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Evaluation of Soil Properties in Major Paddy Growing Soils of Thamirabarani Command Area, Tamil Nadu

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Five major soils of Thamirabarani Command Area of Tamil Nadu having granite gneiss and alluvium parent material under paddy and banana land use were studied for their morphological characteristics, physical and chemical properties. The soils were neutral (6.6-7.3) to very strongly alkaline (>9), deep (100-150 cm) to very deep (>150cm) in depth with iso-hyperthermic and ustic soil moisture regimes. Texture, organic carbon, CEC of the soils ranged from sandy loam to clay, 0.15 to 0.80 per cent and 16 to 53 cmol (p+) kg^{-1}, respectively. Soils were low to high in available nitrogen and phosphorus and medium to high in available potassium. Soils were classified as Vertic Haplustepts, Fluventic Haplustepts, Aquic Haplustalfs, Typic Haplustalfs and Vertic Haplustalfs.

Key words: Soil survey, Thamirabarani Command Area, Soil properties and classification

Soil is the most vulnerable and also the most resistant natural resource, which is known in terms of buffering mechanism. The pressure on land to meet out the growing demand for food, fuel and fiber has been increasing with the ever increasing population in the country. To produce more food, the land has been exploited beyond its capability. This has resulted into land degradation and environmental hazards. These factors demand our focused attention to make the best use of land sustainably for meeting the demands of burgeoning population. Since land is a finite natural resource, there is no scope to increase the area under cultivation. To increase the food production there is only one way left that is, to increase the yield of food grains per unit area.

For this purpose it is required to have thorough knowledge of soils in respect of its characteristics, extent, spatial distribution, physical and chemical properties, limitations and its potentials for various land uses attain much importance for their optimal utilization. Having this in mind, the present investigation was undertaken in major paddy growing soils of Thamirabarani Command Area to evaluate the soil properties for sustainable crop production.

Materials and Methods

The Thamirabarani Command area lies between 8^0 04' to 8^0 17' N Latitude and 77^0 32' to 77^0 54' E Longitude. It encompasses the districts of Kanyakumari and Tirunelveli. This area has a typical monsoonic climate. Mean annual temperature is 33.5^{0}C and it is lowest in the month of December (29.9^{0}C) and highest in May (37.1^{0}C). The mean soil temperature is about 22^{0}C. The mean annual precipitation is 75.9 cm and the peak rainfall period is from October to December months. Physio-graphically this area is broadly classified as inland plains, reverain and marine land form occupied by the tertiary deposits, subjected to degradational or aggradational processes. The total ayacut area of the river basin is about 66,000 hectares in which about five soil series occupied about 90 percent (58,239 ha) of the total ayacut area. They are Ambasamudram, Pettai, Padugai, Manakkarai and Nallur soil series. Of these, the Ambasamudram soil series covers a maximum area of 16,150 ha (Table. 1). Rice is the major land use and occupies about 90% of the total area in the command area and to a lesser extent banana. The detailed morphological descriptions of these five soils were studied in the field as per the procedure outlined in soil survey manual (Soil Survey Staff, 2006). Horizon-wise soil samples were collected and characterized for important physical and physico-chemical properties. Apart from that, surface samples were also collected for the analysis of fertility parameters. The natural vegetation of the area was neem and grasses like *Cyperus spp* and *Cynodan* spp *etc*. The topography of the area is very gently sloping to nearly level plains. The parent materials are granite gneiss derived alluvium material and alluvium of laterite origin.

The analysis of physical, chemical and fertility characteristics of soils was carried out following standard analytical procedures (Black 1965; Jackson 1973). Particle size analysis was carried out by International Pipette Method (Piper 1966). The soil reaction *viz.*, pH and electrical conductivity (EC) (1:2.5 soil water suspension) was determined

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following the procedure given by Jackson, 1973. Organic carbon estimation was carried out by chromic acid wet digestion method (Walkley and Black, 1934) and calcium carbonate content in soils was estimated following methods given by Piper (1966). The CEC was determined by saturation of soils with neutral normal NH_4OAC method (Chapman, 1965). The soils were classified using USDA system of soil classification (Soil Survey Staff, 2006).

Results and Discussion

Morphological characteristics

The soils showed wide variation in their morphological characteristics. The soils were deep (100-150 cm) to very deep (>150 cm), texture varied from sandy loam to clayey with moderate to poor permeability. Among the five pedons studied, pedons 1, 2 and 3 were sandy clay loam textured whereas pedon 4 was clay soil and pedon 5 was fine textured sandy clay soil. The variation in the depth and texture of soil profiles may be attributable to the differential degree of deposition of alluvium as well as pedogenic processes. The colour of the soils varied from brown, grayish brown to black. The soil colour appears to be the function of chemical and mineralogical composition as well as textural make up of soils and conditioned by topographic position and moisture regime (Walia *et al*., 1997). All the soils were found to have 10YR with value ranged from 2 to 7 and chroma from 1 to 6 (Table 3). The structure of the soils were angular blocky and sub angular blocky. The consistency of the soils was hard to very hard (dry), firm and friable (moist), sticky and plastic during moist. It was attributed to the presence of higher quantities of clay fraction (Sharma *et al.* 2004; Sarkar *et al.*2001). Pedons 2, 3 and 4 were showed thin or thick patchy cutans at the subsurface horizon. The progressive increase of clay cutans down the solum indicates the clay illuviation and the formation of argillic sub surface horizon (Shalima Devi and Anil Kumar, 2010). Strong to violent effervescence with dilute HCl was observed in all the pedons except pedon 5. It may be due their relatively poor drainage and high water table conditions associated with the high evaporative demands from the soil led to deposition of calcium carbonate. The horizon boundaries were clear to diffuse in distinctness and smooth to wavy in

Table 1. Major soils of Thamirabarani Command Area and its location and extend

Name of the soil series	Extend of area (ha)	Location
Nallur	20,496	Ranimaharajapuram
Ambasamudram	16,150	Terkukadayam
Padugai	9,797	Aarumugamangalam
Pettai	7,886	Sivaramamangalam
Manakkarai	3,910	Kuliyankaraisal

Table 2. Physical properties of major soils of Thamirabarani Command Area

Ped. No & horizon	Depth (cm)	Clay %	Silt	Sand	Bulk density	Particle density (mg m^{-3})
Pedon 1. VerticHaplustepts						
Ap	0-22	32.5	12.5	53.75	1.31	2.57
B w	22-56	31.5	24	44.5	1.29	2.58
C	56-95	8.5	12	78.75	1.55	2.54
Pedon 2. Fine, AquicHaplustalfs						
Ap	0-27	38.1	11.38	50.47	1.27	2.54
A1	27-65	42.64	14.6	41.15	1.22	2.49
Bt1	65-105	32.62	9.85	57.52	1.32	2.59
Bt2	105-140	46.75	11.35	41.34	1.25	2.60
Pedon 3. TypicHaplustalfs						
Ap	0-25	24.15	14.54	60.94	1.4	2.59
Bt1	25-46	47.3	15.32	36.52	1.22	2.54
Bt2	46-74	37.95	29.5	31.66	1.3	2.65
Bt3	74-110	58.56	6.55	34.21	1.2	2.55
Pedon 4. Fine, VerticHaplustalfs						
Ap	0-15	36.2	6.25	55.25	1.35	2.65
Bt1	15-43	40.25	8.94	50.5	1.32	2.64
Bt2	43-75	37.85	11.35	50.1	1.35	2.70
Bt3	75-110+	46.65	15.15	37.9	1.22	2.54
Pedon 5. FluventicHaplustepts						
Ap	0-32	48.75	9.58	38.9	1.27	2.65
B w	32-67	25.5	15.45	58.5	1.39	2.62
C	67-110	42.25	25.85	31.5	1.22	2.49

Table 3. Morphological properties of major soils of Thamirabarani Command Area

Pedn no & hzn.	Depth (cm)	Colour	Texture	Structure			Consistence			Efferve-scence	Boundary		Cutans			Pores		Roots	
				S	G	T	Dry	Moist	Wet		D	T	TY	TH	Q	S	Q	S	Q
Pedon 1. Vertic Haplustepts																			
Ap	0-22	10YR5/3	scl	m	2	sbk	h	fi	s,p	ev	c	s	-	-	-	f	c	f	c
Bw1	22-56	10YR3/4	cl	m	1	abk	h	fi	ss,sp	ev	c	s	-	-	-	f	c	m	f
C	56-95+	10YR3/2	ls	M	1	sbk	fr	fr	s0,p0	es	-	-	-	-	-	f	f	-	-
Pedon 2. Fine, Aquic Haplustalfs																			
Ap	0-27	10YR4/2	scl	m	2	sbk	vh	vfi	s,p	em	c	s	-	-	-	f	m	f	m
Bt1	27-65	10YR3/1	cl	m	3	abk	vh	vfi	s,p	es	c	s	-	-	-	f	m	f	f
Bt2	65-105	10YR4/2	scl	m	2	sbk	h	fr	s,p	es	c	s	t	th	c	m	f	f	f
Bt3	105-140+	10YR4/3	cl	m	2	sbk	h	fr	s,p	es	-	-	t	th	c	f	f	-	-
Pedon 3. Typic Haplustalfs																			
Ap	0-25	10YR3/1	scl	m	2	sbk	vh	vfi	ss,sp	es	c	s	-	-	-	m	m	m	m
A1	25-46	10YR4/3	c	m	2	sbk	h	fr	s,p	es	c	s	-	-	-	m	f	m	c
Bt1	46-74	10YR4/3	cl	m	1	sbk	h	fr	s,p	es	c	s	t	tn	p	f	m	f	f
Bt2	74-110+	10YR4/3	c	m	1	sbk	h	fr	vs,vp	es	-	-	t	th	p	-	-	-	-
Pedon 4. Fine, Vertic Haplustalfs																			
Ap	0-15	10YR4/2	sc	m	2	sbk	h	fi	s,p	em	c	s	-	-	-	m	c	f	m
Bt1	15-43	10YR3/2	sc	m	2	sbk	h	fr	s,p	es	c	s	-	-	-	f	c	f	c
Bt2	43-75	10YR2/1	sc	c	3	sbk	vh	vfi	s,p	es	g	s	t	tn	p	f	c	f	f
Bt3	75-110+	10YR2/1	c	c	3	abk	vh	vfi	s,p	es	-	-	t	th	p	f	c	f	f
Pedon 5. Fluventic Haplustepts																			
Ap	0-32	10YR3/2	c	m	2	sbk	h	fi	s,p	-	c	s	-	-	-	f	m	f	c
Bw	32-67	10YR7/6	scl	m	1	abk	h	fr	s0,p0	-	c	s	-	-	-	m	m	f	f
C	67-110	10YR5/2	cl	m	1	sbk	h	fr	s,p	-	-	-	-	-	-	f	m	-	-

Texture:	c - clay, cl- clay loam, l-loam, s - sand, sl- sandy loam, scl - sandy clay loam, sc - sandy clay, ls -loamy sand	
Structure:	Size	vf - very fine, f - fine, m - medium, c - coarse
	Grade	0 - structureless, 1- weak, 2 - moderate, 3 - strong
	Type	cr - crumb, sg - single grain, abk - angular blocky, sbk - sub-angular blocky
Consistence	Dry	s - soft, 1- loose, sh - slightly hard, h - hard, vh - very hard
	Moist	1- loose, fr - friable, fi - firm, vfi - very firm
	Wet	so - non-sticky, ss - slightly sticky, s - sticky, vs - very sticky
		po - non-plastic, ps - slightly plastic, p - plastic, vp - very plastic
Cutans	Type	t - argillan,
	Thickness	tn - thin, th - thick
	Quantity	p - patchy, c - continuous
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
Boundary	Distinctness	c - clear, g - gradual, d – diffuse
	Topography	s – smooth, w – wavy
Effervescence	em- mild effervescence es - strong effervescence, ev - violent effervescence	

topography. The roots in different horizons of the pedons were fine to medium in size and few to common in quantity. Further, roots were abundant in surface layer and decreased with depth because the soils were cultivated mostly by field crops.

Physical characteristics

The clay, silt and sand contents in cultivated soils varied from 8.5 to 58.56, 6.25 to 29.5 and 31.5 to 78.75 per cent, respectively. High clay content in surface compared to subsurface soil in pedon 1 and pedon 5 might be because of low lying topographic position which favored the accumulation of fine textured clay particles (Table 2). In general, sub soils of all pedons except pedon 1 and pedon 5 showed higher clay content as compared to surface horizons due to the clay illuviation (vertical migration or translocation). Silt and sand content of all pedons exhibited irregular pattern with depth because of continuous alluvial deposits one above another and also lithological discontinuities in the profiles (Bhaskar *et al.* 2004). The bulk density of different pedons varied from 1.2 to 1.55 Mg m^{-3} and it is influenced by the texture and organic carbon content of the soil. Pedon 2 and pedon 5 showed an increasing trend of bulk density with depth, which, might be due to high sand content, low organic matter, more compaction and less aggregation.

Physico-chemical characteristics

The soil reaction was neutral (6.6-7.3) to very strongly alkaline (> 9.0) in reaction with pH ranging from 7.0 to 9.2. The wide variation of pH might be ascribed due to leaching, presence of calcium carbonate and exchangeable sodium. The pH, by and large, was found to be low in the surface and increasing with depth because of biochemical weathering and leaching of exchangeable bases particularly Na^+ down the profile under high rainfall condition and the impeded drainage in low lying areas. All the pedons showed low to medium electrical conductivity with values ranging from 0.4 to 1.75 dS m^{-1} thereby, indicating non saline nature of the soil. The organic carbon status was found to be low to medium status (0.12 to 0.80 per cent) and the amount was higher in the surface horizon compared to subsurface horizons (Table 4). Generally the organic carbon per cent was decreased with depth might be due to the crop residue addition to the surface soil and its fast mineralization. Regarding CEC, it varied from 15.96 to 52.82 cmol (p^+) kg^{-1}, which depends on the type of clay and organic matter content. In pedon 3 the CEC increased with depth, which might be, due to clay

Table 4. Chemical properties of major soils of Thamirabarani Command Area

Ped. No & horizon	Depth (cm)	pH(1:2.5)	EC (dS m^{-1})	OC %	% Free $CaCO_3$	CEC	Exchangeable cations				Base sat (%)
							Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	
							($cmol(p^{+})kg^{-1}$)				
Pedon 1. VerticHaplustepts											
Ap	0-22	7.7	1.2	0.80	0.78	38.45	25.01	8.56	2.32	2.89	95.66
Bw	22-56	7.5	0.5	0.50	0.65	31.25	14.32	8.52	2.29	2.98	83.55
C	56-95	8.0	0.4	0.22	1.27	15.96	10.05	2.01	2.12	0.74	80.95
Pedon 2. Fine, Aquic Haplustalfs											
Ap	0-27	7.0	0.92	0.65	3.65	45.98	20.85	11.78	2.12	1.83	75.21
Bt1	27-65	7.5	0.55	0.25	3.91	35.82	18.22	10.12	2.19	1.27	83.19
Bt2	65-105	7.5	0.40	0.21	1.46	30.78	10.61	15.58	2.11	1.42	90.06
Bt3	105-140	7.7	0.42	0.19	1.69	32.53	12.95	8.25	2.31	1.58	70.98
Pedon 3. TypicHaplustalfs											
Ap	0-25	8.1	0.96	0.65	5.21	28.85	13.68	6.12	2.47	1.76	89.72
A1	25-46	9.0	1.48	0.34	4.92	31.43	14.77	5.96	2.79	3.83	90.91
Bt2	46-74	9.2	1.21	0.15	5.91	52.19	26.23	12.27	2.94	4.21	92.77
Bt2	74-110+	9.1	1.65	0.22	3.52	31.89	15.45	8.94	2.89	5.08	89.05
Pedon 4. Fine, Vertic Haplustalfs											
Ap	0-15	7.5	1.75	0.78	2.62	35.85	24.39	7.36	2.31	3.01	92.66
Bt1	15-43	8.0	1.22	0.46	4.28	48.41	25.98	17.39	2.48	2.48	95.70
Bt2	43-75	8.4	0.89	0.28	3.64	37.49	19.72	10.94	2.34	1.74	87.33
Bt3	75-113	8.6	1.26	0.21	4.19	52.82	30.94	13.58	2.41	3.81	92.28
Pedon 5. FluventicHaplustepts											
Ap	0-32	8.2	1.45	0.8	0.65	38.65	13.87	6.56	2.65	4.95	87.94
Bw	132-67	9.2	0.56	0.15	0.56	29.74	6.21	3.05	2.35	1.98	80.49
C	67-110+	8.2	1.21	0.12	0.23	34.56	9.46	8.49	2.78	4.25	78.40

illuviation. All the other pedons (1, 2, 4 and 5) showed irregular distribution because of alluvial deposition and its subsequent pedogenic processes in the respective horizons. The base saturation found to be varied from 75.21 to 95.70 per cent. The exchangeable cations viz Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}

Table 5. Soil fertility properties of major soils of Thamirabarani Command Area

Soil Series	Site No.	pH	EC (dS m^{-1})	OC (%)	OM (%)	Available nutrients (kg ha^{-1})			% Free $CaCO_3$
						N	P	K	
S_1 - Nallur soils									
	1	8.15	0.1	0.45	0.78	232	11	185	1.95
	2	7.83	0.05	0.37	0.64	145	16	198	1.72
	3	7.55	0.09	0.67	1.16	241	19	210	1.43
	4	7.76	0.11	0.86	1.48	275	23	199	1.62
	5	6.83	0.07	1.06	1.83	366	30	207	0.99
S_2 - Ambasamudram soils									
	1	8.09	0.12	0.19	0.33	210	14	161	1.91
	2	8.26	0.1	0.13	0.22	243	11	226	1.89
	3	7.36	0.19	0.92	1.59	347	20	198	1.4
	4	8.82	0.47	0.40	0.69	238	12	243	2.89
	5	8.67	0.42	0.51	0.88	187	9	215	2.48
S_3 - Padugai soils									
	1	8.33	0.15	0.22	0.38	299	12	226	2.24
	2	9.07	0.17	0.11	0.19	287	18	239	3.07
	3	8.23	0.58	0.34	0.59	307	13	271	2.45
	4	8.54	0.14	0.45	0.78	257	16	248	2.3
	5	7.82	0.21	0.19	0.33	302	12	322	1.02
S_4 -Pettai soils									
	1	8.55	0.09	0.49	0.84	145	14	245	2.34
	2	7.91	0.11	0.65	1.12	238	13	271	1.77
	3	8.26	0.27	0.53	0.91	209	19	168	2.37
	4	9.11	0.48	0.21	0.36	95	15	216	0.75
	5	7.83	0.05	0.37	0.64	145	16	234	1.72
S_5 -Manakkarai soils									
	1	8.82	0.15	0.43	0.74	364	25	145	1.05
	2	9.03	0.82	0.25	0.43	210	16	168	1.55
	3	8.88	0.69	0.27	0.47	154	8	156	2.84
	4	8.36	1.34	0.33	0.57	179	12	137	2.17
	5	9.12	0.28	0.28	0.36	207	16	129	3.19

varied from 6.21 to 25.98, 3.05 to 17.39, 2.11 to 2.94 and 1.27 to 5.08 cmol (p^+) kg^{-1}, respectively and it follows the order of Ca^{2+}>Mg^{2+}> Na^+> K^+ (Table 4).

Soil classification

Based on soil morphological characteristics and properties, the soils were classified as per keys to soil taxonomy (Soil Survey Staff, 2006). The soil temperature class is iso hyperthermic as they have a difference of less than 5°C between mean summer temperature and mean winter temperatures and a mean annual soil temperature of 22°C or higher. Pedons 2, 3 and 4 had showed the occurrence of argillic subsurface diagnostic horizon which is evidenced by the presence of thin and thick patchy cutans in the layers. In addition, they had base saturation of more than 35 per cent throughout the profile and ustic soil moisture regime has qualified all the three profiles for Alfisol order, Ustalf at suborder and Haplustalfs at great group level soil classification. However, pedon 2 had Haplustalfs that have one or more horizons within 75 cm of the mineral soil surface, redox depletions with chroma of 2 or less, aquic conditions and less than 35 percent gravel in the family control section, this pedon is grouped under fine particle size classes and classified as Fine Aquic Haplustalfs at sub group level.

The pedon 3 had high clay content, which exhibited cracks of 5 mm or wider through a thickness of 30 cm within 125 cm of the mineral soil and slickensides in its upper boundary, it was classified as Vertic Haplustalfs. The pedon 4 was classified under Typic Haplustalfs. The pedon 1 and 5 were classified under Inceptisol order and Haplustepts great group due to the presence of cambic horizon and Ustepts sub order owing to the presence of ustic soil moisture regime. The pedon 1 was grouped under Vertic sub group owing to the presence of cracks within the soil surface that are 5 mm or more wide through a thickness of 30 cm or more for some time in normal years. The pedon 5 was grouped under Fluventic subgroup due to the irregular decrease in organic carbon content.

Soil nutrient status

The soil nutrient status is known to exhibit the amount and availability of different plant nutrients required for plant growth. The available nitrogen content varied from 94 to 366 kg ha^{-1} in the surface samples. Regarding the phosphorus availability, it was found to be varied from 8 to 25 kg ha^{-1}. Available potassium content of soils varied from 129 to 322 kg ha^{-1}. These variations of nutrients in surface soils might be due to continuous monocropping system (rice, banana), rate of fertilizer application and crop management practices. Organic carbon content was observed 0.11 to 1.06 per cent in surface soil samples (Table 5). It depends on the amount of plant residues and organic manure added to the soil coupled with decomposition rate.

Conclusion

The study of morphological, physical and chemical properties of major soils of Thamirabarani Command Area of Tamil Nadu under paddy and banana land use revealed that soils were neutral (6.6-7.3) to very strongly alkaline (>9) reaction, deep (100-150 cm) to very deep (>150cm) in depth and have iso-hyperthermic and ustic soil moisture regimes. Texture, organic carbon, CEC of the soils ranged from sandy loam to clay, 0.15 to 0.80 per cent and 16-53 cmol (p+) kg^{-1}, respectively. Soils were low to high in available nitrogen and phosphorus and medium to high in available potassium. Soils could be classified as Vertic Haplustepts, Fluventic Haplustepts, Aquic Haplustalfs, Typic Haplustalfs and Vertic Haplustalfs under two orders of Alfisol and Inceptisol. Based on soil properties suitable crop management practices may be taken up for achieving sustainable production to maintain the soil health.

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