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Genesis and Classification of Bengal Gram Growing Soils in Brahmanakotkur Watershed of Andhra Pradesh

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ABSTRACT

The study was carried out in bengal gram growing soils of Brahmanakotkur watershed in Kurnool district of Andhra Pradesh viz., plains and uplands originated from limestone parent material under varying land uses were studied for their morphological characteristics, physical and physico-chemical properties and soil genesis. These soils were moderately alkaline to strongly alkaline (8.11 to 8.72) in reaction, non-saline (0.19 to 0.56 dSm^{-1}), very deep in depth and had isohyperthermic temperature and ustic soil moisture regime. The texture, organic carbon (OC), cation exchange capacity (CEC) and base saturation were ranged from clay loam to clay, 0.06 to 0.49 per cent, 34.18 to 52.04 cmol(p+)kg^{-1} and 86.57 to 98.67 per cent, respectively. Pedons 1 and 2 were classified under Vertsiol due to presence of more than 30 percent clay in all the horizons, slickensides and wedge shaped aggregates in sub-surface horizons and cracks in surface horizons and were classified as Typic Haplustert and Sodic Haplustert.

Key words: *Characterization, Classification, Bengal gram, watershed, Cambic horizon, slickensides, Typic Haplustert, Solic Haplustert and Vertisol.*

INTRODUCTION

Andhra Pradesh under being a semi-arid tropical monsoon climate has a number of soil types found. Soil is one of the most important natural resources, maintaining it in good health is necessary for meeting the increasing demand of food, fibre, fodder and fuel. The biggest challenge to the mankind today, is to provide the basic necessities for living, from the ever shrinking and non-renewable soil resource[8]. Soil characterization provides the information for understanding of the physical, chemical, mineralogical and microbiological properties of the soils which are highly essential to grow crops, sustain forests and grasslands as well as support homes and society structures[3]. The coupling of soil characterization and soil classification is a powerful tool in the development of management strategies of soil for food security and environmental sustainability.

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Watershed approach has conventionally been applied for arresting rainwater runoff, its harvesting and in situ soil and moisture conservation. This has been achieved through treatment of wastelands or degraded lands to achieve their greening under various programmes of the Central and state governments.[15]. Though, Brahmanakotkur watershed in Kurnool district of Andhra Pradesh is pre-dominantly under rainfed farming with erratic rainfall distribution associated with low crop productivity, needs site-specific information in terms of soil characteristics, their productivity potentials and limitations, which are not available for Kurnool district in general in and Brahmanakotkur watershed in particular for soil resource management, hence, the present investigation was planned and executed.

MATERIAL AND METHODS

Total geographical area of 2,931 ha and comprises of four villages namely Gargeyapuram, Diguvapadu, Paipalem and Damagatla. The watershed lies in between15°46' and 15°50' N latitudes and 78°09' and 78°13' E longitudes. (Fig.1). Physiographically the land is characterized by nearly level to gently sloping. The soils in the watershed were developed from limestone, dolomite, quartz and shale. The climate of the watershed was semi-arid monsoonic with distinct summer, winter and rainy seasons. The mean annual rainfall recorded for the last 10 years (2008 to 2017) was 543.73 mm of which 96.33per cent was received during May to November. The mean annual temperature was 28.92°C with mean summer temperature of 34.92°C and mean winter temperature of25.62°C. The maximum temperature recorded for the last ten years was 40.67°C and the minimum temperature was 17.47°C in the month of May and December, respectively. The soil moisture regime has been computed as ustic and soil temperature regime as isohypertherrmic. The natural vegetation of the watershed comprises of *Calotropis gigantean, Acacia auriculiformis, Azadirachta indica, Parthenium hysterophorus, Cynodon dactyl, Tamarindus indica, Acacia nilotica, Cassia auriculata etc.* The principal crops cultivated in this area was Tobbacco, Maize, cotton, and redgram.

A detailed soil survey was conducted in Bahmankotkur watershed of Kurnool district located in semi-arid agro-ecological region using 1:10,000 base map as per the procedure outlined by AIS&LUS[1] and selected two pedons in bengal gram growing areas. These pedons were studied in detail and the morphological characteristics were presented in Table1. The detailed morphological description of these pedons was studied in the field as per the procedure outlined in Soil Survey Manual[32]. Later, horizon-wise samples were collected and analyzed for important physical and physico-chemical properties by standard procedures[4] and studied for their genesis. The soils were classified taxonomically[34].

RESULTS AND DISCUSSION

Soil morphology

The detailed morphological properties of the soils were presented in Table 1. The solum depth of pedons 1 and 2 were very deep in depth. These soils were poorly to somewhat poorly drained. The colour in pedon 1 was varied from dark gray to very dark gray colour with a hue of 10YR, value ranged from 3 to 4 and chroma varied between 1 and 3 and pedon 2 showed brown colour with a hue of 7.5 YR, value ranged from 3 to 5 and chroma varied from 2 to 4 (Table 1). The colour appears to be the function of chemical and mineralogical composition of the soil[31]. Vertisols developed on nearly leveled plains and alluvial plains showed very dark grayish brown colour[27]. Furthermore, Vertisols of Andhra Pradesh had 10 YR hue, value 3 to 5 and chroma 1 to 2[35]. Low chroma in surface horizons of some pedons was due to the fact that surface horizons were moist than sub-surface horizons[6]. The dark colour of black soils was due to domination of highly dispersed forms of clay-humus complex in the predominantly smectite dominated soils and decrease in organic matter was responsible for colour change in deeper layers[16,21]. The colour variation in all the soils was mainly due to the differences in relief and consequent transportation of products of weathering or reduction of Fe and Mn[9].

The soils of watershed showed wide textural variations ranging from clay loam to clay. The wide textural variation might be due to variation in parent material topography, *in situ* weathering and translocation of clay by eluviation and age of the soils. Pedon 1 in watershed showed Surface and sub-surface horizons exhibited coarse, moderate to strong and sub-angular blocky to angular blocky structure and consistence varied from very hard to extremely hard, very firm to extremely firm and sticky and plastic to very sticky and very plastic in dry, moist and wet conditions, respectively. Pressure faces and slickensides were observed in sub-surface horizons and shown clear and smooth boundary in surface horizon and diffuse and wavy boundary in sub-surface horizons whereas pedon 2 Surface and sub-surface horizons exhibited medium to coarse, moderate to strong and sub-angular blocky to angular blocky structure and consistence varied from very hard to extremely hard, firm to very firm and sticky and plastic to very sticky and very plastic in dry, moist and wet conditions, respectively. In sub-surface horizons slickensides were observed and surface horizon showed clear and smooth boundary while sub-surface horizons exhibited diffuse and wavy boundary. The blocky structures *i.e.* angular and sub-angular blocky were attributed to the presence of higher quantities of clay fractions[5]. The sharp edges in angular blocky. Presence of extremely hard, extremely firm and slightly plastic and slightly sticky to very sticky and very plastic consistence might be due to large amount of expanding clay minerals[14]. The pedality of black soils was more strongly developed because of the high clay content, CEC, PBS and dominance of smectitic type of clay. The surface horizons and subsurface horizons had blocky structure (either subangular or angular) and the peds were medium to coarse in size with strong grade (strength). Stronger pedality of soils at lower topographic positions might be due to more finer fractions[28]. The uniform distribution of lime concretions (and pebbles) in surface and subsurface horizon of black soils are observed. It may be probably due to the localized movement of the sub-soil as described by Murthy *et al*.[10].

Vertic properties like surface cracks distinguished by high amounts of shrink-swell clays resulting in deep, wide cracks in the dry seasons. Shrinking of the drying soil mass induces cracks which have a polygonal appearance[9]. Vertically oriented cracks expose large blocks or prisms at the surface part of the soil. The swell-shrink soils on wetting develop a characteristic micro-relief consisting of low mounds and shallow depressions. The black soil pedons had shown a prominent gilgai formation due to wide deep surface cracks, the surface soil could have been sloughed off during rainy season and swelling pressures developed in the lower layers pushed the peds upward which leads the development of Intersecting slickensides in the deeper horizons and mounds and depressions on the surface. Similar observations were made by Rajagopal *et.al.*[17].

Pedons 1 and 2 had showed five horizons which were characterized as ABC [A-Bw-C and A-Bss-C] profiles. The A horizon was designated as Ap by taking into consideration change in colour and structure due to cultivation in all the profiles. Similar observation was made by Nasre *et al.*[11] and Rajagopal *et al.*[17] to represent ploughed condition of the soils. Pedons 1 and 2 exhibited cambic (Bw) sub-surface diagnostic horizon and ABC horizons with 'B' horizon differentiated into Bw, Bss1, Bss2 and Bss3 and all the pedons showed slickensides and pressure faces indicating development of Bss. Hence, the symbol 'ss' (sub-ordinate distinction) was suffixed to the master horizon symbol 'B' and sub-surface diagnostic horizons gave strong effervescence with HCl. All these pedons showed clear and smooth boundaries in surface horizons and sub-horizons of 'Bss' horizon in both the pedons was described as diffuse because of the presence slickensides and the clay content was high enough for clay textural class. Similarly diffuse boundary was noticed by Patangray *et al.*[13].

Soil Characteristics

Physical characteristics: The detailed physical characteristics of the soils were presented in Table 2. Particle size analysis revealed that the clay content varied from 37.29 to 56.95 per cent in pedon 1 whereas in pedon 2, clay content was ranged from 35.19 to 51.97 per cent. The enrichment of clay in Bw and Bss horizons of all pedons was primarily due to *in situ* weathering of parent material. The increasing trend of clay with depth was primarily due to vertical migration of clay[36]. More or less increase in clay content with depth might be due to variability of weathering in different horizons. Silt fraction in pedon 1 ranged from 17.51 to 42.46 per cent whereas in pedon 2, silt content was varied from 27.98 to 41.97 per cent Silt content in general exhibited an irregular trend with depth, this irregular distribution of silt might be due to variation in weathering of parent material or *in-situ* formation[7]. The sand content was low in both the pedons and varied from 13.33 to 25.54 per cent. This could be due to the translocation / migration of finer particles into the lower layers and surface erosion. Higher sand content in surface horizons than those of sub-surface horizons, which was opposite to clay content and was due to surface impoverishment of finer particles by runoff water[35].

The bulk density of the soils ranged from 1.29 Mg m^{-3} to 1.30 Mg m-^{3} in surface horizons whereas in subsurface horizons varied from 1.31 Mg m^{-3} to 1.50 Mg m^{-3}. The increase in bulk density with depth might be due to presence of calcium carbonate and low organic carbon content, more compaction, and less aggregation[30]. Similar results were reported by Sharma *et al.*[27] in lower Siwaliks of Himachal Pradesh. The discrepancy in bulk density of these soils was attributed to the moisture content and high content of expanding type of clay minerals. The pore space varied from 55.66 per cent (pedon 1) to 53.64 per cent (pedon 2) in surface horizons, whereas in subsurface horizons ranged from 53.81 per cent in pedon 2 to 54.65 per cent in pedon. Water holding capacity of soils varied from 43.06 to 49.31 per cent and from 38.78 per cent to 49.23 per cent, respectively in both surface and subsurface soils. Higher water holding capacity in surface horizon than in sub-surface horizons, which might be due to presence of higher clay and organic matter content in the surface soils. This variation in water holding capacity was due to the differences in depth, clay, silt and organic carbon content and high water holding capacity in clay soils was due to the high clay and less sand content as evident by highly significant and positive correlation (r =0.631**) between water holding capacity and clay content. The irregular trend of water holding capacity. Volume expansion was varied from 24.59 to 32.79 per cent in pedon 1 and 16.09 to 20.73 per cent in pedon 2. The shrinkage and swelling phenomenon-was exhibited in black soils. Hence, co-efficient of linear extensibility was determined. It ranged from 0.16 to 0.23 in pedon 1 whereas pedon 2 it varied from 0.16 to 0.20 per cent. The black soils fall in the category of very high (greater than 0.09) swell-shrink class[12]. Relatively high percentage of smectite in clay fraction. Higher COLE values of 0.1 to 0.28 were observed in Vertisols than in Inceptisols and Alfisols[35].

Physico-chemical characteristics:

The detailed physico-chemical characteristics of the soils were presented in Table 3. The pH of soils was ranged from moderately alkaline (8.11) to strongly alkaline (8.72). This wide variation in pH of watershed soils was attributed to the nature of the parent material, leaching, presence of calcium carbonate and exchangeable sodium. The increasing trend of pH with depth in pedon 1, might be due releasing of organic acids during decomposition of organic matter and these acids might have brought down the pH in the surface soils (Table 3). The distribution was irregular in pedons 2 which might be due to downward movement of bases and they get adsorbed at different layers irregularly. Higher pH in soils on gently sloping plains may be due to deposition of exchangeable bases brought by runoff water in surface horizons[13] and also prevalence of higher temperature during most part of the year resulted in accumulation of soluble salts indicating high pH in surface soils. The electrical conductivity of soil water extract in watershed soils was ranged from 0.19 to 0.56 dSm^{-1}, indicating that the soils in watershed were non-saline. The low EC in the these soils was due to excess leaching of soluble salts and due to free drainage conditions which favoured the removal of released bases by percolating and drainage water. These observations are in agreement with the findings of Devi *et. al.*[3].

Organic carbon content of watershed soils was low in surface and sub-surface horizons, ranging from 0.06 to 0.49 per cent (Table 3). All the pedons showed a decreasing trend in organic carbon with depth which could be attributed to the fact that the surface horizons showed more organic matter content than sub-surface horizons due to the addition of plant residues and farm yard manure to surface horizons which resulted in higher organic carbon content in surface horizons than in the lower horizons. Low organic content in the soils might be attributed to the prevalence of tropical conditions, where the degradation of organic matter occurs at a faster rate coupled with low vegetative cover, there by leaving less organic carbon in the soils[11,17]. The calcium carbonate content of black soil pedons (1 and 2) containing 3.90 to 11.64 per cent and the highest $CaCO_3$ content was noticed in pedon 1, which might be due to semi-arid climate which is responsible for the pedogenic processes resulting in the depletion of Ca^{+2} ions from the soil solution in the form of calcretes[6]. The irregular distribution of CaCO3 in pedons 1 and 2 with depth could be due to the variable nature of the geological material that contributed to these soils or due to rapid leaching of carbonates from the porous sandy soils[19].

The CEC of soils was higher in both the pedons varied from 34.18 to 52.04 $cmol(p^{+})kg^{-1}$ soil (Table 4) which corresponds to clay content in the horizons, organic carbon content and also type of clay mineral present in these soils. The high CEC of the black soils was attributed to the high clay content and smectitic clay mineralogy[9]. The CEC/clay ratios were found to vary from 0.62 to 1.20. The higher values of CEC/ clay ratio indicate the less weathered nature of the soils with weatherable primary minerals[2].

The exchangeable bases of the two pedons were in the order of $Ca^{2+}> Mg^{2+}> Na^{+}> K^{+}$ on the exchange complex (Table 4). Soil exchange complex was dominated with Ca compared to other exchangeable cations. These results are in conformity with findings of Patangray *et al.*[13]. The per cent base saturation varied from 86.57 (pedon 2) and 98.67 (pedon 1) per cent. The very highe base saturation observed in both pedons, might be due to higher amount of Ca^{2+} occupying exchange sites on the colloidal complex. The differences in per cent base saturation indicated the degree of leaching. The variation in base saturation of the soils might be due to variation in nature and / or content of soil colloids and relatively high base saturation in surface layer could be attributed to the recycling of basic cations through vegetation[11]. The ratio between Ca and Mg ranged from2.56 to 5.11 and narrower Ca^{+2} / Mg^{+2} ratio was due to suppression of Ca solubility, substitution of Mg^{+2} or Ca^{+2} by plants and recycling of unusual amount of Mg[26]. The ESP was ranged from 8.29 per cent to 10.27 per cent in surface horizons whereas, in subsurface horizons ranged from 8.67 per cent 19.80 per cent. ESP more than 15 per cent in deeper layers, this might be due to the fact that the parent material was rich in sodium. Similarly, high exchangeable sodium (ESP >15) in Vertisols of Nandyal farm in Kurnool district of Andhra Pradesh was reported by Reddy[23]. ESP values ranging from 13 to 23.1 per cent were observed in deeper horizons of black soils of ICRISAT, Hyderabad in Andhra Pradesh[25].

Soil genesis

An examination of soil profiles showed distinctive horizontal layers, some of which were highly visible. Significant changes occurred as the soils were developed from relatively unconsolidated parent material. Pedons 1 and 2 were developed from limestone. Simonson[29] outlined the process of soil formation include a) additions of organic and mineral materials to the soil as solids, liquids and gases b) losses of these from the soil c) translocation of materials from one point to another within the soil and d) transformation of mineral and organic substances within the soil.

As per the outlines, in the watershed, the addition of organic matter was noticed due to accumulation of organic matter and humus on the surface soils and to certain depth of sub-soil was noticed in all the pedons of the study area. The surface horizon in all these pedons was dark in colour as compared to sub-surface horizons due to accumulation of organic matter. Higher organic matter in the surface soils was due to addition of organic matter through leaf fall, stubbles, roots and organic manures restricting to the surface soils only[3]. Further, the organic carbon was leached to lower layers along with percolating water leading to its loss from the surface soils[24].

Next to soil formation was translocation of material from one point to another within the soil. In this category eluviation and illuviation were of importance. The development of B horizons in all both pedons was a result of illuviation and eluviation. Due to these processes the cambic (Bw) horizon was formed in both pedons 1 and 2. And also showed Bss horizon indicating development of slickensides in the B horizon which qualifies, these soils to be classified under Vertisols. The Vertisols of ICRISAT production agricultural field, India were exhibiting the sub-surface horizons of Bss1, Bss2, Bss3, Bssck1, Bssck2 and Bck[33].

Owing to soil forming processes were the transformation of minerals and organic substances indicated that colour and structure get transformed in the sub-soil leading to the development of cambic horizon (Bw) in pedons 1 and 2. These processes also revealed that the formation of smectite resulted through transformation from the weathering sequence of mica-vermiculite-smectite. However, kaolinite could be formed from montmorillonite by loss of alkalis and iron. The study area has semi-arid climate with high summer temperatures with scarce rainfall and monsoonic type of climate. Natural vegetation in watershed was annuals and short grasses. Further, the topography of the study area varied from nearly level plains to gently sloping. The interplay of climate, topography and vegetation acting on parent material over a period of time resulted in the development of Vertisols in bengal gram growing areas.

Soil classification

Based on morphological characteristics, physical and physico-chemical properties of the typifying pedons and climatic parameters like moisture and temperature regimes the soils were classified up to family level[34] (Table 4). The soils are very deep and ideal for cultivation of cotton, sorghum, tobacco, bengal gram, redgram, sunflower, maize and pearlmillet. Pedons 1 and 2 showed intersecting slickensides, wedge shaped aggregates, more than 30 percent clay in all the horizons and cracks (2-5cm wide) in the B horizon resulting in the development of Bss horizon and absence of lithic or paralithic contact, duripan, petrocalcic horizon within 50 cm from the surface. Based on these characters the soils were classified as Vertisol (Table 4). Pedons 1 and 2 were grouped under Ustert at sub-order level due to ustic soil moisture regime. Rao and Prasadini[22] classified the black soils of Telugu Ganga project of Andhra Pradesh. Both pedons were grouped under Haplustert at great group level because these pedons did not have salic, gypsic, calcic or petrocalcic horizons within 100 cm of mineral soil surface and Alkaline pH. Based on the similar features Surekha *et al.*[35] and Patangray *et al.*[13] classified Vertisols of Andhra Pradseh and black soils of Kupti watershed in Yavatmal district of Maharashtra.

Further, pedons 2 did not exhibit any intergradation with other taxa or an extragradation from the central concept, absence of lithic contact within 100 cm of the mineral soil surface and also absence of calcic, halic, petrocalcic, gypsic and sodic horizons. Hence, these pedon were classified as Typic Haplustert at sub-group level. Surekha *et al.*[35] and Rajeshwar and Mani[18] taxonomically classified some Vertisols of Andhra Pradesh and some cotton growing soils in semi-arid tropics of Tamil Nadu as Typic Haplusterts, respectively and pedon 1 was placed under Sodic Haplustert at sub-group level due to presence of sodic horizon (ESP > 15) and absence of halic, petrocalcic, gypsic and calcic horizons and absence of lithic contact. Nasre *et al.*[11] taxonomically classified soils of Karanji watershed in Maharashtra, as Sodic Haplustert at great group level.

Table 1: Morphological characters of the soils

Pedon No. & Horizon	Depth (m)	Colour		Texture	Structure			Consistence			Effervescence	Boundary		Cutans			Pores		Roots		Other features
		Dry	Moist		S	G	T	Dry	Moist	Wet		D	T	TY	TH	Q	S	Q	S	Q	
Pedon 1	**Fine, smectitic, isohyperthermic, Sodic Haplustert**																				
Ap	0.00 – 0.22	10 YR 4/1	10 YR 3/1	c	c	2	sbk	vh	vfi	sp	-	c	s	-	-	-	-	-	f	f	-
Bw	0.22 – 0.50	10 YR 3/1	10 YR 2/1	c	vc	3	abk	eh	efi	vsvp	-	d	w	-	-	-	-	-	f	f	pressure faces
Bss1	0.50 – 0.93	7.5 YR 3/2	7.5 YR 2/1	c	vc	3	abk	eh	efi	vsvp	-	d	w								slickensides
Bss2	0.93 – 1.20	10 YR 3/1	10 YR 2/1	sic	vc	3	abk	eh	efi	vsvp	es	d	w	-	-	-	-	-	-	-	slickensides
Bss3	1.20 – 1.50+	10 YR 3/1	10 YR 2/1	cl	c	3	abk	eh	efi	vsvp	es	-	-								slickensides
Pedon 2	**Fine, smectitic, isohyperthermic, Typic Haplustert**																				
Ap	0.00 – 0.20	7.5 YR 5/4	7.5 YR 3/2	cl	m	2	sbk	vh	fi	sp	-	c	s	-	-	-	-	-	f	f	-
Bw	0.20 – 0.51	7.5 YR 5/4	7.5 Y 3/3	sic	c	3	abk	eh	vfi	vsvp	-	d	w	-	-	-	-	-	-	-	-
Bss1	0.51 – 0.72	7.5 YR 5/3	7.5 YR 3/3	c	c	3	abk	eh	vfi	vsvp	-	d	w								slickensides
Bss2	0.72 – 1.15	7.5 YR 5/4	7.5 YR 3/4	sic	c	3	abk	eh	vfi	vsvp	es	d	w	-	-	-	-	-	-	-	slickensides
Bss3	1.15- 1.50+	7.5 YR 5/4	7.5 YR 3/4	c	c	3	abk	eh	vfi	vsvp	es	-	-								slickensides

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 (S) – vf – very fine, f – fine, m – medium, c – coarse; Grade (G) – O – structureless, l – weak, 2 – moderate, 3 – strong;

Type (T) cr – crumb, sg – single grain, abk – angular blocky,sbk – sub-angular blocky.

Consistence:

Dry : s – soft, l – loose, sh – slightly hard, h – hard, vh – very hard, eh – extremely hard

Moist : l – loose, fr – friable, fi – firm, vfi – very firm, efi – extremely 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 : Ty – type – t – Argillan, Th – Thickness, tn – thin, th – thick, Quantity (Q), p – patchy, c – continuous

Pores : Size (S) f – fine, m- medium, c- coarse; Q – Quantity, f – few, c – common, m - many

Roots : Size (S) f – fine, m- medium, c- coarse; Q – Quantity, f – few, c – common, m - many

Effervescence : es – strong effervescence, ev – violent effervescence

Boundary : D – Distinctness, c – clear, g – gradual, d – diffuse, T – Topography; s – smooth; w – wavy

Table 2: Physical characteristics of the soils

Pedon No. & Horizon	Depth (m)	Sand (%) (0.05-2.0 mm)	Silt(%) (0.002-0.05 mm)	Clay(%) (<0.002 mm)	Bulk density (Mg m^{-3})	Volume expansion (%)	Water holding capacity (%)	COLE
Pedon 1	**Fine, smectitic, isohyperthermic, Sodic Haplustert**							
Ap	0.00 – 0.22	25.36	33.51	41.13	1.29	24.59	49.31	0.16
Bw	0.22 – 0.50	25.54	17.51	56.95	1.32	26.58	49.23	0.21
Bss1	0.50 – 0.93	13.33	37.91	48.76	1.32	25.88	57.92	0.21
Bss2	0.93 – 1.20	18.98	40.40	40.62	1.31	27.14	54.94	0.23
Bss3	1.20 – 1.50+	20.25	42.46	37.29	1.38	32.79	55.98	0.22
Pedon 2	**Fine, smectitic, isohyperthermic, Typic Haplustert**							
Ap	0.00 – 0.20	24.57	40.24	35.19	1.30	16.09	43.06	0.16
Bw	0.20 – 0.51	17.52	40.09	42.39	1.38	16.17	38.78	0.16
Bss1	0.51 – 0.72	20.05	27.98	51.97	1.44	14.45	40.83	0.20
Bss2	0.72 – 1.15	17.00	41.49	41.51	1.42	20.73	38.35	0.20
Bss3	1.15 – 1.50+	16.34	36.75	46.91	1.50	20.16	37.13	0.19

Table 3: Physicochemical properties of the soils

Pedon No. & Horizon	Depth (m)	pH 1:2.5		EC (dSm^{-1})	Organic carbon (%)	$CaCO_3$ (%)	CEC (cmol (p^+) kg^1) (1 *N* NH_4 OAc, pH 7.0)	Exchangeable bases (c mol (p^+) kg^{-1}) (1 *N* NH_4 OAc, pH 7.0)				Base saturation (%) (1 *N* NH_4 OAc, pH 7.0)	ESP (%)	Ca / Mg	CEC/ Clay
		H_2O	1*N* Kcl					Ca^{2+}	Mg^{2+}	Na^+	K^+				
Pedon 1	**Fine, smectitic, isohyperthermic, Sodic Haplustert**														
Ap	0.00 – 0.22	8.48	7.09	0.19	0.49	11.15	36.54	26.50	5.30	3.03	0.55	96.83	8.29	5.00	0.89
Bw	0.22 – 0.50	8.56	7.11	0.19	0.39	11.64	35.05	24.00	6.80	3.04	0.23	97.20	8.67	3.53	0.62
Bss1	0.50 – 0.93	8.60	7.18	0.24	0.22	9.10	39.08	23.50	7.60	7.16	0.30	98.67	18.32	3.09	0.80
Bss2	0.93 – 1.20	8.61	7.02	0.47	0.10	11.25	40.90	23.00	9.00	8.10	0.25	98.66	19.80	2.56	1.01
Bss3	1.20 – 1.50+	8.72	7.28	0.49	0.06	10.86	44.87	25.00	9.10	8.10	0.32	94.76	18.05	2.75	1.20
Pedon 2	**Fine, smectitic, isohyperthermic, Typic Haplustert**														
Ap	0.00 – 0.20	8.21	7.20	0.26	0.23	6.45	34.18	22.10	4.60	3.51	0.53	89.94	10.27	4.80	0.97
Bw	0.20 – 0.51	8.23	6.91	0.35	0.17	6.65	43.67	29.30	6.50	4.89	0.38	94.05	11.20	4.51	1.03
Bss1	0.51 – 0.72	8.41	7.12	0.15	0.15	4.39	51.04	32.50	9.60	4.85	0.48	92.93	9.50	3.39	0.98
Bss2	0.72 – 1.15	8.23	7.08	0.22	0.14	3.90	36.56	23.40	6.90	5.01	0.41	97.70	13.70	3.39	0.88
Bss3	1.15 – 1.50+	8.11	7.31	0.56	0.12	5.96	52.04	33.20	6.50	4.90	0.45	86.57	9.42	5.11	1.11

Table 4: Soil classification of bengalgram growing soils in Brhamanakotkur watershed area

Pedon No.	Order	Sub-order	Great group	Sub-group	Family
1	Vertisol	Ustert	Haplustert	Sodic Haplustert	Fine, smectitic, isohyperthermic, Sodic Haplustert
2	Vertisol	Ustert	Haplustert	Typic Haplustert	Fine, smectitic, isohyperthermic, Typic Haplustert

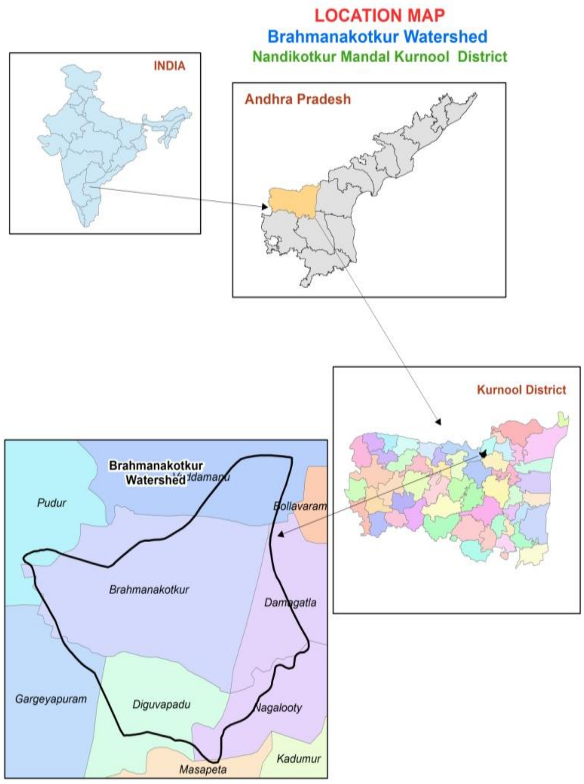

Fig. 1: Location map of Brahmanakotkur watershed

CONCLUSIONS

The morphological, physical and physico-chemical properties of Brahmanakotkur watershed soils in Kurnool district revealed that the soils were moderately to strongly alkaline in reaction, non-saline and low in organic carbon. The CEC values were medium to high and exchange complex was dominated by Ca^{2+} followed by Mg^{2+}, Na^{+} and K^{+}. The bengal gram growing soils in Brahmanakotkur watershed area were classified as Typic Haplustert and Sodic Haplustert.

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