Research Article

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Coconut-growing soils in southern Karnataka: Characterization and classification

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Abstract

A study was carried out to characterize and classify major coconut-growing soils of southern Karnataka and to evaluate the suitability of these soils for coconut cultivation. Seven locations were selected on the map of coconut-growing areas in southern Karnataka and delineated based on the variability of agro-climate with the help of land resource map and report of Karnataka state, generated at 1: 2,50,000 scale by ICAR-NBSSLUP. The regions included Hosadurga (central dry zone), Gubbi and Turuvekere (eastern dry zone), Krishnarajapet (southern dry zone), Arasikere (southern transition zone), Belthangadi and Brahmavara (coastal zone) representing the density of coconut-growing areas in different agro-climatic zones. Soil profiles were studied at these selected sites. The coconut growing soils of southern Karnataka are generally deep, gravelly and well drained, sandy clay loam to clayey in texture with good structure. Soils of high rainfall areas of Belthangadi and Brahmavara were strongly acidic and rich in soil organic carbon, whereas other locations of sub-humid to semi-arid were near neutral to moderately alkaline soils with medium organic carbon content. Cation Exchange Capacity and base saturation were very low in coastal red and lateritic coconut soils and ranged from medium to high in other areas. The major taxa of the soils identified at sub-group level of soil taxonomy are *Rhodic Kanhaplustults, Ustic Kandihumults, Rhodic Paleustalfs, Typic Rhodustalfs and Vertic Haplustepts.*

Keywords: Coconut, characterization, soil classification, southern Karnataka

Introduction

In India, coconut is grown in 17 states and three union territories mostly along the coastal regions of the country. Recent estimates indicate that coconut is grown in an area of about 11.97 million ha and India ranks third in area and production, with Indonesia and the Philippines ranking first and second, respectively (APCC, 2017). In India, coconut occupies an area of about 2 million ha contributing towards an annual production of about 20,425.6 million nuts. Karnataka occupies the 2nd position both in area under cultivation and production behind Kerala and Tamil Nadu, respectively, with a monopoly of desiccated coconut industry and tender coconut production in the country.

The crop is grown in a variety of soil types *viz.* lateritic, coastal sandy, alluvial, loamy and reclaimed soils of of the marshy low lands. However, soils that have good water-holding capacity and proper drainage along with presence of water table at a depth of three meters and absence of any hard substratum or rock within two meters of the surface are known to be ideal for improved growth and performance of the palm.

Coconut palms are grown in Karnataka either in the gardens irrigated by tank water, in wide shallow valleys or on river banks for satisfactory yield. On inland areas, palm requires soils that permit root penetration and good aeration with adequate moisture, as its roots cannot withstand stagnation of water. The light textured soils with good drainage conditions are fairly superior to a rich fertile soil with impeded drainage. Coconut is being grown in almost all the parts of Southern Karnataka but the major areas are Hosadurga in Chitradurga (central dry zone), Gubbi and Turuvekere in Tumkur

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(eastern dry zone), Krishnarajapet in Mandya (southern dry zone), Arasikere in Hassan (southern transition zone), Belthangadi in Dakshina Kannada (Western Ghats foot hills) and Brahmavara (Lateritic mounds) in Udupi (coastal zone) (Fig.1). Climate and topography of the region, geological formations influence the nature and properties of soil. Granite gneiss and laterite rocks are common in the study area. A variety of soils ranging from light textured sandy loam to black coloured clayey soils are found in these areas. Adequate information on characterization of these soils towards suitability of coconut cultivation is lacking and hence the present investigation was undertaken in the major coconut-growing areas of Karnataka to characterize and classify these coconut-growing soils.

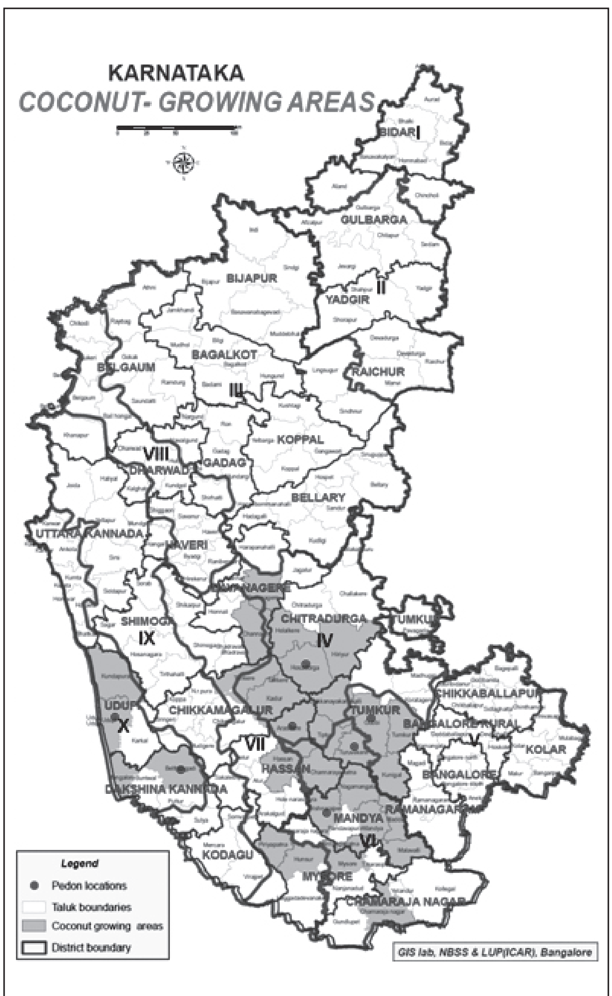

Fig. 1. Traditional coconut growing soils of Karnataka and pedon locations

Material and methods

Major coconut-growing areas in Southern Karnataka were selected based on the variability in agro-climate and the identified locations included Hosadurga (central dry zone), Gubbi and Turuvekere (eastern dry zone), Krishnarajapet (southern dry zone), Arasikere (southern transition zone), Belthangadi and Brahmavara (coastal zone). The locations and site characteristics are given in Table 1. Hosadurga, Gubbi, Turuvekere, Krishnarajapet and Arasikere experience hot moist semi-arid climate recording average annual rainfall of 661 mm, 813 mm, 728 mm, 758 mm and 733 mm and length of dry period 168, 178, 175, 144 and 161 days, respectively. Belthangadi and Brahmavara experience hot humid climate receiving annual average rainfall of 4440 mm and 3842 mm with 112 and 168 days of dry period. Extensive field traversing was done. Based on the variability in site characteristics and productivity of coconut, seven pedons from different agro-climatic zones were studied to assess the land quality at different locations. Soil samples from all the pedons were collected from horizons for the laboratory analysis to understand physical and chemical properties. Morphological properties of the soils were studied following the procedure explained in Soil Survey Manual (Soil Survey Staff, 2014). Particle-size analyses were done by International Pipette method (Sarma *et al*., 1987). The pH was determined in 1:2.5 soil-water suspension and electrical conductivity in its supernatant portion (Jackson, 1973). Cation exchange capacity of the soils was determined by the ammonium acetate leaching method (Sarma *et al.,* 1987). Climatic parameters were arrived at using the data recorded by the Indian Meteorological Department for Karnataka from 1966 to 2002.

Results and Discussion

Morphological characteristics

Relevant soil morphological characteristics and textural properties are furnished in Table 2. Coconut-growing soils were deep to very deep with their depths varying from 107 cm to more than 175 cm. The variation in topography and slope gradient have resulted in the variation in depth (Vinay, 2007). Solum depth reflects the balance between soil formation and soil loss by erosion in any area. Arasikere soil recorded lesser depth (107 cm)

Table 1. Locations and site characteristics

Pedon No./ Name	Latitude (N)	Longitude (E)	Elevation (m)	Rainfall (mm)	Physiography	Slope (%)	Drainage	Erosion	Parent material
P1:Hosadurga (Central dry zone)	13^0 24’23.0"	74^0 46'04.2"	733	661	Nearly level and undulating	1-3	Well drained	Moderate	Alluvium
P2:Gubbi (Eastern dry zone)	13^0 26’14.3"	76^0 51'16.1"	850	813	Gently sloping Sloping upland	1-3	Well drained	Moderate	Granite gneiss
P3: Turuvakere (Eastern dry zone)	13^0 09’39.6"	76^0 34'54.4"	801	728	Undulating	3-5	Well drained	Moderate	Granite gneiss
P4:Krishnarajapet (Southern dry zone)	12^0 47’34.13	76^0 23’24.5"	830	758	Undulating	3-5	Well drained	Moderate	Granite gneiss
P5:Arasikere (Southern transition zone)	13^0 25’59.0"	76^0 08’55.0"	762	733	Undulating	3-5	Well drained	Moderate	Granite gneiss
P6:Belthangadi (Coastal zone- Western Ghats foot hills)	13^0 04’36.9"	75^0 12’53.5"	151	4440	Moderately steep sloping foot hills	15-25	Well drained	Moderate	Laterite/ weathered ferrugi- ous quartzite schist
P7:Brahmavara (Coastal zone- Laterite midlands)	13^0 25’19.3"	74^0 45’33.22"	23	3842	Undulating	5-10	Well drained	Moderate	Laterite/ weathered ferrugin -ous quartzite schist

relatively as the land was not protected well in the past and the top soil was eroded. Among the pedons, the distinctness of soil boundary varied from clear to gradual and topography of smooth to wavy boundary. The argillic-pedoturbation in black soil pedons made it difficult to differentiate horizons in them; however, it was comparatively easier in red soil pedons.

The hue (soil colour) of Munsell colour chart notation ranged mainly in 2.5 YR to 10 YR, value from 3 to 4 and chroma from 3 to 6. Soil colour of pedons other than coastal zone varied from dark brown to dark reddish brown in surface and dark reddish brown to reddish brown in lower horizons. This is attributed to the differential degrees of erosion, lesser content of organic matter and iron oxide (Patil and Dasog, 1999) and intense leaching of bases resulting in sesquioxides at the surface. Soils of Arasikere and Belthangadi were brown (7.5 YR 3/3 M and 7.5 YR 3/4 M, respectively) in their surface due to higher organic matter content and brown to yellowish red in sub-surface due to high weathering conditions along with dominance of limonite offered by heavy rainfall and high temperature. The mineralogical and chemical composition of soil coupled with texture and topographic position result in variations in soil colour (Walia and Rao, 1997).

Table 2. Morphological characteristics of the pedons

Horizons	Depth (cm)	Boun-dary	Colour		Texture	Structure	Consistence			Roots	Pores
			Dry	Moist			Dry	Moist	Wet		
P1: Hosadurga (Central dry zone)											
Ap	0-20	c s	7.5YR 4/4	7.5YR 3/4	scl	1Fsbk	h	fr	ss & sp	c m	m m
Bw1	20-44	c s	7.5YR 3/4	7.5YR 3/3	sc	2Msbk	vh	fr	ms & mp	m c	c f
Bw2	44-65	c s	7.5YR 3/3	7.5YR 3/2	c	2Msbk	vh	fr	ms & mp	c c	c f
Bw3	65-94	c s	7.5YR 4/3	7.5YR 4/2	c	2Msbk	h	fr	ms & mp	f f	c vf
Bw4	94-133	c s	10 YR 5/3	7.5YR 4/2	c	2Msbk	h	fr	ms & mp	f m	c vf
Bw5	133-151	c s	10 YR 5/3	7.5YR 3/3	c	2Msbk	h	fr	ms & mp	f m	c vf
P2. Gubbi (Eastern dry zone)											
Ap	0-14	c s	5YR 4/4	5YR 3/4	scl	1Fgr	sh	fr	ss & sp	f f	m m
Bw1	14-30	c s	5YR 4/3	5YR 3/3	scl	1Fsbk	sh	fr	vs & vp	c c	c m
Bw2	30-48	c s	5YR 4/4	5YR 4/4	sc	1Msbk	sh	fr	vs & vp	c f	c f
Bt1	48-66	c s	5YR 4/4	2.5YR 3/4	gscl	2Msbk	sh	fr	ms & sp	f f	c f
Bt2	66-94	c s	5YR 4/4	2.5YR 2.5/4	gc	2Msbk	sh	fr	vs & mp	f m	c f
BC	94-134	c s	5YR 4/4	7.5YR 3/4	vgc	1Msbk	sh	fr	vs & mp	f f	f f
B/C	134-156	c s	5YR 4/4	7.5YR 4/3	vgsic	1Msbk	sh	fr	vs & mp	f f	f f
P3. Turuvekere (Eastern dry zone)											
Ap	0-13	c s	5YR 4/4	5YR 3/4	c	2F sbk	sh	fr	ms & vp	fvf	cf-vf
Bt1	13-34	c s	2.5 YR 3/4	2.5YR 2.5/4	c	2Msbk	sh	fr	ms & sp	mf-mc	mm
Bt2	34-62	c s	2.5 YR 3/4	2.5YR 3/4	c	2Msbk	sh	fr	ms & sp	mf-mc	mf
Bt	362-90	c s	2.5 YR 3/4	2.5YR 3/6	c	2Msbk	sh	fr	ms & sp	cm	mf
Bt4	90-125	c s	2.5 YR 3/4	2.5 YR 3/4	c	3Msbk	sh	fr	vs & sp	cf-fm	cf

Bt5	125-163	c s	2.5 YR 3/4	2.5 YR 3/4	c	3Msbk	sh	fr	vs & sp	cf-m	cf
Bt6	163-175	c s	2.5 YR 3/4	2.5 YR 3/6	c	3Msbk	sh	fr	vs & sp	fm	cf
P4: Krishnarajapet (Southern dry zone)											
Ap	0-14	cs	7.5YR 3/4	7.5YR 3/4	scl	2F sbk	sh	fr	ss & sp	f m	c f
Bt1	14-29	cs	7.5YR 3/3	7.5YR 3/3	sc	2F sbk	sh	fr	ms & mp	c m	c f
Bt2	29-46	cs	5YR 3/3	5YR 3/3	sc	2M sbk	sh	fr	ms & mp	m m	c f
Bt3	46-68	cs	2.5YR 4/4	2.5YR 3/4	egsc	2M sbk	h	fr	ms & vp	f m	f vf
Bt4	68-90	cw	2.5YR 4/6	2.5YR 3/4	vgsc	m	vh	fr	vs & vp	f m	f vf
Bt5	90-111	cw	2.5YR 4/4	2.5YR 3/4	gsc	1C sbk	vh	fr	vs & mp	f m	f vf
Bt6	111-146	cw	2.5YR 4/6	2.5YR 3/6	vgsc	1C sbk	vh	fr	vs & mp	f m	f vf
Cr	146-156		10YR 8/2	10YR 8/2		m	vh				
P5: Arasikere (Southern transition zone)											
Ap	0-15	cs	7.5YR 3/3	7.5YR 3/3	scl	1F sbk	sh	fr	ms & mp	f f	m m
Bt1	15-45	cs	2.5YR 3/4	2.5YR 3/4	vgsc	1C sbk	h	fr	ms & mp	c m	c m
Bt2	45-73	cs	2.5YR 3/4	2.5YR 4/6	vgsc	1M sbk	h	fr	ms & mp	f f	c f
BC	73-107	cs	2.5YR 3/4	2.5YR 4/4	egsc	1M sbk	h	fr	ms & sp	c m	f f
Cr	107-126					m	h				
P6: Belthangadi (Coastal zone-Western Ghats foot hills)											
Ap	0-19	cs	7.5YR 4/4	7.5YR 3/4	scl	2F sbk	h	fr	ss & sp	f f	c m
AB	19-46	cs	7.5YR 4/3	7.5YR 3/3	scl	2F sbk	h	fr	ss & sp	c m	c f
Bt1	46-74	cs	5YR 4/4	5YR 3/4	sc	2M sbk	sh	fr	ms & sp	f m	c f
Bt2	74-103	cs	5YR 4/4	5YR 3/4	sc	1M sbk	sh	fr	ms & sp	c m	c f
Bt3	103-127	cs	5YR 4/6	5YR 4/3	sc	1M sbk	sh	fr	ms & sp	c f	c f

Bc1	27-151	cs	5YR 4/6	5YR 4/6	gsc	1M sbk	sh	fr	ms & sp	f m	c f
P7: Brahmavara (Coastal zone-Lateritic mounds)											
Ap	0-12	g s	7.5YR 4/4	7.5YR 4/6	gsc	11F sbk	h	fr	ss &sp	f m	c m
Bt1	12-36	c s	2.5YR 4/6	2.5YR 3/6	egscl	1M sbk	h	fr	ms & sp	c f	c m
Bt2	36-55	c s	2.5YR 4/6	2.5YR 3/6	egsc	1M sbk	h	fr	ms & sp	f c	c f
Bt3	55-82	c s	2.5YR 4/6	2.5YR 3/6	egsc	1M sbk	h	fr	ms & sp	f f	c f
Bt4	82-108	c w	2.5YR 4/4	2.5YR 3/6	egsc	1M sbk	h	fr	ms & sp	f f	c f
BC	108-142	c w	5YR 4/6	5YR 4/6	egscl	1C m	h	fr	ss & sp	c m	f f
CB	142-170		5YR 4/6	5YR 4/6	egscl	1C m	h	fr	ss & sp	f f	f f

Soil texture varied from sandy clay loam to clay among the soils. This has resulted from different processes of soil formation, *in situ* weathering and illuviation of clay (Geetha and Naidu, 2013). Surface soil structure varied from weak to moderate fine sub-angular blocky in surface except in Gubbi (P2), where, it was granular. The structure varied from weak to strong, fine to coarse, sub-angular blocky in the sub-surface. Moderate medium sub-angular blocky was the dominant structure. Soil structure was better in coconut growing soils of coastal zone (Belthangadi and Brahmavara) owing to better aggregation due to higher organic carbon and relatively lower bulk density. Consistency of soil varied from slightly hard to hard when dry, friable when moist, slightly sticky and slightly plastic to very sticky and very plastic when wet. The clay content in a soil influences soil consistency (Sarkar *et al*., 2001) and an increase in clay content increases soil consistency.

Physical and chemical characteristics

Physical and chemical characteristics of the pedons are furnished in Table 3. Coconut growing soils of different agro-climatic zones of southern Karnataka recorded a clay content ranging from 17.83 to 60.37 per cent. An increase in clay content with depth could be observed due to the soil development processes. Illuviation of clay towards the lower surface from the surface soil resulted in increased clay content in the sub-surface horizons (Sarkar *et al*., 2002; Srinivasan *et al*., 2013). Illuviation process has also contributed to the depth wise distribution of sand and silt contents. Silt content ranged from 3.12 to 42.39 per cent. The trend of silt distribution with depth was irregular due to the differences in weathering of parent material. Sand content varied from 8.75 to 74.77 per cent and it was more in the surface compared to sub-surface horizons. Other than Hosadurga and Turuvekere soils, all the other soils recorded higher sand content than the silt and clay fractions. This indicated the nature of parent material (Srinivasan *et al*., 2013; Chandra Sekhar *et al*., 2017). Sandy soils possess limitations to coconut production due to poor nutrient retention, water holding capacity and therefore moisture availability to the palm (Arachchi and Somasiri, 1997). These soils have to be properly managed to improve the coconut production.

The bulk density ranged from 1.17 to 1.84 Mg m^{-1} among the coconut growing soils. The bulk density increased with depth in all the pedons. The lower bulk density in the surface horizon could be a result of higher organic carbon content at the surface. Among these, Krishnarajapet (P4) and Gubbi (P2) soils recorded higher surface bulk density due to their coarser texture where clay and silt particles were eroded from the surface layer leaving well drained dense sand particles.

The pH in soil water suspension ranged from 4.99 to 8.89. The soil reaction varied from near neutral to moderately alkaline among the soils due to the accumulation of basic salts from weathered parent material except in Belthangadi (P6) and Brahmavara (P7), where the soils were acidic and non-saline due to the acidic parent material (granite or granite gneiss). Granite gneiss parent materials result in soils that vary from near neutral to slightly acidic in soil reaction (Shivaprasad *et al*., 1998).

Electrical conductivity ranged from 0.01 to 0.22 dS m^{-1}, which indicated non-saline nature of soils. This could also be an indication of low status of cations and anions that are important in coconut nutrition (Nair *et al*., 2018). The organic carbon content ranged from 0.10 to 1.49 per cent. Coastal zone soils- Belthangadi (P6) and Brahmavara (P7) recorded high and moderate organic carbon content in the surface soils, decreasing with increasing depth. Surface soils recorded higher organic carbon content than sub-surface soils due to an increased amount of litter and crop residues at the surface and faster rates of decomposition. Organic carbon content decreased with depth in all the pedons (Avinash, 2017).

Cation exchange capacity of coastal soils was generally low and it varied from 3.86 to 7.85 cmol (p+) kg^{-1} of soil. Low CEC values even with high clay content indicate the dominance of low activity clays particularly; 1:1 type clay minerals. Higher CEC values were observed in surface horizons due to higher organic matter at the surface. In other pedons cation exchange capacity varied both location-wise and depth-wise. It varied from 8.71 to 43.26 cmol (p+) kg^{-1}. Cation exchange capacity increased with profile depth and followed a similar trend to that of clay content in soils of Krishnarajapet (P4) and Hosadurga (P1). CEC/clay ratio varied from 0.10 to 0.86 which indicates nature of clay minerals in different pedons. The soils of southern dry zone, southern transition zone and eastern dry zone pointed to semi active clays, whereas coastal zone soils (P6 and P7) had low activity clays. Central Dry Zone (P1) pointed to super active clays *i.e.* smectitic type. The base saturation ranged from 47.19 to 95.96 per cent. Soils were highly base saturated except coastal soils as indicated by Belthangadi (P6) and Brahmavara (P7). Percolating water takes along with it, bases from the surface to lower horizons resulting in increased base saturation with the depth in pedons 1, 2, 5 and 7.

Soil classification

Based on the internationally accepted system of soil classification, soil taxonomy (USDA), the studied soils were classified which is presented in Table 4.

Central Dry Zone

The soil sampled at Hosadurga representing central dry zone is classified under *Inceptisols*, keyed out to *Vertic Haplustepts*, as they do not possess kandic and petrocalcic horizons, duripan, and having the presence of swell-shrink clays. When the soil moisture control section is dry in some or all parts for more than 90 cumulative days in a year, it represents ustic moisture regime. Ustalf suborder is keyed out due to ustic moisture regime. At the family level the soil texture is fine (>35 % clay) with smectitic mineralogy, super active (CEC to clay ratio > 0.60) and isohyperthermic temperature regime.

Eastern Dry Zone

The soil sampled at Gubbi representing eastern dry zone is classified under *Alfisols* with argillic sub-surface horizon and this is keyed out to *Rhodustalfs* at great group level, as they have colour hue in more than 50 per cent of the area within upper 100 cm or the entire argillic horizon of 2.5YR or redder, and colour values (moist) ⩽ 3 and dry values are not more than 1 unit higher than moist values. At the family level the soil texture is fine-loamy with mixed mineralogy, semi-active at cation exchange activity classes because the ratio of CEC to per cent clay (by weight) was between 0.24 and 0.40 and isohyperthermic temperature regime. The soil sampled at Turuvekere representing eastern dry zone is classified under *Alfisols* with argillic sub-surface horizon and >35 per cent base saturation throughout the depth of argillic horizons. At the family level the soil texture is fine (>35 % clay) with mixed mineralogy, semi-active at cation exchange activity classes because the ratio of CEC to per cent clay (by weight) was between 0.24 and 0.40 and isohyperthermic temperature regime.

Southern Dry Zone

The soil sampled at Krishnarajapet representing Southern dry zone belong to the order *Alfisols* having an argillic horizon with increased clay content with depth and clay accumulation in sub-surface. Ustic moisture regime resulted in Ustalf suborder.

Table 3. Physical and chemical properties

Horizon	Sand	Silt (%)	Clay	BD Mg m^{-3}	pH	EC dS/m	OC (%)	Base saturation	CEC c mol (p+) kg^{-1} soil	CEC / Clay ratio
P 1: Hosadurga (Central dry zone) : Fine, smectitic, super-active, isohyperthermic, *Vertic Haplustepts*										
Ap	51.09	14.26	34.65	1.25	8.17	0.08	0.42	88.55	16.48	0.48
Bw1	44.03	11.28	44.69	1.34	7.75	0.09	0.34	92.79	19.96	0.45
Bw2	37.60	13.13	49.27	1.41	8.02	0.10	0.22	95.88	21.50	0.44
Bw3	34.60	15.24	50.16	1.46	8.87	0.18	0.18	95.96	37.56	0.75
Bw4	39.84	10.08	50.08	1.62	8.89	0.20	0.10	93.55	43.26	0.86
Bw5	37.72	8.99	53.29	1.46	8.82	0.22	0.10	90.46	27.11	0.51
P2. Gubbi (Eastern dry zone) : Fine-loamy, mixed, semi-active, isohyperthermic, *Typic Rhodustalfs*										
Ap	63.32	8.15	28.53	1.46	8.31	0.08	0.76	82.15	10.69	0.37
Bw1	67.54	9.51	22.95	1.70	8.28	0.09	0.42	86.55	12.3	0.54
Bw2	74.77	7.40	17.83	1.84	8.06	0.09	0.40	75.53	9.86	0.55
Bt1	51.73	15.66	32.61	1.79	7.87	0.06	0.26	77.98	8.71	0.27
Bt2	35.64	23.35	41.01	1.84	7.79	0.07	0.24	86.52	11.93	0.29
BC	16.16	38.65	45.19	1.69	7.83	0.08	0.18	89.53	18.02	0.40
B/C	8.75	42.39	48.86	1.67	7.90	0.07	0.16	86.29	18.89	0.39
P3:Turuvekere (Eastern dry zone): Fine, mixed, semi-active, isohyperthermic, *Rhodic Paleustalfs*										
Ap	45.37	5.81	48.82	1.17	8.08	0.12	0.78	93.42	28.86	0.59
Bt1	44.28	5.21	50.51	1.42	7.99	0.08	0.50	86.56	13.99	0.28
Bt2	43.97	5.83	50.20	1.45	7.72	0.10	0.34	87.45	15.18	0.30
Bt3	35.24	9.85	54.91	1.46	7.85	0.12	0.34	86.97	14.70	0.27
Bt4	34.56	8.99	56.45	1.50	7.72	0.11	0.32	88.00	15.79	0.28
Bt5	32.39	7.24	60.37	1.56	7.71	0.12	0.28	88.44	16.34	0.27
Bt6	32.81	7.17	60.02	1.53	7.75	0.10	0.18	88.01	15.73	0.26
P4: Krishnarajapet (Southern dry zone): Clayey-skeletal, mixed, semi-active,isohyperthermic *Rhodic Paleustalfs*										
Ap	59.49	6.81	33.70	1.52	7.59	0.07	0.61	86.74	14.24	0.42
Bt1	57.32	3.12	39.56	1.66	7.26	0.06	0.44	85.96	13.59	0.34
Bt2	53.86	4.33	41.81	1.74	7.51	0.06	0.56	86.71	14.32	0.34
Bt3	49.13	5.23	45.64	1.64	7.76	0.06	0.28	87.53	14.83	0.32
Bt4	47.90	3.17	48.93	1.75	7.70	0.05	0.26	87.48	15.03	0.30
Bt5	46.68	4.15	49.17	1.74	7.87	0.04	0.22	89.18	16.99	0.34
Bt6	49.38	3.76	46.86	ND	7.87	0.04	0.18	89.80	17.39	0.37

P5: Arasikere (Southern transition zone): Clayey-skeletal, mixed, semi-active, isohyperthermic, *Typic Rhodustalfs*										
Ap	55.87	11.24	32.89	1.35	8.39	0.08	0.48	91.79	13.88	0.42
Bt1	47.03	9.85	43.12	1.54	8.27	0.12	0.44	92.40	15.82	0.37
Bt2	45.19	8.53	46.28	1.53	8.49	0.10	0.18	91.63	15.31	0.33
BC	44.60	14.21	41.19	1.74	8.70	0.08	0.14	93.59	13.26	0.32
P6. Belthangadi (Coastal zone-Western Ghats foot hills): Fine, kaolinitic,sub-active, isohyperthermic *Ustic Kandihumults*										
Ap	66.44	4.10	29.46	1.20	5.64	0.03	1.49	24.65	7.85	0.27
AB	58.63	5.77	35.60	1.25	5.71	0.02	1.43	16.46	3.94	0.11
Bt1	54.79	6.98	38.23	1.34	5.68	0.01	1.07	13.71	4.83	0.13
Bt2	50.96	9.87	39.17	1.38	5.39	0.01	0.82	11.57	3.86	0.10
Bt3	49.47	8.33	42.20	1.32	5.56	0.01	0.50	11.24	5.16	0.12
Bt4	52.72	8.16	39.12	1.40	5.56	0.01	0.40	7.91	5.32	0.14
P7. Brahmavara (Coastal zone-Lateritic mounds): Clayey-skeletal, acid, kaolinitic, sub-active, isohyperthermic, *Rhodic Kanhaplustults*										
Ap	56.88	14.23	28.89	1.27	5.52	0.04	1.49	23.73	7.83	0.27
Bt1	51.16	15.63	33.21	1.38	5.25	0.02	0.96	20.35	5.62	0.17
Bt2	51.15	11.87	36.98	1.47	5.17	0.02	0.92	19.52	5.33	0.14
Bt3	53.78	9.95	36.27	1.50	4.99	0.02	0.38	17.25	4.01	0.11
Bt4	53.27	8.77	37.96	1.52	5.07	0.02	0.36	14.84	4.35	0.11
BC	57.46	10.29	32.25	ND	5.13	0.01	0.32	14.10	4.28	0.13
CB	58.62	12.25	29.13	ND	5.09	0.01	0.12	10.86	4.09	0.14

An argillic horizon that has both a clayey or clayey-skeletal particle size class throughout one or more sub-horizons in its upper part and at its upper boundary, a clay increase of either 20 per cent or more within a vertical distance of 7.5 cm or of 15 per cent or more within a vertical distance of 2.5 cm is assigned to great group *Paleustalfs* and the red color (hue 2.5 or redder and value, moist, 3 or less) throughout the solum lead to Rhodic. The presence of > 35 per cent coarse fragments in the subsoil horizons pointed to clayey-skeletal particle size class at the family level with mixed mineralogy, semi active cation exchange activity classes as the ratio of CEC to per cent clay (by weight) was between 0.24 and 0.40 and isohyperthermic temperature regime (characterized by MAT of > 22 °C with MAST and MWST differ by less than 5 °C).

Southern Transition Zone

The soil sampled at Arasikere representing southern transition zone belong to order *Alfisols* indicated by an argillic horizon. Ustic moisture regime lead to Ustalfs sub-order and the hue of 2.5 or redder and moist value of 3 or less and dry value more than 1 unit higher than the moist value throughout the argillic horizon or top 100 cm, if deeper keyed to *Rhodustalfs* at the great group level. The presence of >35 per cent coarse fragments in the subsoil horizons pointed to clayey-skeletal particle size class at the family level with mixed mineralogy, semi active cation exchange activity classes as the ratio of CEC to percent clay (by weight) was between 0.24 and 0.40 and isohyperthermic temperature regime (characterized by MAT of >22 °C with MAST and MWST differ by less than 5 °C).

Table 4. Classification of the soils

Agroclimatic zone	Site	Classification
Central dry zone	Hosadurga	Fine, smectitic, super-active, isohyperthermic, Vertic Haplustepts
Eastern dry zone	Gubbi	Fine-loamy, mixed, semi-active, isohyperthermic, Typic Rhodustalfs
Eastern dry zone	Turuvekere	Fine, mixed, semi-active, isohyperthermic, Rhodic Paleustalfs
Southern dry zone	Krishnarajapet	Clayey-skeletal, mixed, semi-active,isohyperthermic Rhodic Paleustalfs
Southern transition zone	Arasikere	Clayey-skeletal, mixed, semi-active, isohyperthermic,Typic Rhodustalfs
Coastal zone-Western Ghats foot hills	Belthangadi	Fine, kaolinitic,sub-active, isohyperthermic Ustic Kandihumults
Coastal zone-Lateritic mounds	Brahmavara	Clayey-skeletal, acid, kaolinitic, sub-active, isohyperthermic, Rhodic Kanhaplustults

Coastal Zone

The soil sampled at Belthangadi representing coastal zone- Western Ghats foot hills belong to order *Ultisols* having base saturation by sum of cations of less than 35 per cent with ustic moisture regime and argillic sub-surface horizon with no clay decrease with increasing depth of 20 per cent or more and with high organic carbon status of more than 0.90 per cent assigned the soil to great group *Kandihumults*. At the family level the soil texture is fine (>35 % clay) with kaolinitic mineralogy and isohyperthermic temperature regime.

The soil sampled at Brahmavara representing coastal zone-Laterite midland mounds belong to order *Ultisols*. Ustults sub-order is assigned owing to moderate levels of soil organic carbon in the top 50 cm (< 0.9 %) and both showed low CEC clay ratio of <0.16 and low ECEC by clay ratio of < 0.12 and have a kandic horizon and belong to great group *Kanhaplustults*. Sub-group level Brahmavara soils are assigned with Rhodic due to 2.5YR colour with value 3 or less in aroud half of argillic/kandic horizon. These two soils of coastal zone were classified as sub-active clays due to CEC to clay ratio > 0.24.

The study area was classified under hyperthermic as the mean annual soil temperature (MAST) calculated was 27.5 °C (by adding 3.5 °C from the MAAT (24 °C),with the difference between mean winter and summer temperature not more than 6 °C making it belong to isohyperthermic soil temperature regime (Sehgal, 1996).

Conclusion

Coconut growing soils of eastern and southern dry zones (Gubbi, Turuvekere, Krishnarajapet, and Arasikere) in southern Karnataka have an argillic sub-surface horizon without plaggen epipedon and spodic or oxic sub-surface horizons above the argillic horizon. Further, clay illuviation has resulted in the development of argillic and had an increase of 20 per cent clay content and it was also more than one-tenth as thick as the sum of the thickness of all the overlying horizons. The base saturation was more than 35 per cent throughout the depth of the horizon. Hence were classified under *Paleustalfs* and *Rhodustalfs*. Coconut growing soils of coastal zone (Belthangadi and Brahmavara) were very deep, acidic, yellowish red to dark red, low in CEC and base saturation and were classified under *Kandihumults* and *Kanhaplustults* respectively. Central dry zone soils (Hosadurga) were classified into *Haplustepts* as there was no other diagnostic horizon than cambic horizon and absence of duripan, kandic and petrocalcic horizons. The soils had swell- shrink clays and hence placed under vertic sub-group.

The USDA soil taxonomy and the family level classification followed in this study has helped in reflecting the soil properties and their variability among the different agro-climatic zones of southern Karnataka.

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