, around five to six months in a year. It comprises the midlands and foot hills north of Thrissur district to Kasaragod and western Palakkad. Around 44 per cent of coconut-growing areas in the state come under this region. Mean annual precipitation is 3669.4 mm. The soil profile was exposed in a coconut garden on nearly level land at Pilathara, Cheruthazham panchayat, Kannur district (12° 04′ 55.2″ N; 75° 15′ 20.3″ E).

Morphological description of soil

Ap 0-20 cm	Reddish brown (5YR 4/4 M) sandy clay loam; 27 per cent gravel; weak medium sub-angular blocky structure; friable sticky and plastic; many fine pores; common medium and coarse roots; pH 5.48; gradual smooth boundary.
Bt1 21-46 cm	Red (2.5YR 4/6 M) clay; 37 per cent gravel; moderate medium sub-angular blocky structure; friable sticky and plastic; many fine pores; many coarse roots; pH 5.41; gradual smooth boundary.
Bt2 47-71 cm	Red (2.5YR 4/6 M) clay; 41 per cent gravel; moderate medium sub-angular blocky structure; friable sticky and plastic; thin patchy cutans; many fine pores; many coarse roots; pH 5.38; gradual smooth boundary.
Bt3 72-103 cm	Red (2.5 YR 4/8 M) clay; 46 per cent gravel and 10 per cent stone and boulders; moderate medium sub-angular blocky structure; friable sticky and plastic; thick patchy clay cutans; many fine pores; few coarse roots; pH 5.41; gradual smooth boundary.
Bt4 104-150 cm	Red (2.5 YR 4/8 M) clay; 30 per cent gravel and 30 per cent stones and boulders; moderate medium sub-angular blocky structure; friable sticky and plastic; thin patchy clay cutans; many fine pores; very few coarse roots; pH 5.66.

Soils of Central Kerala

The Central Kerala region is delineated to represent coconut-growing areas with high rainfall and short dry period (3 months). Mean annual precipitation is 2827.3 mm. The region covers midlands and foot hills north of Thiruvananthapuram city to Ernakulam district. Around 36 per cent of coconut-growing areas in the state belong to this region. The lateritic soil of the region was studied and sampled at Kalluvathukkal in Kollam district (08° 49′ 33.6″ N; 76° 44′ 35.0″ E).

Morphological description of soil

Ap 0-22 cm	Yellowish brown (10YR 5/6 M) sandy clay loam; 5 per cent gravel; weak medium sub-angular blocky structure; friable slightly sticky and slightly plastic; many fine pores; many fine, many fine roots; pH 5.18; clear smooth boundary.
Bt1 23-40 cm	Strong brown (7.5YR 5/6 M) sandy clay loam; 2 per cent gravel; moderate medium sub-angular blocky structure; friable sticky and plastic; many fine pores; many coarse roots; pH 5.19; gradual smooth boundary.
Bt2 41-66 cm	Yellowish red (5YR 5/6 M) sandy clay loam; 4 per cent gravel; moderate medium sub-angular blocky structure; friable, sticky and plastic; thin patchy cutans; many fine pores; common coarse roots; pH 5.02; gradual smooth boundary.
Bt3 67-102 cm	Red (2.5 YR 4/8 M) sandy clay loam; 44 per cent gravel; weak medium sub-angular blocky structure; friable sticky and plastic; thin patchy clay cutans; many fine pores; few coarse roots; pH 5.28; clear smooth boundary.
Bt4 103-120 cm	Red (2.5 YR 4/6 M) sandy clay loam; 60 per cent gravel; weak medium sub-angular blocky structure; friable sticky and plastic; many fine pores; pH 5.24; gradual smooth boundary.
BC 120+ cm	Laterite (plinthite layer)

Soils of Southern Kerala

The region represents coconut-growing areas with relatively low rainfall, but short dry period. Mean annual precipitation is 1884 mm. The well distributed rainfall received from both the monsoons ensure very short soil moisture stress period, just around two months. The land area of the unit is south of Thiruvananthapuram city till the border to Tamil Nadu. This region covers just 2.7 per cent of coconut-growing areas in the state. A soil profile was exposed in a terraced coconut garden in Thirupuram panchayat of Neyytinkara taluk (08^{o} 20' 49.8'' N and 77^{o} 03' 45.4'' E).

Morphological description of soil

Ap 0-14 cm	Dark reddish brown (5YR 3/4 M) clay loam; weak medium sub-angular blocky structure; friable slightly sticky and slightly plastic; common medium pores; few coarse roots; pH 6.4; clear smooth boundary.
Bt1 15-31 cm	Dark reddish brown (2.5YR 3/4 M) clay; moderate medium sub-angular blocky structure; friable sticky and plastic; common medium pores; common coarse roots: thin patchy cutans on ped faces; pH 6.6; clear smooth boundary.
Bt2 32-52 cm	Dark red (2.5YR 3/6 M) clay; moderate medium sub-angular blocky structure; friable sticky and plastic; common medium pores; common coarse roots: thin patchy cutans on ped faces; pH 6.8; gradual smooth boundary.
Bt3 53-87 cm	Dark red (10 R 3/6 M) clay; moderate medium sub-angular blocky structure; friable sticky and plastic; common medium pores; common coarse roots; thin patchy cutans on ped faces; pH 6.5; gradual smooth boundary.
Bt4 88-127 cm	Dark red (10 R 3/6 M) clay; moderate medium sub-angular blocky structure; friable sticky and plastic; common medium pores; few coarse roots: thin patchy cutans on ped faces; pH 5.5; gradual smooth boundary.
Bt5 128-150 cm	Dark red (10 R 3/6 M) clay; moderate medium sub-angular blocky structure; friable sticky and plastic; common medium pores; few coarse roots: thin patchy cutans on ped faces; pH 5.4; gradual smooth boundary.
Bt6 151-180 cm	Dark red (10 R 3/6 M) clay; moderate medium sub-angular blocky structure; friable sticky and plastic; common medium pores; thin patchy cutans on ped faces; pH 5.3; gradual smooth boundary.
Bt7 181-200 cm	Dark red (10 R 3/6 M) clay; moderate medium sub-angular blocky structure; friable sticky and plastic; common medium pores; thin patchy cutans on ped faces; pH 5.3; gradual smooth boundary.

Soils of Onattukara sandy plain

The region comprises the sandy plain extending inward from coast, well into the midlands, often described as Onattukara sandy plain. It covers parts of Kollam and Alappuzha districts in Central Kerala. The region covers around 2.7 per cent of the coconut-growing areas in the state. Average annual precipitation is 2491.8 mm. In most parts of the region, have shallow water table, sometime reaches near surface. A soil profile was studied in Chettikulangara panchayat of Alappuzha district (09° 12′ 49.7″ N; 76° 31′ 47.6″ E).

Morphological description of soil

Ap 0-17 cm	Grey (10YR 5/1 M) sand; single grain; loose; many fine pores; many fine roots; pH 5.55; gradual smooth boundary.
AC 18-36 cm	Grey (10YR 5/1 M) sand; single grain; loose; many fine pores; many coarse roots; pH 5.46; gradual smooth boundary.
C1 37-62 cm	Grey (10YR 5/1M) sand; single grain; loose; many fine pores; many coarse roots; pH 5.43; gradual smooth boundary.
C2 63-95 cm	Greyish brown (10 YR 5/2 M) sand; single grain; loose; many fine pores; common coarse roots; pH 5.42; gradual smooth boundary.
95+ cm	Water table

Coastal sandy plain

Coastal sandy plain is delineated to represent the coconut-growing areas with sandy soil, along the coast, from southern end of the state to the northern end. The region covers around 9 per cent of the coconut-growing areas in the state. Average annual precipitation is 2491.8 mm (range: 2299.1 to 3020.9 mm). The soil was studied very near to beach at Mayyanad panchayat in Kollam district (08° 49′ 51″ N; 76° 38′ 11.8″ E).

Morphological description of soil

Ap 0-13 cm	Dark yellowish brown (10YR 4/ 4 M); sand; single grain; loose; many fine pores; many fine and medium roots; pH 6.33; gradual smooth boundary.
AC1 14-48 cm	Dark yellowish brown (10YR 4/6 M) sand; single grain; loose; many fine pores; many coarse roots; pH 6.45; gradual smooth boundary.
C1 49-69 cm	Brown (10YR 5/3 M) sand; single grain; loose; many fine pores many common coarse roots; pH 6.58; gradual smooth boundary.
C2 70-99 cm	Brown (10 YR 5/3 M) sand; single grain; loose; many fine pores; few coarse roots; pH 6.46; gradual smooth boundary.
C3 100-130 cm	Brown (10 YR 5/3 M) sand; single grain; loose; many fine pores; few coarse roots; pH 6.76.

Physical properties of the soils

Coconut-growing soils are generally deep to very deep, except at few places where hard laterite layer in subsoil limits root growth. However, in laterite soils of Northern and Central Kerala the presence of large quantities of coarse fragments often limit effective soil volume (Rao and Jessy, 2007). Soils of other regions are fairly free of coarse fragments. Two broad classes of soil textures are encountered, sandy and clayey, the former confined to coastal and Onattukara sandy plains. The binding of primary particles by oxides of iron and aluminium to macro aggregates is responsible for the moderately strong sub-angular blocky structure of laterite soils. These structural aggregates coupled with large porosity created by the presence of gravel and other coarse fragments ensure rapid infiltration and permeability of water in the coconut-growing soils. The coarse sand particles ensure rapid water transmission in the structure less sandy soils of Coastal and Onattukara regions.

Chemical properties

Coconut-growing soils across the state differ significantly in chemical properties (Table 2).

Soil reaction (pH) and exchangeable Aluminium

Coconut-growing soils from Palakkad, Southern Kerala and Coastal Sandy Plain tested for slightly alkaline to near neutral reaction. The soils of Northern Kerala, Central Kerala and Onattukara Sandy Plain are strongly acid in surface and subsoil layers. While the slightly alkaline to near neutral soils did not yield any Al^{3+} ions on extraction with 1*N* KCl solution, all the strongly acid soils tested positive for exchangeable Al. The Al saturation of exchange complex ranged from 7.39 to 68.65 per cent in different soil layers of Northern and Central Kerala. Al saturation was very high in Onattukara sandy soils with a range of 14 to 82 per cent, increasing with depth.

Electrical conductivity

Electrical conductivity of soil solution, the measure of soluble salts in soils, was very low (trace to 0.12 dS m^{-1}) for all the samples, including those drawn from uplands near the sea coast. The extremely high leaching environment of the humid climate is responsible for the very low salt content. The very low soluble salt points to the low levels of anions and cations in soil solution, some of them important coconut nutrients: cations Ca, Mg, K and anions chloride and sulphate.

Table 2. Physical and chemical properties of soils

Depth (cm)	Sand	Silt	Clay	Coarse frag. (% vol.)	Textrl. class	BD, Mg m^{-3}	O.C. (%)	pH (1:2.5) water	pH (1:5) 0.01 *M* $CaCl_2$	E.C. dS m^{-1}	CEC NH_4 OAc (pH 7.0)	CEC ECEC	CEC Total bases	KCl Extr. Al.	Base sat., % CEC 7.0	Base sat., % CEC 8.2	Al. sat., %	Ratio CEC/ Clay
	% <2 mm										cmol (+) kg^{-1} soil							
Soils of Central and Eastern Palakkad: Fine, mixed, isohyperthermic Typic Haplustalfs																		
0-15	78.60	13.12	8.28	5	ls	1.18	1.20	7.74	7.00	0.12	7.45			0.00	100		0.00	0.90
16-30	67.32	16.08	16.60	8	sl	1.42	0.52	7.84	6.81	0.07	6.72			0.00	100		0.00	0.40
31-49	62.07	15.28	22.64	8	scl	1.50	0.53	7.88	6.77	0.06	8.74			0.00	100		0.00	0.39
50-77	44.09	14.88	41.03	5	c	1.41	0.56	7.84	6.78	0.08	12.14			0.00	100		0.00	0.30
78-103	36.42	14.01	49.57	0	c	1.36	0.44	7.72	6.65	0.08	14.72			0.00	100		0.00	0.30
104-133	36.48	16.63	46.89	0	c	1.46	0.32	7.67	6.55	0.09	14.90			0.00	100		0.00	0.32
134-160	42.39	14.14	43.48	3	c	1.47	0.39	7.54	6.48	0.08	14.44			0.00	100		0.00	0.33
Soils of Northern Kerala: Clayey-skeletal, kaolinitic, isohyerthermic Plinthic Palehumults																		
0-20	48.71	20.93	30.36	27	scl	1.24	2.09	5.48	4.48	0.04	11.13	4.32	3.70	0.63	33	17	14.46	0.37
21-46	31.97	27.47	40.56	37	c	1.32	1.26	5.41	4.38	0.02	9.84	2.94	1.79	1.15	18	9	39.17	0.24
47-71	32.54	15.78	51.68	41	c	1.39	0.99	5.38	4.36	0.02	10.30	3.30	1.85	1.45	18	10	43.93	0.20
72-103	36.55	12.95	50.49	47	c	1.63	0.78	5.41	4.35	0.01	9.48	2.76	1.54	1.23	16	9	44.32	0.19
104-150	39.52	13.28	47.19	30	c	1.73	0.59	5.66	4.62	0.02	7.18	2.37	2.19	0.18	31	14	7.39	0.15
Soils of Central Kerala: Fine-loamy, kaolinitic, isohyperthermic Typic Plinthustults																		
0-22	68.97	10.28	20.75	5	scl	1.42	0.70	5.18	4.26	0.02	3.86	1.46	0.46	1.00	12	5	68.65	0.19
23-40	56.73	9.34	33.93	2	scl	1.15	0.55	5.19	4.39	0.02	4.60	1.74	0.94	0.80	20	10	45.97	0.14
41-66	58.37	8.37	33.26	4	scl	1.14	0.54	5.02	4.28	0.03	5.06	1.83	0.90	0.93	18	9	50.63	0.15
67-102	55.83	10.35	33.82	44	scl	1.59	0.37	5.28	4.38	0.03	4.32	1.64	0.99	0.65	23	9	39.54	0.13
103-120	57.26	11.95	30.79	60	scl	1.70	0.35	5.24	4.34	0.02	3.22	0.96	0.46	0.50	14	4	51.96	0.10
Soils of Southern Kerala: Clayey, kaolinitic, isohyperthermic Rhodic Kandiustults																		
0-14	75.4	1.2	23.4	0	scl	1.55	0.93	6.4	5.8	tr	4.3	4.3	4.2	0.00	98	81	0.00	0.18
15-31	61.1	2.3	36.6	0	sc	1.47	0.70	6.6	5.9	tr	4.3	4.1	4.0	0.00	93	66	0.00	0.12
32-52	54.9	4.7	40.4	0	sc	1.45	0.57	6.8	6.0	0.05	4.2	4.1	4.1	0.00	98	80	0.00	0.10
53-87	45.4	4.5	50.1	0	c	1.35	0.57	6.5	5.8	0.03	3.3	2.9	2.9	0.00	88	24	0.00	0.07
88-127	45.8	2.4	51.8	0	c	1.35	0.50	5.5	4.7	0.03	3.3	1.9	1.7	0.10	52	25	0.00	0.06
128-150	44.9	1.8	53.3	0	c	1.40	0.50	5.4	4.5	0.03	3.5	2.2	2.0	0.10	57	28	0.00	0.07
Soils of Onattukara sandy plain: Mixed, isohyperthermic Aquic Ustipsamments																		
0-17	94.14	2.37	3.48	0	s	1.34	0.32	5.55	4.40	0.02	2.12	0.73	0.63	0.10	30	12	13.75	0.61
18-36	92.70	3.22	4.08	0	s	1.45	0.29	5.46	4.46	0.03	2.08	0.59	0.59	0.30	28	8	33.63	0.51
37-62	92.30	4.79	2.91	0	s	1.32	0.32	5.43	4.41	0.01	2.12	0.64	0.19	0.45	9	5	69.78	0.73
63-95	90.72	6.35	2.93	0	s	1.35	0.67	5.42	4.49	0.01	2.39	0.64	0.11	0.53	5	1	82.30	0.82
Soils of Coastal Sandy Plain: Mixed, isohyperthermic Typic Ustipsamments																		
0-13	99.39	0.30	0.31	0	s	1.35	0.52	6.33	5.08	0.04	1.10	1.22	1.02	0.00	93	20	0.00	3.56
14-48	99.19	0.40	0.41	0	s	1.50	0.15	6.45	5.06	0.02	0.55	0.49	0.49	0.00	88	8	0.00	1.35
49-69	99.19	0.40	0.41	0	s	1.47	0.15	6.58	5.05	0.02	0.60	0.36	0.36	0.00	59	11	0.00	1.46
70-99	99.80	0.10	0.10	0	s	1.57	0.06	6.46	5.26	0.04	0.64	0.08	0.08	0.00	13	3	0.00	6.44
100-130	99.80	0.10	0.10	0	s	1.62	0.08	6.76	5.66	0.03	0.55	0.15	0.15	0.00	27	13	0.00	5.52

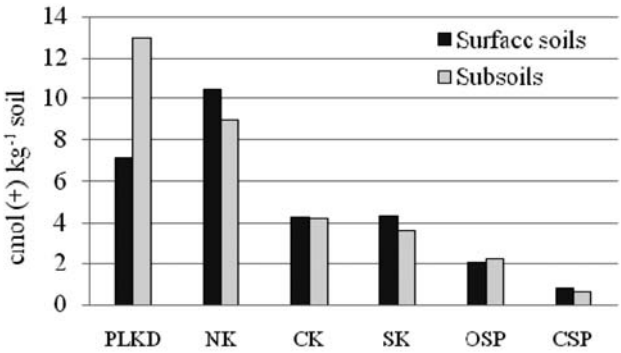
Organic carbon content

Organic carbon content of the soils assumes greater significance for the low activity soils of the state due to its contribution to cation exchange capacity of the soils. The organic carbon content of the surface and subsoil of Central Kerala and the sandy soils of Onattukara and Coastal plain are very low. Organic carbon levels in Palakkad and Northern Kerala soils, both surface and subsoil can be considered satisfactory.

Cation exchange capacity

Cation exchange capacity (CEC), the indicator of the soil ability to hold and exchange basic plant nutrient ions, varied significantly among coconut-growing soils. CEC of the fine earth was moderately high in surface and subsoils of Palakkad

(range: 7.45 to 14.90 cmol (+) kg^{-1} soil). CEC were lower, around 10 cmol (+) kg^{-1} soil, in Northern Kerala and further down to around 5 cmol kg^{-1} soil in Central and Southern Kerala soils (Table 2; Fig. 2). CEC was abysmally low for sandy soils (range: 0.55 to 2.39 cmol (+) kg^{-1} soil). The relatively high clay CEC (>24 cmol (+) kg^{-1} clay) and CEC/clay ratio (0.30 to 0.40 in subsoil layers) in soils of Palakkad is indicative of the presence of active clay minerals. The low effective cation exchange capacity (ECEC) coupled with low CEC/clay ratio, especially in subsoil layers, points to low activity clay in the laterite soils of Northern, Central and Southern Kerala. Kaolinite and hydroxy interlayered vermiculites and gibbsite that dominate the laterite soils of Kerala (Chandran *et al*., 2005) have very low cation exchange capacity. The source of CEC in sandy soils, with little or no clay, is organic matter alone.

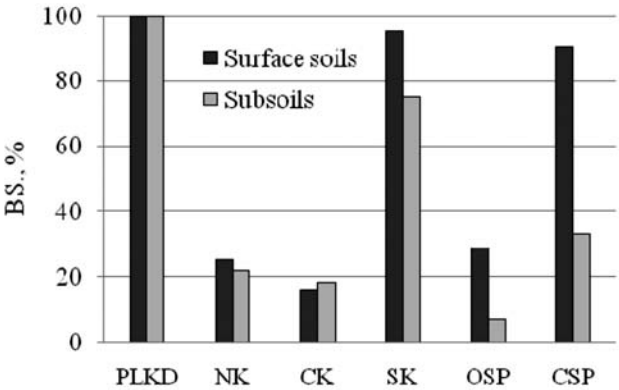


PLKD- Palakkad; NK-Northern Kerala; CK-Central Kerala; SK-Southern Kerala; OSP-Onattukara sandy plain; CSP-coastal sandy plain

Fig. 2. Cation exchange capacity of coconut-growing soils

Base saturation of soils

Coconut-growing soils of Central and Eastern Palakkad are saturated with bases and often contain free $CaCO_3$, especially in soil of the Eastern most Palakkad. Base saturation is very low in laterite soils of Northern and Central Kerala and the sandy soils of Onattukara. The soils of Southern Kerala and coastal sandy plain have high base saturation in surface and subsoil layers (Table 2; Fig. 3). However, high base saturation of sandy soils (with very low CEC) does not assure adequate levels of basic cations. For the low activity clay soils, total bases is a better measure of soil quality than base saturation.



PLKD- Palakkad; NK-Northern Kerala; CK-Central Kerala; SK-Southern Kerala; OSP-Onattukara sandy plain; CSP-coastal sandy plain

Fig. 3. Base saturation of coconut-growing soils of Kerala

Soil classification

The studied soils were classified in accordance with the internationally accepted system of soil classification, Soil Taxonomy (USDA). Table 3 presents the classification of the soils at the family level of the system.

The soil sampled at Elapully to represent Central and Eastern Palakkad belong to the order Alfisols having an argillic horizon as evidenced by clay accumulation in the sub-soil horizon as evidenced by higher clay content in subsoil horizons. Soil moisture control section dry in some or all parts for more than 90 cumulative days in a year (ustic moisture regime) are keyed to Ustalf sub-order.

Table 3. Classification of the soils

Region	Sampling site	Soil taxonomy (USDA)
Central and Eastern Palakkad	Elapully	Fine, mixed, isohyperthermic Typic Haplustalfs
Northern Kerala	Pilathara	Clayey-skeletal, kaolinitic, isohyperthermic Plinthic Palehumults
Central Kerala	Kalluvathukkal	Fine-loamy, kaolinitic, isohyperthermic Typic Plinthustults
Southern Kerala	Thirupuram	Clayey, kaolinitic, isohyperthermic Rhodic Kandiustults
Onattukara Sandy Plain	Chettikulangara	Mixed, isohyperthermic Aquic Ustipsamments
Coatal Sandy Plain	Mayyanad	Mixed, isohyperthermic, Typic Ustipsamments

The absence of any special sub-soil horizon like kandic or natric horizon and no root limiting layers within 150 cm from surface, the soil keyed out to Haplustalf at the great group level. Well drained soil conditions, high base saturation and the presence active clay minerals (as indicated by clay/CEC ratio >0.2) makes it Typic Haplustalf at the sub-group level. At the family level the soil texture is fine (>35 per cent clay), mineralogy mixed and the temperature regime isohyperthermic (characterized by MAT of >22 °C with MAST and MWST differ by less than 5 °C).

The soils of Northern Kerala sampled at Pilathara belong to Ultisol order of Soil Taxonomy due to the presence of argillic horizon with a base saturation of less than 35 per cent at a depth of 125 cm below from the top of argillic hoizon. The presence >0.9 per cent organic carbon in the top 15 cm of the argillic horizon made it Humult at the suborder level. In the absence of root limiting layer within a depth of 150 cm of the mineral soil surface and uniformly high clay content in the argillic horizon. The soil is keyed out to Palehumult at the great group level and the presence of more than 5 per cent plinthite in subsoils made it Plinthic Palehumult. At the family level the particle size class is clayey-skeletal due to the presence of >35 per cent coarse fragments in subsoil layers. The mineralogy class is kaolinite as evidenced from the low CEC/clay ratio (<0.2) of subsoil layers and studies on the clay mineralogy of laterite soils of Kerala (Chandran *et al*., 2005).

The soils of Central Kerala sampled at Kalluvathukkal belong to Ultisol order due to the presence of kandic horizon (CEC of clay less than 16 cmol (+) kg^{-1} clay in more than 50 per cent of the illuvial clay sub-soil horizons) and less than 35 per cent base saturation. The ustic moisture regime made it Ustult at suborder level due to the presence of plinthite as continuous layer within 150 cm of the mineral soil surface. At great group level the soil is keyed to Plinthustults. Uniformly high illuvial clay content in the kandic horizon, keyed out to Typic Plinthustult at sub group level. Less than 35 per cent clay lead to fine-loamy particle size family class and the dominance of low activity clay to kaolinitic mineralogy class. The soil moisture regime is isohyperthermic as in other parts of the state.

The soils of Southern Kerala sampled at Thirupuram with kandic horizon and a base saturation by sum of cations is less than 35 per cent at 150 cm below the upper boundary of kandic horizon assigns them to Ultisol order, despite the base rich surface and subsoil layers to a depth of 50 cm from surface. The ustic moisture regime led to Ustult at suborder level. The kandic subsoil horizon assigned the soils to great group Kandiustult and red color (hue 2.5 or redder and value, moist, 3 or less) throughout the solum lead to Rhodic Kandiustult at subgroup level.

The soils of Onattukara and Mayyanad belong to the Entisol order as they lack any significant soil development expressed through diagnostic horizons or alterations in morphological features. Both keys out to Psamments at suborder level due to dominantly sandy texture of the entire soil column and to Ustipsamments at great group as the soil belongs to soil moisture regime “ustic”. The presence of shallow (fluctuating) water table and the associated redoximorphic features lead to classification of the Onattukara soils to Aquic Ustpsamments at subgroup level and absence of any special feature resulted in keying out of the Mayyanad soils to Typic Ustpsamments.

The classification followed USDA Soil Taxonomy truly reflected the soil properties, soil development, and chemical properties, in particular the exchange properties and content of basic cations. The soils of Palakkad classified as Typic Haplustalf is distinctly different from the Ultisols of Northern, Central and Southern Kerala in terms of cation exchange capacity and content of basic cations. The use of criteria pertaining to plinthite at Great Group or Sub-group level help distinguish between low activity clay soils with and without plinthite. Overall, the family level classification of the soils reflects the soil properties and their variability for the highly weathered, humid, tropical soils of Kerala.

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