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Characterization, Classification and Crop Suitability of Black Cotton Soils of Southern Tamil Nadu

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ABSTRACT

The study area is located at 9^0 16' of North latitude and 77^0 92' of East longitude with an altitude of 90 m above mean sea level (MSL) in Tuticorin district of Tamil Nadu. The surface soil colour ranged from very dark grayish brown (10 YR 3/2) to very dark gray (10 YR 3/1). The soil reaction ranged from moderately alkaline to very strongly alkaline in surface and sub surface soils. Organic carbon content of the surface soils was low, ranging from 0.31 to 0.37 $g\ kg^{-1}$. Cation exchange capacity (CEC) of the surface soils was high, ranging from 47.7 to 51.5 $cmol(p^+)kg^{-1}$. These soils were low in available nitrogen and phosphorus and high in available potassium. The DTPA–Cu, Fe and Mn were generally well above the critical limits whereas, DTPA-Zn was deficient in all soils. The soil were classified as Typic Haplusterts. As per land capability classifications, these soils were classified as IIIs and IIIes and require soil conservation measures for suitable crop cultivation. The soils were moderately suitable (S2) for sorghum, cotton, sunflower and coriander. Some soils were marginally suitable for groundnut, coconut, ber and citrus.

Key words : Black cotton soil, Classification, Morphology, Physical and chemical properties.

Black cotton soils occupy an area of 4,98,000 ha in Ramanathapuram, Tuticorin, Tirunelveli and Virudhunagar districts of Tamil Nadu. The basaltic parent materials has influenced the black soil formation (Soil Survey Staff 2003). Black cotton soils and associated black soils constitute a major soil group in India with the extend of 73.2 Mha (Vertisols) mainly under rainfed agro eco-system (Zade Swati, 2010). Despite high potentials of these soils pose the problem of poor internal drainage, which cause high clay content, ESP, EMP and pedogenic carbonate (Bhattacharyya *et al.* 2005). These soils are often difficult to cultivate, particularly for small farmers using handheld or animal drawn implements. Sub soil porosity and aeration are generally poor and roots of annual crops do not penetrate deeply. Farmers faced with these difficulties allow these soils to lie fallow for one or more rainy seasons (Pal *et al.* 2009). Scientific knowledge of soils, characterization and classification of these soils are essential for developing optimum land use plan for maximizing agricultural production. These soils differ greatly in their, morphological, physical, chemical and biological characteristics. Since these characters control the productivity of crops, it is essential to have information about these characters of each soil. In the arid climatic environments the weathering of primary minerals contributes very little towards the formation of pedogenic carbonates (PC) is the prime chemical reaction that triggers the increase in pH, exchangeable magnesium and sodium on the exchangeable complex (Srivastava *et al.* 2002).

Evaluation of crop suitability is a method of assessing the potential of soil for sustainable agriculture. Many international methods are in vogue such as land capability index, Storie index (Storie, 1933), Riequier's index (Riequier *et al.* 1970) and Sys index (Sys *et al.* 1991). These methods have been applied for Indian conditions for different crops (Naidu and Hunsigi 2001; Tamgadge *et al.* 2002; Kadu *et al.* 2003). But the applicability of these methods under varying rainfall regimes needs investigation. Keeping in view, an attempt has been made to characterize, classify and evaluate the crop suitability for some black soils of southern Tamil Nadu.

MATERIAL AND METHODS

Site description

The study area lies between the latitude 9^0 16' North and longitude 77^0 92' East with an altitude of 90 m MSL falling in Ettayapuram taluk

Table 1. Physical and chemical properties of soils of the study area.

Depth (cm)	Colour	Clay (%)	Silt (%)	Coarse sand (%)	Fine sand (%)	Tex-ture	pH	EC (dSm^{-1})	OC (%)	Free $CaCO_3$ (%)	CEC (c mol $^{(+)}$ kg^{-1})	Exch. cations (c mol $^{(+)}$ kg^{-1}) Ca^{2+}	Mg^{2+}	Na^+	K^+	ESP (%)	BSP (%)
P1 Kumarapuram Series (Kp); Fine, smectitic, calcareous, deep, isohyperthermic Typic Haplusterts.																	
0-23	10YR 3/2	51.2	6.9	29.2	12.7	c	7.9	0.13	0.33	3.20	51.5	39.3	8.5	2.3	0.4	4.4	97.9
23-52	10YR 3/1	52.2	7.2	28.0	12.6	c	8.4	0.12	0.31	3.25	52.8	41.0	8.0	2.5	0.2	4.7	97.9
52-89	10YR 3/1	53.7	7.5	27.7	11.1	c	8.5	0.15	0.27	3.30	53.7	40.5	8.0	4.5	0.1	8.4	98.9
89-115	10YR 3/1	55.2	7.7	26.2	10.9	c	8.6	0.20	0.25	4.00	54.5	41.5	7.8	4.8	0.2	8.7	99.4
P2 Kalugachalapuram Series (Kl); Fine, smectitic, calcareous, deep, isohyperthermic Typic Haplusterts.																	
0-19	10YR 3/2	51.7	7.2	28.9	12.2	c	8.4	0.10	0.37	3.25	50.2	36.5	7.5	4.5	0.6	9.0	97.8
19-36	10YR 3/2	53.2	7.5	27.5	11.8	c	8.5	0.15	0.35	3.45	51.1	37.0	7.5	5.5	0.3	10.8	98.4
36-72	10YR 3/1	54.2	8.0	26.6	11.2	c	8.7	0.27	0.33	3.40	52.4	37.0	6.8	8.0	0.3	15.3	99.3
72-87	10YR 3/1	55.2	7.9	25.5	11.4	c	8.9	0.44	0.33	4.05	53.7	37.8	6.8	8.5	0.3	15.8	99.2
87-101	10YR 3/2	56.2	7.2	26.2	10.4	c	8.7	0.99	0.31	4.75	54.1	38.0	7.0	8.5	0.3	15.7	99.4
101-124	10YR 4/2	52.7	7.6	27.7	12.0	c	8.0	3.90	0.27	5.55	50.5	36.3	8.8	4.5	0.3	8.9	98.5
P2 Kalugachalapuram Series (Kl); Fine, smectitic, calcareous, deep, isohyperthermic Typic Haplusterts.																	
0-20	10YR 3/2	52.2	6.6	27.4	13.8	c	8.3	0.17	0.31	3.3	51.4	38.5	8.5	2.3	0.6	4.4	97.0
20-45	10YR 3/2	53.7	6.7	26.6	13.0	c	8.5	0.19	0.27	3.3	52.1	38.0	8.5	4.3	0.3	8.2	98.0
45-70	10YR 3/1	54.2	7.2	24.4	14.2	c	8.6	0.25	0.25	3.4	53.3	38.5	7.8	6.3	0.3	11.7	99.1
70-107	10YR 4/2	55.2	7.4	24.0	13.4	c	8.6	0.40	0.23	4.0	54.2	39.3	7.8	6.5	0.4	12.0	99.3
107-155+	10YR 4/2	51.7	6.9	27.3	14.2	c	8.2	2.90	0.21	6.1	51.8	40.0	9.0	0.5	0.3	1.0	96.1
P4 Chidambarapuram Series (Cp); Fine, smectitic, calcareous, very deep, isolyperthemic Typic Haplusterts.																	
0-19	10YR 3/2	49.5	7.5	29.1	13.9	c	8.7	0.15	0.35	3.10	47.7	33.0	6.3	7.5	0.5	15.7	99.0
19-40	10YR 3/2	50.7	7.8	28.5	13.0	c	9.0	0.23	0.33	3.40	48.1	33.8	5.8	8.0	0.3	16.6	99.3
40-57	10YR 3/2	51.7	8.1	27.7	12.5	C	9.1	0.45	0.31	3.20	49.5	34.3	6.0	8.5	0.3	17.2	99.0
57-91	10YR 3/1	52.7	7.9	27.2	12.2	c	8.7	1.10	0.29	3.75	49.9	35.3	6.5	7.5	0.3	15.0	99.2
91-110	10YR 3/1	45.7	6.2	32.9	15.2	sc	8.5	2.40	0.29	4.80	35.5	26.0	5.0	4.0	0.1	11.3	99.0
110-128	10YR 3/1	46.7	5.9	32.5	14.9	sc	8.2	4.20	0.29	4.50	32.8	23.5	5.0	3.5	0.2	10.7	98.2
128-150+	10YR 3/1	47.2	6.0	33.1	13.7	sc	8.1	4.20	0.27	4.75	30.6	22.3	4.8	2.9	0.2	9.4	98.3

Table 2. Fertility status of soils.

Pedon No.	Depth (cm)	Available macro nutrients (kg ha^{-1})			DTPA – extractable micronutrients (mg kg^{-1})			
		N	P	K	Zn	Cu	Fe	Mn
P1	0-23	249	12.5	416	0.58	1.58	13.85	8.33
	23-52	215	10.2	387	0.44	1.28	10.58	6.88
P2	0-19	218	10.6	408	0.55	1.32	15.66	12.34
	19-36	197	8.6	394	0.35	1.08	12.43	10.62
P3	0-20	198	11.4	432	0.53	1.12	11.82	9.65
	20-45	181	9.8	414	0.47	0.82	9.55	7.23
P4	0-19	258	9.7	403	0.45	1.34	8.85	10.52
	19-40	222	9.5	388	0.28	1.04	5.42	8.89

of Tuticorin district of Tamil Nadu (Fig. 1). The total study area was 250 ha. Vast stretch of piedmont plain with a slope gradient of less than 1.0 per cent is the most dominant physiography in the study area. The region belongs to semi arid climate. The soil temperature and soil moisture regime are 'Isohyperthermic' and 'Ustic' respectively. The major rainy season is north - east monsoon (55 %) followed by summer monsoon (21 per cent) and south west monsoon (24 %) rainfall. The mean annual maximum temperature is 35.0^0 C and mean annual minimum temperature is 22.5^0 C with mean annual temperature of 31.0^0 C. The mean annual rainfall is 713 mm.

Soil sample collection and methods of analysis

The detailed soil survey was carried out using cadastral map in the scale of 1:10,000. Profiles were opened at random locations upto 200 cm or rock or hard indurated substratum and studied in detail for all their morphological and physical characteristics. Four representative pedons were studied from different places for their morphological properties as per soil survey manual (IARI 1970) and field manual (Sehgal *et al.* 1987). Horizon-wise soil samples were analysed for various physical and chemical properties (Piper 1966); Jackson 1973). Available N, P, K and DTPA extractable Fe, Mn, Zn and Cu were estimated for surface and sub surface soils (Lindsay and Norvell 1978).

Crop suitability assessment

The observations on the required parameters recorded from the profile studies were used to arrive land capability class and land suitability class. Soils were classified according to Soil Taxonomy (Soil Survey Staff 2003) and were evaluated for land capability using criteria laid by Requier *et. al.* (1970). Considering the potentials and limitations of the land and soils, a rational land use plan was also suggested. Soil suitability evaluation was carried out following FAO frame work (FAO 1976) and as per guide lines described by Sys *et al.* (1991).

RESULTS AND DISCUSSION

Soil morphological properties

Based on the profile study, four soil series *viz.,*Kumarapuram Series (Kp), Kalugachalapuram Series (Kl), Chandragiri Series (Cg) and Chidambarapuram Series (Cp) were identified and classified in the study area. The morphological characteristics were presented in Table 1 the soils of these region were clayey, the maximum depth of the soil ranged from 115 to 150 cm. The colour of the soils were in hue 10 YR, with value varied from 3 - 4 and chroma 1-2 due to the presence of free cations (SS & LUO Staff, 2003). The structure of the soils was mainly sub angular blocky. The sub surface horizons with well developed slikensides in this soil had angular blocky structure. This may be due to swell – shrink phenomenon of smectitic clay dominantly present in these soils resulting in the development of slikensides (Kharche and Pharande, 2010). This soils had high stickiness and plasticity and showed slight to strong effervescence. The soils showed well developed deep wide cracks in summer indicating high swell – shrink potential is due to dominantly smectitic clays (Kataria and Bhakare, 2013).

Table 3 major limitations of soil and suggested land use.

Pedon No.	Land capability sub class	Major limitations	Present land use	Suggested land use
P1	IIIes	Heavy clayey texture, alkalinity moderately erosion	Shrubs with thorny plants, Acacia and Prosopis spp. And rainfed cultivation	Suitable for minor millets and filed crops like bajra, sorghum, ragi and horticultural crops like senna, aonla, ber, custard apple
P2	IIIs	Heavy clayey texture, alkalinity, subsoil salinity, powdery $CaCO_3$ in the subsoil, slightly erosion	Rainfed cultivation of millets and pulses	Suitable for filed crops like sunflower, maize, ragi, chilly, Bengal gram, citrus, aonla, ber, pomagranate
P3	IIIs	Heavy clayey texture, alkalinity, subsoil salinity, powdery $CaCO_3$ in the subsoil	Rainfed cultivation of millets and pulses	Suitable for minor millets and filed crops like bajra, sorghum, ragi, chilly, groundnut, citrus, sapota, aonla, ber, pomagranate
P4	IIIes	Heavy clayey texture, moderately erosion strong alkalinity, subsoil salinity	Shrubs with thorny plants, Acacia and Prosopis spp. And rainfed cultivation	Suitable for filed crops like bajra, sorghum, maize, ragi, chilly, Bengal gram, citrus, aonla, ber

Physical properties

The gravel and sand contents were lower in soils whereas, the clay and silt contents were higher. The surface soils of four pedons were clay in texture with clay content ranged from 49.5 to 52.2 and 50.7 to 53.7 per cent, in surface and sub surface, respectively. The clay content is increased with depth of the soil (Table 1). The fine sized smectitic, clay which was translocated from surface soils and accumulated in sub surface horizons. The presence of $CaCO_3$ caused flocculation and moved to sub surface due to illuviation and its subsequent accumulation in the Bss horizons resulted the calcareous soils. In general the clay and calcium carbonate contents increased with depth because of illuviation (Srinivasarao *et al,* 2008).

Chemical properties

The soil reaction ranged from moderately alkaline (pH 7.9 to 8.7) to very strongly alkaline (8.5 to 9.0) in surface and sub surface, respectively (Table 1). Low rainfall associated with high evapo-transpiration responsible for high pH. The organic carbon content of the surface soil ranged from 0.31 to 0.37 g kg^{-1} and it decreased with the increase in solum depth. The electrical conductivity of surface soil was less than 1.0 dS m^{-1}, whereas the highest EC value (4.2dS m^{-1}) was observed in the lower most layer of P3. Generally, electrical conductivity increased with depth. Cation exchange capacity (CEC) of the surface soils varied from 47.7 to 51.4 cmol(p^+) kg^{-1}. The EC increased with depth in black soils and it was clear that cations leached from the upper horizons to lower horizons. The $CaCO_3$ content and CEC showed an increasing trend likewise the EC (Zade, P. Swati, 2010). The free calcium carbonate content varied from 3.2 to 6.1 per cent in the form of concretions and nodules. The precipitation of calcium carbonate from the solution rich in carbonate resulted in the high pH values. Similar results were indicated earlier by Anil *et al,* (2008). The base saturation of these soils was more than 90 per cent and it increased with pH. High base saturation in these soils is due to high amount of bases in the soil parent materials. The exchangeable cations and extractable bases were considerably high among the four soils. Among the exchangeable cations, Ca was predominant followed by Mg, Na and K. Similar observations were made by Nayak *et al.* (2006).

Table 4. Soil suitability of different crops.

Soil series	Mapping unit	Soil suitability*												
		Sorghum	Bajra	Minor millets	Cotton	Coconut	Ground nut	Sesame	Sunflo wer	Chilli	Coriander	Ber	Aonla	Citrus
Kumarapuram	KpcA1	S2	S2	S2	S2	S3	S3	S2	S2	S2	S2	S3	S3	S3
Kalugachalapuram	KlcA1	S2	S2	S2	S2	S3	S3	S2	S2	S3	S2	S3	S3	S3
Chandragiri	CgcA1	S2	S2	S2	S2	S3	S3	S2	S2	S3	S2	S3	S3	S3
Chidambaraspuram	CpcA1	S2	S2	S3	S3	S3	S3	S2	S2	S3	S2	S3	S3	S3

*S2 Moderately suitable, S3 Marginally suitable

Soil fertility status

The surface and sub surface soils were analysed for fertility status and presented in table 2. The soils were rated as low (<272 kg ha^{-1}) medium, (272 to 544 kg ha^{-1}) and high (> 544 kg ha^{-1}) in case of available nitrogen; low (< 12.4 kg ha^{-1}) medium, (12.4 to 22.4 kg ha^{-1}) and high (> 22.4 kg ha^{-1}) in case of available phosphorus; and low (<113 kg ha^{-1}) medium, (113 -280 kg ha^{-1}) and high (> 280 kg ha^{-1}) in case of available potassium (Arora 2002). Available nitrogen content was low and it ranged between 181 and 258 kg ha^{-1}. Available phosphorus was also low and it varied from 9.5 to 12.5 kg ha^{-1}. The available potassium was high in all four soils with the ranges between 388 and 432 kg ha^{-1}.

The available zinc content (DTPA – extractable) was deficient and ranged from 0.28 to 0.58 mg kg^{-1}. The critical limit for the DTPA extractable micronutrients Zn, Cu, Fe and Mn is 0.6, 0.2, 2.5 and 2.0 mg kg^{-1}, respectively (Katyal and Rattan 2003). Available copper, iron and manganese in these soils ranged from 0.82 to 1.58, 9.5 to 18.85 and 3.88 to 10.52 mg kg^{-1}, respectively and they were sufficient in all the soils.

Soil classification

Based on the morphological, physical and chemical properties, the soils were classified taxonomically into the order of Vertisol (Soil Survey Staff, 2010). The solum depth in all four series ranged from 100 to 150 cm. Thickness of 'A' horizon ranged from 15 to 25 cm. It's colour was very dark grayish brown in the hues of 10 YR and 2.5 Y or dark brown in the hue of 10 YR. All the four series consisted imperfectly drained, calcareous, clayey soils occurring in nearly level lands. They developed deep, wide cracks in periods of moisture stress. The frail cambic 'B' horizon was about 40 to 60 cm. It's colour was very dark grayish brown or very dark gray of 10 YR hue. Slickensides were noticed in the subsoil. The soils were taxonomically classified as fine, smectitic, calcareous, deep, isohyperthermic Typic Haplusterts.

Land capability classification

Land capability classification is an interpretative grouping of soils mainly based on the inherent soil characteristics, external land features and environmental factors that limit the use of land (Sehgal, 1996). The soil site characteristics of soil units were matched with criteria for land capability classification. All the four mapping units (KpcA1, KlcA1, CgcA1 and CpcA1) classified under IIIs' and 'IIIes' (Table 3). The clayey soil texture, high erosion, poor drainage and poor rainfall distribution placed the soil under class III. The 'e' and 's' are the sub classes indicating that the best management of the soils lies in their successful handling.

Soil suitability classification

The suitability of different soil mapping units for various crops is presented in Table 4.

The optimum requirements of a crop are always region specific. Climate and soil-site parameters play a significant role in maximizing the crop yields. Based on the degree of limitations the soils were classified using USDA system of soil classification (Soil Survey Staff, 2003). Soil suitability evaluation was carried out following FAO frame work (FAO 1976) and as per guide lines described by Sys *et al.* (1991).

The soils of all four series showed moderately suitable (S2) for bajra, jowar, cotton, sesamum and coriander mainly due to constraints of soil texture, alkalinity and drainage. This is in agreement with the earlier classification for maize and soybean by Arunkumar and Sriramachandrasekaran, (2013). The area showed marginally suitable (S3) for coconut, groundnut, chilli, citrus, aonla and ber. Similar classification were done earlier by Kharche and Pharande, (2010). The dominant limitations governing the suitability of most of the crops comprised of soil texture, soil alkalinity drainage and $CaCO_3$.

It can be concluded from the available data that the soils of these area degraded due to hot dry weather, high clay, calcareous, alkalinity and erosion and less vegetative cover and require proper conservation measures for normal cultivation. These black cotton soils may be used for cultivation of field crops and some drought tolerant horticultural crops. Further, careful soil management technique with conservation practices coupled with selection of suitable crop can help in better sustained output from the soils.

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