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Pedogenesis and land evaluation of some sugarcane growing red laterite soils in semi arid tropical region of Telangana

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Abstract
The study was carried out to characterize and classify the sugarcane growing red laterite soils of Medak district of Telangana State and assess the suitability for growing sugarcane to develop strong soil resource database for proper appraisal of their productivity potential and rational use. Based on the morphological characteristics and land elevation, five geo referenced pedons were selected. The area was under the semi-arid monsoon type climate. The selected red laterite soils (pedon 1, 2, 3, 4 and 5) developed on weathered granite-gneiss over hard laterite parent material at gently sloping lands. The soil colour varied from dark red (2.5 YR3/6) to brown (7.5YR4/4) under dry condition and dark reddish brown (2.5 YR3/4) to dark brown (7.5YR3/4) under moist condition in different horizons and locations. The texture was widely ranging from gravelly sandy loam (coarse) and sandy clay loam (medium) in the surface horizons and sandy clay and clay (fine) in sub-surface horizons. Soil developed weak pedality with granular structure in the surface horizons and sub-angular blocky peds in sub-surface layers. The clay content ranged from 24.5 to 50.7 per cent in surface horizons and 34.6 to 60.6 per cent in subsurface horizons. The sand content varied from 37.8 to 68.4 per cent in surface horizons and 28.5 to 53.2 in subsurface horizons. The silt clay ratio was found to be less than 0.5 indicating the moderate weathering. The bulk density was increased with increasing depth. Soil pH ranged from moderately acidic to slightly acidic (5.1 to 6.8).The organic carbon found to vary from low to medium (4.9 to 5.7 g kg^{-1}) in surface horizons whereas in subsurface horizons it was low from 1.5 to 4.9 g kg^{-1}. The $CaCO_3$ content was absent. The exchangeable bases were in the order $Ca^{+2} > Mg^{+2} > K^{+} > Na^{+}$. The base saturation percentage ranged from 35.21 to 53.48 per cent in surface horizons, whereas in subsurface horizons ranged from 21.17 to 49.25 per cent. Sub surface hardening and gravelly hardened in-situ as crust was observed, which leads the impedance to root penetration and proliferation. The soils were classified as per USDA soil taxonomy as Alfisols.

Keywords: Sugarcane growing red laterite soils, morphological, physical, physico-chemical properties, soil classification, soil formation and land evaluation

Introduction
Land is a finite natural resource and there is little scope to increase the areas under cultivation. The efforts made in the past to bring new areas under cultivation at the cost of forests have reduced to 20% of total geographical area of the country. For decades, advancement in agricultural practices has been a necessity due to ever increasing demand caused by growing population. Sugarcane (*Saccharum officinarum* L) is being cultivated in India in an area of 42.45 lakh ha in the states of Karnataka, Maharashtra, Madhya Pradesh, Telangana, Andhra Pradesh, Tamil Nadu, Goa and Kerala with total sugar production of 192.67 lakh tones. India is one of the largest producers of sugar and shares about 41.11% and 13.25% of Asian and Worlds sugar production respectively. The population in India is increasing steadily and as well the demand for sugar and other sweetening agents because of changing food habits. There is no scope to increase the area under sugarcane to meet the requirements. This envisages the adoption of better crop production and protection technologies for increased production per unit area and time apart from varietal improvement.

Telangana state being under a semi-arid tropical monsoon climate, has a number of soil types which are found in all types of climates, occupying 3.5 per cent (114,840 sq. km. or 114.84 lakh ha or 11.484 m.ha) of the country’s geographical area. Hence their management varies from place to place besides the crop variation. Maintaining the soil with high productivity on sustainable basis is important to meet basic needs of the people. Hence delineating the sugarcane growing soils for their fertility helps in understanding the soil related constraints and their intensity which is essential to develop site specific management strategies. Classification of sugarcane growing soils in a taxonomic perspective provides information on the nature and its potential production capabilities.

The characterization and classification of soils helps in determining the soil potential, identifying constraints and giving detailed information on different soil properties of the sugarcane growing areas. The present investigation is aimed to assess the characteristics of soils and land resources to comprehend the potential capability of sugarcane growing soils of Medak district in the perspective of developed land use decision for effective utilization of resources.

Materials and Methods

Location and brief description of the study area

Medak district of Telangana state is with a geographical area of 9,519 km^2 forms a part of Deccan Plateau under Godavari river basin and lies between North Latitudes 17^O 27' and 18^O 18' and East longitudes 77^O 28' and 79^O 10'. Sugarcane is cultivated in the district in an area of 22076 hectares producing 1721 thousand tonnes with an average productivity of 74.41 t ha^{-1} (Center for Monitoring Indian Economy, 2014-15). It is bounded by the Nizamabad district on the north, Karimnagar district on the north and north-east, Warangal and Nalgonda district on the east, Hyderabad and Rangareddy district on the south and Bidar district (Karnataka) on the west. It is divided into three revenue divisions, *viz.*, Sangareddy, Medak and Siddipet with 46 revenue mandals/tehsil and 1223 villages in the district. The district is drained by a major river Manjira and three minor rivers, *viz*., Haldi, Kundlair and Mohedamada and several other ephemeral streams and channels. The drainage is parallel to sub-parallel and dendritic. Based on the morphological characteristics and physiography, five geo-referenced pedons (Table 1) were selected in Zaheeraad devision of Medak district such as Paidigummal (Pedon 1), Burdipad (Pedon 2), Kuppanagar (Pedon 3), Basanthpur (Pedon 4) and Kothur (Pedon 5). The district forms part of South Deccan Plateau. It is an ancient plateau exposed for long ages to denudation. Sheet-wash and retreat of hill slopes are the major geomorphic processes responsible for sculpturing of the present day landforms under semi-arid conditions. The plateau has two erosional surfaces with altitudes of 150-600 m and 300-900 m above MSL.

The climate is semi-arid. The mean annual rainfall is 870 mm of which 76 per cent is received during the southwest monsoon (June to September), 14 per cent during the northeast monsoon (October to December) and 8 per cent during the pre-monsoon period (March to May). The mean maximum and minimum temperature vary from 40 °C to 26 °C. Mean humidity varies from 65 per cent in July to 74 per cent in December. The soil moisture content is dry for more than 90 cumulative days or 45 consecutive days in the months of summer solstice. The soil moisture and temperature regimes of the study area are Ustic and Isohyperthermic, respectively. The natural vegetation existing in the study area are grasses, shrubs, thorny bushes such as *Cynodon dactylon, Cyprus rotundus*, *Butea frondosa, Dalbergia latifolia, Azadirachta indica*, *Tectona grandis*, *Terminalia tomertosa* and *Acacia* spp. *Prosopis juliflora, Cacia* sp, broad leaf weeds such as *Selotia, Parthenium, Eucalyptus, Euforbia* sps., etc. The principal crops cultivated are Rice, Maize, Sugarcane, cotton, redgram, Greengram, Blackgram, Groundnut and potato.

Collection and processing of soil samples

The geo-referenced pedons were selected on the basis of soil heterogeneity and land forms in different locations of sugarcane growing areas of the district. Horizon wise soil samples were collected from the representative pedons for laboratory analysis. The soil samples were air-dried in shade, processed and screened through a 2 mm sieve. Particles greater than 2mm were considered as gravel. Relevant physical and chemical properties were determined by following standard analytical procedures. The Soil pH, EC (1:2.5 soil water suspension); exchangeable cations (Jackson 1973) [21]; cation exchange capacity (Chapman, 1965) [9]; organic carbon (Walkly and Black, 1934) [57]; free $CaCO_3$ (Piper 1966) [32]; bulk density (Blake and Hartze 1986) [7]; water holding capacity and volume expansion (Sankaram, 1966) [43]; gravel by gravimetry method (Govindarajan and Koppar, 1975) [19]; Soil texture by International Pipette Method (Piper, 1966) [32]. The soils were characterized and classified as per Keys to Soil Taxonomy (Soil Survey Staff, 2010) [52].

Results and Discussion

Morphological properties

The details of the morphological properties of the soils were presented in Table 1. Major part of the study area is coming under gently sloping land forms with 3-8 per cent slopes and well drained. Thin clay films were noticed. Soil depth of the pedon 1 and 4 were moderate (50-75 cm), pedon 2 and 3 was moderately deep (75-100 cm), pedon 5 was deep (>100 cm). Soil depth was moderate in moderate steep slope whereas deep soils were found in nearly level to very gently sloping plain. The variation of depth in relation to physiography, mainly because of non-availability of adequate amount of water for prolonged period on upland soils associated with removal of finer particles and their deposition at lower pediplain have resulted in shallow soils in uplands and deeper soils in lowland physiographic units. The same types of observations were reported by Meena *et al*. (2009) [24] and Rajeshwar and Mani (2013) [35]. In pedon 2, 3, 4 and 5 five horizons and in pedon 1 four horizons were demarcated. All the pedons were characterized as A- B-C horizons. All the pedons showed considerable homogeneity in soil pedon development (A-Bt-C). The boundary between the horizons was smooth, clear and abrupt.

The surface horizon was designated as 'Ap' horizon at all the location because of the ploughed and disturbed condition due to cultivation (Rajeshwar *et al*. (2009) [36] and Ashok Kumar and Jagadish Prasad (2010) [1] to represent ploughed condition of the soils. The surface horizon was characterized as 'ochric' epipedon because of less organic matter content and light colour as per the requirements specified by Soil Survey Staff (1999) [51] and Balapande *et al.* (2007) [2]. Argillic horizon was developed in the subsurface layers which might be due to illuviation of clay from the surface horizon. Clay orientation had taken place in the 'B' horizon which resulted in the formation of clay cutans or clay skins. The patchy, thin argillans were recorded between 14 and 100 cm depth Nagassa and Gebrekidan, (2003) [27] and by Singh and Agarwal (2005) [50] due to sufficient clay illuviation in argillic horizon (Bt) from the overlying horizons, the texture had become finer. Hence, the boundary between Bt horizon and overlying horizon was clear (Thangasamy *et al.*, 2005) [53].

Table 1: Morphological characteristics of Sugarcane growing red laterite soil pedons of the Medak district

Pedon	Location	Horizon	Depth (cm)	Colour		Texture	Structure	Consistency			Effervescence	Pores	Roots	Boundary	Cutans	Other features
				Dry	Moist			Dry	Moist	Wet						
Zaheerabad division																
1	Paidigummal	Clayey-Skeltal, Kaolinitic, Subactive, Isohyperthermic ultic haplustalfs (17 º 32’39.17” N, 77 º 44’14.26” E, 651 m MSL)														
		Ap	0-16	5YR4/4	5YR3/4	gsc	m3gr	sh	fr	ss	-	ff	mf	-	-	Sub surface hardening, insitu crusting, indurated laterite layer, massive and tough
		Bt1	16-43	2.5YR4/6	2.5YR3/6	gc	m2sbk	h	fi	ss&sp	-	ff	mf	cs	t tk p	
		Bt2	45-68	2.5YR3/6	2.5YR3/6	gc	m2sbk	h	fi	ss&sp	-	ff	-	cs	t tn p	
		C	67+	Weathered Laterite hard pan												
2	Burdipad	Clayey, Kaolinitic, Semiactive, Isohyperthermic ultic haplustalfs (17 o 43’43.50” N, 77 o 33’38.09” E, 602 m MSL)														
		Ap	0-16	7.5YR4/4	7.5YR3/4	scl	m1gr-sbk	sh	vfr	ss&sp	-	ff	mf	-	-	Sub surface hardening, insitu crusting, indurated laterite layer, massive and tough
		Bt1	16-38	2.5 YR3/6	2.5YR3/4	sc	m1sbk	h	vfr	ss&sp	-	ff	ff	gs	t tk p	
		Bt2	38-70	2.5YR3/6	2.5YR3/4	sc	m2sbk	h	vfr	ss&sp	-	ff	-			
		Bt3	70-95	2.5YR4/8	2.5YR4/6	sc	m2sbk	h	vfr	ss	-	ff	-	cs	t tn p	
		C	95+	Weathered laterite hard pan												
3	Kuppanagar	Clayey-skeltal, Kaolinitic, Semiactive, Isohyperthermic kanhaplic rhodustalfs (17 º 44’31.90” N, 77 º 41’38.59” E,626 m MSL)														
		Ap	0-14	2.5YR4/6	2.5 YR4/4	scl	m2gr	sh	vfr	ss&sp	-	ff	mf	cs	-	Sub surface hardening, insitu crusting, indurated laterite layer, massive and tough
		Bt1	14-30	2.5YR4/3	2.5YR3/3	gc	m3sbk	sh	vfr	ss&sp	-	ff	cf	cs	-	
		Bt1	30-50	2.5YR4/4	2.5YR3/4	gc	m3sbk	vh	fr	ss&sp	-	ff	ff	as	-	
		Bt2	50-81	2.5YR4/6	2.5YR3/6	gc	m3sbk	vh	fr	ss	-	ff	-	ds	-	
		C	81+	Weathered laterite hard pan												
4	Basanthpur	Clayey-skeletal, Kaolinitic, Semiactive, Isohyperthermic kanhaplic rhodustalfs (17 o 47’40.52” N, 77 o 32’50.03” E,615 m MSL)														
		Ap	0-20	2.5YR4/4	2.5 YR3/4	sc	m2gr	h	fr	ss&sp		ff	mf	cs	-	Sub surface hardening, insitu crusting, indurated laterite layer, massive and tough
		Bt1	20-38	2.5YR4/4	2.5YR3/4	sc	m1sbk	h	fr	ss&sp	-	ff	ff	cs	t tn p	
		Bt2	38-56	2.5YR4/6	2.5YR4/4	sc	m2sbk	h	fr	ss&sp	-	ff	-	ds	t tk p	
		Bt3	56-70	2.5YR4/6	2.5YR4/4	sc	m2sbk	h	fr	ss&sp	-	ff	-	ds	t tk p	
		C	70+	Hard lithic contact which roots cannot penetrated												
5	Kothur	Clayey-skeltal, Kaolinitic, Semiactive, Isohyperthermic ultic haplustalfs (17 o 43’52.78” N, 77 o 36’15.96” E,611m MSL)														
		Ap	0-15	2.5YR3/6	2.5YR3/4	sc	m2gr	sh	fr	ss&sp	-	ff	mf	cs	-	Sub surface hardening, insitu crusting, indurated laterite layer, massive and tough
		Bt1	15-45	2.5YR3/6	2.5YR3/4	gc	m3sbk	sh	fr	ss&sp	-	ff	cf	gs	-	
		Bt2	45-75	2.5YR4/4	2.5YR3/4	gc	m3sbk	h	fr	ss&sp	-	ff	-	ds	t tn p	
		Bt3	75-105	2.5YR4/6	2.5YR3/6	gc	m3sbk	h	fr	ss	-	ff	-	ds	t tk p	
		C	105+	Hard lithic contact which roots cannot penetrated												

Soil texture : ls-Loamy sand, sl-Sandy loam, scl-Sandy clay loam, sc-Sandy clay, cl-Clay loam and c-Clay
Soil Structure : c-coarse, m-medium, f-fine, 1-weak, 2-moderate, 3-strong, gr-granular, abk-angular blocky, sbk-sub-angular blocky
Soil Consistence : l-loose, sh-slightly hard, h-hard, vh-very hard, vfr-very friable, fr-friable, fi-firm, vf-very firm, so-non sticky, ss-slightly sticky, s-sticky, vs-very sticky, po-non plastic, ps-slightly plastic, p-plastic, vp-very plastic
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
Effervescence : m-mild, ms-moderately strong s-strong vs-very strong
Boundary : c-clear, d-diffuse, s-smooth, w-wavy, g-gradual, a-abrupt
Cutans: T-Argillans; tn-thin; p-patchy

The soil colour varies from dark red (2.5 YR3/6) to brown (7.5YR4/4) under dry condition and dark reddish brown (2.5 YR3/4) to dark brown (7.5YR3/4) under moist condition in different horizons and locations which are indicative of release of oxides of iron during the process of weathering and different stages of hydration. The intensity of the color increased in sub surface horizons. The differences in colour might be due to various pedological process and also variation in organic matter content, quality of iron, diffusion of iron oxides in mineral matters of soil, the degree of oxidation and imperfect hydration as reported by Yadav *et al.* (1977) [58]; Gangopadhyay *et al.* (1990) [18] and Rajeshwar and Mani (2013) [35]. The soils were developed weak pedality with granular structure in the surface horizons and sub-angular blocky peds in sub-surface layers. The surface horizons were generally granular type because of organic matter and inter-cultivation operations. The strength of the peds was weak to moderate whereas, the size of the peds was very fine to medium. This type of weak pedality was attributed to less clay content, low CEC and dominance of illite/kaolinite type of clay (Nagassa and Gebrekidan, 2003; Patil and Prasad, 2004; Rajeshwar and Mani, 2013) [27, 30, 35].

The texture was ranging from sandy clay loam (medium) to gravelly sandy clay (fine) in the surface horizons and gravelly sandy clay and clay (fine) in sub-surface horizons. As the red laterite soils were derived from acidic coarse to medium grained granite- gneissic parent material, the red soils were exhibiting these textural classes. Gupta *et al.* (2003) [20]; Singh and Agarwal (2005) [50]; Rajeshwar and Mani (2013) [35] reported similar textural classes. The consistence varied from slightly hard to hard, friable to firm and non-sticky and non-plastic to slightly sticky and slightly plastic in dry, moist and wet conditions, respectively. This physical behaviour of soils influenced by dry, moist and wet conditions was not only due to the textural make up but also due to type of clay minerals present in these soils. The C horizon of all the pedons had shown non-sticky and non-plastic or slightly sticky and slightly plastic consistence, which might be due to less amount of clay (Thangasamy *et al.*, 2005) [53]. No effervescence was observed in surface horizons and subsurface layers of red laterite soil pedons might be due to leaching of basic cations. Similar results were reported by Rajeshwar and Mani (2013) [35]. Red, reddish brown brownish yellow to straw yellow and brownish black mottles were observed due to periodic wetting and drying favoured concretion formation and more permanent wetting leads to mottling. Brownish yellow to straw yellow mottles were observed might be due to oxidation of FeS_2. The reddish mottles were composed predominantly of Fe whereas black mottles were assumed due to manganese. Similar result was reported by Veneman *et al.* (1976) [55] and Diwakar and Singh (1994) [15]. The presence of concretions of Fe and Mn and of clay skins was a common feature of red laterite soil pedons.

Subsurface hardening and insitu crusting

Sub surface hardening and gravelly hardened in-situ as crust was observed in red laterite soil pedons of the study area which leads the impedance to root penetration and proliferation below plough layer. Shallow root system makes the plant susceptible to drought during dry spells. In the second and third horizon of all red laterite soil pedons mottles with evidence of enrichment of sesquioxide was observed. The third and fourth horizon which overlies on the weathered parent rocks is referred to as the pallid or leached zone. These soils are red in colour as it is mixed with iron oxides and also used as building materials in Zaheerabad division of Medak district, but the farmers practicing agriculture with the application of huge amount of fertilizers.

Physical properties

The data on fine earth fractions of the soil pedons are presented in Table 2. The clay content of the soils ranged from 24.5 per cent (pedon 2) to 50.7 per cent (pedon 1) in surface horizons whereas in subsurface horizons it ranged from 34.6 per cent (pedon 4) to 60.6 per cent (pedon 3). Pedon 1 and 2, showed increasing trends with increased soil depth, while all other pedons showed irregular trend with soil depth. Increase of clay up to certain depth and a decrease was observed in pedon 3, 4 and 5 due to the illuviation process occurring during soil development (Tripathi *et al.*, 2006) [54]. The clay content was found gradually increased in pedon 1 and 2. The increased clay content with depth was an evidence of pedogenic development as their formation and distribution is time dependent (Bhaskar *et al.*, 2009) [5]. These variations could be attributed to the parent material, topography, *in situ* weathering and pedogenesis. These results were in concurrence with those of Rudramurthy and Dasog (2001) [40]. The silt content of the soil pedons varied from 5.6 (pedon 2) to 12.4 (pedon 3) per cent in surface horizons, whereas in subsurface horizons ranged from 6.1 (pedon 2) to 18.3 (pedon 3) per cent. There was a gradual decrease in silt content with depth in pedon 2 and no uniform trend was observed in the distribution pattern of silt content with depth in all other pedons**.** The silt content of the pedons showed an irregular trend with soil depth might be due to coarse nature of silt than clay, which restricts its movement with percolating water (Sharma *et al*., 2001) [47] and Rajeshwar and Mani, (2013) [35]. The sand content of soils varied from 37.8 (pedon 1) to 68.4 (pedon 2) per cent in surface horizons and in subsurface horizons 28.5 (pedon 3) to 53.2 (pedon 2) per cent. A decreasing trend in sand content with depth was observed in pedon 2, 3 and 5, whereas remaining pedons did not exhibit any regular trend with depth in the distribution pattern of sand fractions could be due to the translocation and migration of finer particles into the lower layers and surface erosion (Bhaskar and Subbaiah, 1995; Sarkar *et al.*, 2001; Monday *et al.*, 2003) [3, 45, 25]. The high sand content in pedon 2, 4 and 5 were indicative of high degree of transportation of fine fraction of the soil from higher topography to lower topography. To confirm the presence or absence of lithological discontinuity among adjacent horizons in different soil pedons, the ratios of fine earth fractions were computed (Table 3). The soils (pedons 1, 2, 3, 4 and 5) contained relatively higher sand/silt (1.56 (pedon 3) to 12.21 (pedon 2)), silt/clay (0.12 (pedon 5) to 0.35 (pedon 3)) and sand/(silt + clay) (0.40 (pedon 3) to 2.27 (pedon 2)) ratios. The silt clay ratio was found to be less than 0.5 indicating the moderate weathering (Rajeshwar and Mani, 2013) [35]. The gravel content varied from 24.2 (pedon 2) to 35.6 (pedon 1) per cent in surface horizons whereas in subsurface horizons ranged from 28.9 (pedon 2) to 67.8 (pedon 3) per cent. An increasing trend of gravel content with depth was observed in all the pedons with soil depth. The process like erosion and physical weathering are responsible for different proportions of gravel content in the pedons (Rajeshwar and Mani, 2013) [35]. The gravels of the red laterite soils were found to be very hard probably due to periodic wetting and drying favoured concretion formation and more permanent wetting leads to mottling (Manickam *et al.*, 1973) [23]; Rajeshwar and Mani (2013) [35].

The bulk density of the soils ranged from 1.39 Mg m^{-3} (pedon 5) to 1.47 Mg m^{-3} (pedon 4) in surface horizons whereas in subsurface horizons ranged from1.41 Mg m^{-3} in (pedon 5) to 1.54 Mg m^{-3} (pedon 1). Bulk density increased with increasing depth in all pedons. The increase in bulk density with depth might be due to decrease in organic matter content, more compaction, and less aggregation (Rajeshwar and Mani, 2013) [35]. The surface soils were less compact due to high organic matter content and more plant root concentration (Coughlan *et al.*, 1986) [11]. The water holding capacity was found to vary from 19.0 per cent (pedon 3) to 24.0 per cent (pedon 4) in surface horizons whereas in subsurface horizons ranged from 19.0 to 27.0 per cent in pedon 4 (red laterite soils) and pedon 2 respectively. The water holding capacity showed increasing trend with soil depth in pedon 1 and 2. The other pedons were exhibited an irregular trend with depth. In all the locations these values showed increasing trend with increasing clay content in general. These types of trends were in accordance with those of Rudramurthy and Dasog (2001) [40] and Bhaskar *et al.* (2005) [4]. The pedons was recorded pore space (39.0 per cent pedon 1 to 53.0 per cent pedon 5). An increase in porosity with depth was observed in pedon 4 and 5. There was no trend in the distribution pattern in other pedons. Similar trend was noticed by Rajeshwar and Mani (2013) [35]. The lower volume of expansion was found in soil pedon might be due to presence of illitic or kaolinitic types of non-expanding clay minerals showed increasing trend with soil depth in pedon 1 and 2 (Rajeshwar and Mani, 2013) [35].

Table 2: Physical characteristics of Sugarcane growing red laterite soil pedons of the Medak district

Pedon	Location	Horizon	Depth (cm)	Gravel (%)	Particle size distribution (%)			B.D (Mg m-3)	Pore space (%)	W.H.C (%)	Volume expansion (%)
					Sand	Silt	Clay				
Zaheerabad division											
1	Paidigummal	Clayey-Skeltal, Kaolinitic, Subactive, Isohyperthermic ultic haplustalfs (17 ° 32'39.17" N, 77 ° 44'14.26" E, 651 m MSL)									
		Ap	0-16	35.6	37.8	10.2	50.7	1.46	39.0	21.0	3.10
		Bt1	16-43	41.5	30.8	9.8	57.2	1.52	41.0	23.0	3.20
		Bt2	45-68	61.2	33.6	8.3	57.9	1.54	40.0	24.0	3.30
		C	67+	Weathered Laterite hard pan							
2	Burdipad	Clayey, Kaolinitic, Semiactive, Isohyperthermic Ultic Haplustalfs (17 o 43'43.50" N, 77 o 33'38.09" E, 602 m MSL)									
		Ap	0-16	24.2	68.4	5.6	24.5	1.45	41.0	23.0	3.13
		Bt1	16-38	28.9	53.2	6.2	39.2	1.49	45.0	25.0	3.25
		Bt2	38-70	34.5	51.2	6.1	41.2	1.51	43.0	27.0	3.26
		Bt3	70-95	51.2	48.6	8.9	41.9	1.51	42.0	27.0	3.42
		C	95+	Weathered Laterite hard pan							
3	Kuppanagar	Clayey-Skeltal, Kaolinitic, Semiactive, Isohyperthermic kanhaplic rhodustalfs (17 ° 44'31.90" N, 77 ° 41'38.59" E,626 m MSL)									
		Ap	0-14	31.2	45.6	12.4	41.2	1.46	44.0	19.0	3.10
		Bt1	14-30	36.5	37.5	12.1	50.1	1.47	42.0	20.0	3.35
		Bt2	30-50	38.9	30.5	8.3	60.6	1.49	46.0	20.0	3.36
		Bt3	50-81	67.8	28.5	18.3	52.5	1.51	49.0	21.0	3.81
		C	81+	Weathered Laterite hard pan							
4	Basanthpur	Clayey-Skeletal, Kaolinitic, Semiactive, Isohyperthermic kanhaplic rhodustalfs (17 o 47'40.52" N, 77 o 32'50.03" E,615 m MSL)									
		Ap	0-20	35.0	56.1	8.2	35.2	1.47	39.0	24.0	2.88
		Bt1	20-38	46.3	53.2	9.3	37.1	1.48	41.0	23.0	3.12
		Bt2	38-56	52.1	51.0	8.4	40.3	1.50	42.0	21.0	3.30
		Bt3	56-70	61.3	53.3	11.6	34.6	1.51	44.0	19.0	3.45
		C	70+	Hard lithic contact which roots cannot penetrated							
5	Kothur	Clayey-Skeltal, Kaolinitic, Semiactive, Isohyperthermic ultic haplustalfs (17 o 43'52.78" N, 77 o 36'15.96" E,611m MSL)									
		Ap	0-15	29.2	55.3	8.4	35.6	1.39	47.0	23.0	2.95
		Bt1	15-45	39.2	34.8	8.9	55.6	1.41	49.0	22.0	3.12
		Bt2	45-75	45.3	32.2	7.2	60.2	1.44	49.0	26.0	3.81
		Bt3	75-105	58.3	30.2	10.3	58.6	1.49	53.0	24.0	3.66
		C	105+	Hard lithic contact which roots cannot penetrated							

Sand (0.02-2.0 mm); Silt (0.002- 0.02mm) and Clay (<0.002mm)

Table 3: Ratios of fine earth fractions of pedons (Particle size-analysis)

Pedon	Location	Horizon	Depth (cm)	Sand + Silt	Silt + Clay	Sand/Silt	Silt/Clay	Sand/(Sand + Silt)	Sand/(Silt + Clay)
Zaheerabad division									
1	Paidigummal	Ap	0-16	48.0	60.9	3.71	0.20	0.79	0.62
		Bt1	16-43	40.6	67.0	3.14	0.17	0.76	0.46
		Bt2	45-68	41.9	66.2	4.05	0.14	0.80	0.51
		C	67+	Weathered Laterite hard pan					
2	Burdipad	Ap	0-16	74.0	30.1	12.21	0.23	0.92	2.27
		Bt1	16-38	59.4	45.4	8.58	0.16	0.90	1.17
		Bt2	38-70	57.3	47.3	8.39	0.15	0.89	1.08
		Bt3	70-95	57.5	50.8	5.46	0.21	0.85	0.96
		C	95+	Weathered Laterite hard pan					
3	Kuppanagar	Ap	0-14	58.0	53.6	3.68	0.30	0.79	0.85
		Bt1	14-30	49.6	62.2	3.10	0.24	0.76	0.60
		Bt1	30-50	38.8	68.9	3.67	0.14	0.79	0.44
		Bt2	50-81	46.8	70.8	1.56	0.35	0.61	0.40
		C	81+	Weathered Laterite hard pan					
4	Basanthpur	Ap	0-20	64.3	43.4	6.84	0.23	0.87	1.29
		Bt1	20-38	62.5	46.4	5.72	0.25	0.85	1.15
		Bt2	38-56	59.4	48.7	6.07	0.21	0.86	1.05
		Bt3	56-70	64.9	46.2	4.59	0.34	0.82	1.15
		C	70+	Hard lithic contact which roots cannot penetrated					
5	Kothur	Ap	0-15	63.7	44.0	6.58	0.24	0.87	1.26
		Bt1	15-45	43.7	64.5	3.91	0.16	0.80	0.54
		Bt2	45-75	39.4	67.4	4.47	0.12	0.82	0.48
		Bt3	75-105	40.5	68.9	2.93	0.18	0.75	0.44
		C	105+	Hard lithic contact which roots cannot penetrated					

Physico-chemical properties

The pedon wise physico-chemical properties of red laterite soils of sugarcane growing areas are described in (Table 4). The pH value of soils (pedon 1, 2, 3, 4 and 5) ranged from 5.1 (pedon 4) to 6.0 (pedon 1) in surface horizons whereas in subsurface horizons ranged from 5.6 (pedon 4) to 6.5 (pedon 3) (moderately acidic to slightly acidic). The pH increased with depth in the pedon 3, 4 and 5 might be due to increase in bases with depth and their complete downward leaching. The pedons 1 showed decreasing trend which might be due to the chemical weathering which leads to accumulation of exchangeable H^+, Al^{3+}, Fe and Al oxides and clay minerals (Bipul Deka *et al.*, 2009) [6]. The distribution was irregular in pedon 2 which might be due to downward movement of bases and they get adsorbed at different layers irregularly (Rajeshwar and Mani, 2013) [35]. The lower pH values in surface layers of pedon 1, 2, 3, 4 and 5 which might be due to continuous removal of basic cations by crop plants and leaching (Nagassa and Gebrekidan, 2003) [27], movement of basic cations to deeper layers (Singh and Agarwal, 2003) [49]. The pH value of majority of these surface soils are moderately acidic in soil reaction and appeared to be related with acidic parent materials and leaching of bases such as calcium, magnesium, potassium and sodium from the soil leading to high hydrogen ion concentration caused by heavy precipitation during rainy season (Nayak *et al.*, 2002 and Rajeshwar and Mani, 2014) [34].

The EC values ranged from 0.06 dS m^{-1} (pedon 5) to 0.17 dS m^{-1} (pedon 1) in surface horizons whereas in subsurface horizons ranged from 0.08 dS m^{-1} (pedon 4) to 0.13 dS m^{-1} (pedon 2) which indicating that these soils were non-saline in nature. The EC was very low in red laterite soils even in lower horizons because they were formed on relatively higher elevations. The EC values suggesting low amount of soluble salts which could be attributed to loss of bases (Sidhu *et al.*, 1994) due to heavy rainfall during monsoon.

The OC values was from 4.9g kg^{-1} m^{-1} (pedon 1) to 5.7 g kg^{-1} (pedon 3) in surface horizons whereas in subsurface horizons ranged from 1.5 g kg^{-1} (pedon 5) to 4.9 g kg^{-1}(pedon 3). The depth wise distribution of organic carbon showed a decreasing trend in all the pedons. The organic carbon content ranged from low to medium in surface horizons could be attributed to the rapid oxidation and decomposition of added organic matter under tropical condition (Saha *et al.*, 1996, Mustapha *et al.*, 2011) [42, 26]. The organic carbon content relatively higher in surface horizons than sub-surface horizons might be due to the addition of farmyard manure and plant residues to surface horizons which resulted in higher organic carbon content in surface horizons than that of lower horizons (Rajeshwar *et al.*, 2009) [33]. The calcium carbonate content of red laterite soils (pedons 2, 3, 4, 5 and 6) was absent.

Table 4: Physico-chemical characteristics Sugarcane growing red laterite soil pedons of the Medak district

Pedon	Location	Horizon	Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC (g kg^{-1})	Exchangeable Cations (c mol (p+) kg^{-1})				Total Ex. Bases	BS (%)	CEC (cmol (p+) kg^{-1})	Free CaCO3 (%)	ESP (%)	SAR	CEC/ Clay ratio
							Ca	Mg	Na	K							
Zaheerabad division																	
1	Paidigummal	Clayey-Skeltal, Kaolinitic, Subactive, Isohyperthermic Ultic Haplustalfs (17 º 32’39.17” N, 77 º 44’14.26” E, 651 m MSL)															
		Ap	0-16	6.0	0.17	4.9	2.2	1.3	0.1	0.81	4.41	50.11	8.8	-	1.14	0.48	0.17
		Bt1	16-43	5.9	0.13	3.6	2.0	1.7	0.1	0.78	4.58	49.25	9.3	-	1.08	0.46	0.16
		Bt2	45-68	5.4	0.11	2.2	1.5	1.3	0.1	1.17	4.07	39.90	10.2	-	0.98	0.80	0.18
		C	67+	Weathered Laterite hard pan													
2	Burdipad	Clayey, Kaolinitic, Semiactive, Isohyperthermic Ultic Haplustalfs (17 o 43’43.50” N, 77 o 33’38.09” E, 602 m MSL															
		Ap	0-16	5.8	0.10	5.5	2.0	1.5	0.14	0.96	4.60	41.07	11.2	-	1.25	0.58	0.46
		Bt1	16-38	6.4	0.10	4.3	2.4	1.9	0.15	0.86	5.31	43.88	12.1	-	1.24	0.47	0.31
		Bt2	38-70	6.3	0.11	2.2	2.7	1.3	0.16	0.57	4.73	35.83	13.2	-	1.21	0.31	0.32
		Bt3	70-95	6.0	0.10	2.6	2.8	1.2	0.15	0.37	4.52	32.06	14.1	-	1.06	0.20	0.34
		C	95+	Weathered Laterite hard pan													
3	Kuppanagar	Clayey-Skeltal, Kaolinitic, Semiactive, Isohyperthermic Kanhaplic Rhodustalfs (17 º 44’31.90” N, 77 º 41’38.59” E,626 m MSL)															
		Ap	0-14	5.6	0.08	5.7	2.4	1.8	0.11	0.45	4.76	53.48	8.9	-	1.24	0.25	0.22
		Bt1	14-30	6.1	0.09	4.9	2.2	1.2	0.16	0.69	4.25	41.67	10.2	-	1.57	0.41	0.20
		Bt1	30-50	6.4	0.08	2.7	2.0	1.2	0.15	0.65	4.00	25.81	15.5	-	0.97	0.40	0.26
		Bt2	50-81	6.5	0.09	2.6	1.7	0.9	0.12	0.54	3.26	21.17	15.4	-	0.78	0.37	0.29
		C	81+	Weathered Laterite hard pan													
4	Basanthpur	Clayey-Skeletal, Kaolinitic, Semiactive, Isohyperthermic Kanhaplic Rhodustalfs (17 o 47’40.52” N, 77 o 32’50.03” E,615 m MSL)															
		Ap	0-20	5.1	0.07	5.5	1.2	0.9	0.10	0.66	2.78	36.10	7.7	-	1.30	0.45	0.22
		Bt1	20-38	5.6	0.08	3.6	1.5	1.0	0.11	0.80	3.41	41.59	8.2	-	1.34	0.57	0.22
		Bt2	38-56	6.1	0.10	3.1	2.4	1.2	0.11	0.72	4.43	47.63	9.3	-	1.18	0.42	0.23
		Bt3	56-70	6.1	0.12	3.0	2.5	1.3	0.12	0.69	4.61	38.10	12.1	-	0.99	0.39	0.35
		C	70+	Hard lithic contact which roots cannot penetrated													
5	Kothur	Clayey-Skeltal, Kaolinitic, Semiactive, Isohyperthermic Ultic Haplustalfs (17 o 43’52.78” N, 77 o 36’15.96” E,611m MSL)															
		Ap	0-15	5.4	0.06	4.9	2.0	1.1	0.10	0.85	4.05	35.21	11.5	-	0.87	0.31	0.32
		Bt1	15-45	5.9	0.11	2.7	2.4	1.6	0.10	0.77	4.87	36.07	13.5	-	0.74	0.43	0.24
		Bt2	45-75	6.3	0.09	2.5	2.9	1.8	0.15	0.87	5.72	39.18	14.6	-	1.03	0.45	0.24
		Bt3	75-105	6.5	0.09	1.5	3.0	1.8	0.15	0.65	5.60	38.10	14.7	-	1.02	0.33	0.25
		C	105+	Hard lithic contact which roots cannot penetrated													

Exchangeable properties

The cation exchange capacity (CEC) values varied from 7.7 (pedon 4) to 15.5 c mol (p^+) kg^{-1} (pedon 3) and CEC/clay ratio ranged from 0.16 (pedon 1) to 0.46 (pedon 2). The CEC of the red laterite soils was quite low despite high clay content indicating that the dominance of low activity clay minerals (Rajeshwar and Mani, 2013) [35]. Soil exchange complex was dominated with Ca in all the pedons compared to other exchangeable cations varied from 1.2 c mol (p^+) kg^{-1} (pedon 4) to 2.4 c mol (p^+) kg^{-1} (pedon 3) in surface layers and 1.5 c mol (p^+) kg^{-1} (pedon 1) to 3.0 c mol (p^+) kg^{-1} (pedon 5) in sub surface layers. The exchangeable Ca content increased with depth in pedons 2, 4 and 5, whereas it was decreased with depth in pedon 1 and 3. The Exchangeable magnesium varied from 0.9 c mol (p^+) kg^{-1} (pedon 4) to 1.8 c mol (p^+) kg^{-1} (pedon 3) in surface and 0.9 c mol (p^+) kg^{-1} (pedon 3) to 1.9 c mol (p^+) kg^{-1} (pedon 2) in sub surface layers. Pedons 4 and 5 showed increasing trends with soil depth, while in the other pedons did not show a clear trend with depth**.** The exchangeable sodium ranged from 0.10 c mol (p^+) kg^{-1} (pedon 1) to 0.14 c mol (p^+) kg^{-1} (pedon 2) in surface and 0.10 c mol (p^+) kg^{-1} (pedon 1) to 0.16 c mol (p^+) kg^{-1}(pedon 2) in sub surface layers. The exchangeable Na content increased with depth in pedons 1, 4 and 5. In the rest of the pedons, the depth wise distribution was irregular (Rajeshwar and Mani, 2013) [35].

The exchangeable potassium varied from (0.45 c mol (p^+) kg^{-1} (pedon 3) to 0.96 c mol (p^+) kg^{-1} (pedon 2) in surface and 0.37 c mol (p^+) kg^{-1} (pedon 2) to 0.87 c mol (p^+) kg^{-1}(pedon 5) in sub surface layers. The pedon 2 shows that the exchangeable K content decreased with depth. The remaining pedons showed inconsistent pattern with depth. The exchangeable

bases were in order $Ca^{+2} > Mg^{+2} > K^{+} > Na^{+}$. Low exchangeable Na and K percentage was noticed in all the pedons as the exchange complex was dominated by divalent cations like Ca and Mg (Rajeshwar and Mani, 2013) [35].
The BSP was low to medium in red laterite soil pedons ranged from 28.66 per cent (pedon 5) to 53.48 per cent (pedon 3) in surface and 21.17 per cent (pedon 3) to 49.25 per cent (pedon 1) in sub surface layers might be due to kaolinite mineralogy in clay fraction and moderately acidic to slightly acidic reaction. The decreasing trend with increased depth was noticed in pedon 1 and 3. The base saturation increased up to certain depth and then decreased in pedon 4 and 5. Other pedons did not exhibit any regular pattern of distribution. These results were in accordance with the findings of Singh and Agarwal (2005) [50] and Gabhane *et al.* (2006) [17]. The ESP of red laterite soils ranged from 0.87 (pedon 5) to 1.30 (pedon 4) in surface layers and 0.74 (pedon 5) to 1.57 (pedon 3) in sub surface layers. The pedon 1 and 2 was exhibited decreasing trend. All other pedons exhibited an irregular distribution pattern with the increase in depth. Similar observations reported by Patel *et al.* (2012). The SAR was ranges between 0.25 (pedon 3) to 0.58 (pedon 2) in surface horizons, whereas in subsurface horizons ranged from 0.20 (pedon 2) to 0.80 (pedon 1). The pedons 1, 7 found to follow an increasing trend with the increase in depth and the remaining pedons exhibited an irregular distribution pattern with the increase in depth.

Soil classification
Sugar cane growing soils of Medak district were classified based on morphological, physical, physico-chemical, chemical and meteorological data, according to revisions of USDA Soil Taxonomy (2010) [52]. The soils of the study area were characterized and classified into soil order Alfisols. The pedon 1, 2, 3, 4 and 5 are classified under Alfisols because of the presence of an argillic horizon and base saturation was more than 35 per cent. As the moisture regime is Ustic, the pedons were classified as Ustalfs at sub order level. The pedons 3 and 4 were classified as Rhodustalfs at great group level because of presence of an argillic horizon in the upper 100 cm and or throughout the argillic horizon, the soil colors have Hue of 2.5YR and Value of 2.5 to 3 under moist condition and have Hue of 2.5YR and Value of 4 under dry condition. The pedons 1, 2 and 3 were classified as Haplustalfs because of presence of an argillic horizon. Similar results were reported by Mahapatra *et al.* (2000) [22].
The pedon 3 and 4 classified as Kanhaplic Rhodustalfs at sub group level because of Rhodustalfs that do not have a lithic contact within 50 cm of the mineral soil surface and have a CEC of less than 24 c mol (p^{+}) kg clay (by 1N NH4OAc pH 7). The pedons 1, 2 and 5 classified as Ultic Haplustalfs due to a base saturation (by sum of cations) of less than 75 percent throughout depth of pedon. The pedons 1, 3, 4 and 5 had showed 35 percent or more (by volume) rock fragments and clay content more than 35 per cent on weighted average in fine earth fraction. Hence qualified for "clayey-skeletal" particle size class. The pedon 2 had showed less than 35 percent (by volume) rock fragments and clay content more than 35 per cent on weighted average in fine earth fraction. Hence qualified for "Clayey" particle size class. The difference between mean summer and winter temperatures was less than 6 ^{O}C and the mean annual soil temperature was more than 22 ^{O}C. Therefore, the study area was classified as "Iso- hyperthermic" temperature regime (Thangasamy *et al.*, 2005) [53].

Pedogenesis
The temperature and rainfall pattern of the study area indicated that the climate is semi-arid with distinct and well-defined dry season and wet season. The soil moisture control section is dry for more than 90 cumulative days or 45 consecutive days in the months of summer solstice. The soil moisture and soil temperature regimes of the study area are Ustic and Isohyperthermic, respectively. The formation and development of red laterite soils were occurring under the semi-arid climate (Rudramurthy *et al.*, 1997; Reddy and Shivaprasad, 1999) [41, 38]. The red laterite soils (pedon 1, 2, 3, 4 and 5) were developed on weathered granite-gneiss over hard lateritic parent material and are farraginous aluminous rock. They are formed by decomposition; because of they are found in black soil regions having heavy rainfall in the study area. The rocks are completely leached out having a high proportion of iron and aluminium as residue. High temperature and heavy rainfall transformed the black soil into laterite. Red laterite soils were formed near the foothills of laterite granitic - gneiss with the slope varying from 3 to 8 per cent on gently sloping lands. Many scientists in different locations also reported formation of red soils on higher elements of topography and black soils on lower elements of topography (Nagelschmidt *et al.* (1940) [28]; Curi and Franzmeir (1984) [13]; Nagassa and Gebrekidan (2003) [27]. Undulating and gently sloping lands had developed deep to very deep, well drained and moderately eroded Haplustalfs in south of Eastern Ghats on granite-gneiss landform (Reddy *et al.*, 1996) [39].
The natural vegetation in the study area included *Cynodon dactylon, Cyprus rotundus, Azadirata indica, Prosopis juliflora, cacia* sps., *Manjifera indica, Tectona grandis, Tamarindus indica, Palmyra, Tadipalm,* broad leaf weeds such as *Selotia, Parthenium, Euforbia* spp., and shrubs etc. Similar type of vegetation was reported by Satish (2003) [46]; Bhaskar (2005) [4]; and Thangasamy *et al.* (2005) [53]. Though vegetation served as a good sign of indication of soil properties, the influence of natural vegetation on soil formation and development was not observed, as the natural vegetation was sparse in different locations of the study area. The red laterite soils of the study area might have been formed during Archean period about 3800 million years back (Rao *et al.*, 1995) [37]. Digar and Barde (1982) [14] reported that it was during Archean period, the red soils were formed.

Soil forming processes
Argillic horizons (textural clay enriched 'B' horizons) were recognized in the sub-surface of red laterite soils (pedon 1, 2, 3, 4 and 5) due to presence of clay cutans (argillans). There was a translocation of clay and iron oxides from 'Ap' horizon to 'B' horizon in the solum. The clay enrichment due to illuviation was sufficient enough to meet the requirement of argillic horizon (Bt). The texture was finer than the overlying horizon. Thus illuviation was the main pedogenic process. Similar observations were also reported by Peterschmitt *et al.*, 1996 [31]; Dutta *et al.*, 1999 [16]; Walia *et al.*, 2000 [22, 56]; Singh and Agarwal, 2005 [50].

Land capability classification
Land capability classification is an interpretive grouping of soils mainly based on the inherent soil characteristics, external land features and environmental factors that limits the use of land. The classification of units provide information on the physiography, colour, texture, structure of soil, type of clay mineral, consistence, permeability, depth of soil and soil

reaction. Each of above factor have definite role to play in behavior of soil and its management. Based on soil properties, the red laterite soils and black soils were classified into land capability classes III. Similar observations were also made by Sarkar *et al.* (2002) [44]. Pedon wise land capability classification of the sugarcane growing soils of Medak district is given in Table 5.

Table 5: Land capability classification of Sugarcane growing red laterite soil pedons of Medak District based on soil characteristics

Physiographic unit	Location	Topography			Physical soil characteristics				Pedon development	Soil fertility factors			LCC
		Slope	Erosion	Drainage	Texture	Sur. coarse Fragments	Sub surface coarse fragments	Soil Depth		CEC	BS	OC	
Pedon 1	Paidigummal	III	III	I	V	III	IV	III	II	IV	IV	III	IIIstef
Pedon 2	Burdipad	III	III	I	IV	III	III	III	II	IV	IV	IV	IIIstef
Pedon 3	Kuppanagar	III	III	II	IV	III	III	III	II	IV	III	III	IIIstef
Pedon 4	Basanthpur	III	III	II	V	III	IV	III	II	IV	III	III	IIIstef
Pedon 5	Kothur	III	III	I	V	III	III	II	II	IV	IV	IV	IIIstef

The soil pedons were classified into 'III tsef' land capability sub-class due to the limitations of slope, texture, soil depth, erosion and soil fertility. The red laterite soils (of the study area were found marginally suitable (Table 6 and Table 7). The soil constraints for sugar cane in red laterite soils were light to medium in surface texture, shallow, moderately deep to deep rooting depth and gravelliness with kaolinite clay mineralogy resulting in poor water holding capacity. Surface crusting is common problem in this soil. The low water holding capacity does not permit post-rainy season cropping without irrigation. They are denuded and subject to serious erosion problems. Intensive leaching causes nutrient losses and release of free iron and aluminium oxides. The free iron and aluminium causes toxicity and nutrient imbalances in terms of N, K, P and Zn. Due to low pH of these soils, acidification causes P fixation with Fe or Al ions and hydroxides resulting in deficiency of phosphorus in the form of insoluble compound of $Al_2 (H_2PO_4)_3$ and FeH_2PO_4; reduced availability of K, Ca, Mg and toxicity due to high availability of Mn, Fe, B and Mo. Improved management practices have good potential to enhance productivity on these soils. Therefore to realize the full potential, these soils should be properly managed, supplemented with organic manures and inorganic fertilizers and to be provided with assured irrigation. If the improvements could be done, there is scope that the area under marginally suitable may be converted to moderately suitable to highly suitable for the cultivation.

Table 6: Soil-site characteristics for land evaluation of sugarcane growing soils of Medak District

Physiographic unit	Location	Climate				Land form characteristics			Physico-chemical characteristics(weighted averages)						
		Rain fall (mm)	Max. temp (oC)	Min. temp (oC)	RH (%)	Slope (%)	Erosion	Drainage	Depth (cm)	Sur. coarse fragments (Vol %)	Texture	pH (1:2.5)	OC (g kg^{-1})	CEC (Cmol (p+)/kg)	B.S (%)
Pedon 1	Paidigummal	855	40.0	26.2	74.0	3-8	Severe	Well	67	35.6	gsc	6.0	4.9	8.8	50.11
Pedon 2	Burdipad	980	40.0	26.2	74.0	3-8	Severe	Well	95	24.2	scl	5.8	5.5	11.2	41.07
Pedon 3	Kuppanagar	980	40.0	26.2	74.0	3-8	Severe	Well	81	31.2	scl	5.6	5.7	8.9	53.48
Pedon 4	Basanthpur	980	40.0	26.2	74.0	3-8	Severe	Well	70	35.0	sc	5.1	5.5	7.7	36.10
Pedon 5	Kothur	980	40.0	26.2	74.0	3-8	Severe	Well	105	29.2	sc	5.4	4.9	11.5	35.21

Table 7: Actual and potential soil suitability for sugarcane growing soils of Medak District

Pedon No	Location	Max. temp (c)	Min. Temp (c)	RH (c)	Slope (t)	Drainage (w)	Texture (s)	Depth (s)	$CaCO^3$ (s)	EC (n)	ESP (n)	pH (n)	BSP (f)	CEC (f)	OC (f)	Actual suitability	Potential suitability
Pedon 1	Paidigummal	S1	S1	S1	S3	S1	S3	S3	S3	S1	S1	S2	S3	S3	S3	S3	S2
Pedon 2	Burdipad	S1	S1	S1	S3	S1	S1	S2	S3	S1	S1	S2	S3	S2	S2	S3	S2
Pedon 3	Kuppanagar	S1	S1	S1	S3	S1	S1	S2	S3	S1	S1	S2	S3	S3	S2	S3	S2
Pedon 4	Basanthpur	S1	S1	S1	S3	S1	S3	S3	S3	S1	S1	S3	S3	S3	S2	S3	S2
Pedon 5	Kothur	S1	S1	S1	S3	S1	S3	S1	S3	S1	S1	S3	S3	S3	S3	S3	S2

Soil suitability class: S_1-Highly suitable; S_2-Moderately suitable; S_3-Marginally suitable
Not suitability class: N_1-Temporarily not suitable N_2-Permanently not suitable AS-Actual Suitability PS-Potential Suitability

References

1. Ashok Kumar HP, Jagdish Prasad. Some typical sugarcane-growing soils of Ahmadnagar district of Maharashtra: Their characterization and classification and nutritional status of soils and plants. J Indian Soc. Soil Sci. 2010; 58(3):257-266.
2. Balpande HS, Challa O, Prasad J. Characterization and classification of grape-growing soils in Nasik district, Maharashtra. Journal of the Indian Society of Soil Science. 2007; 55:80-83.
3. Bhaskar BP, Subbaiah GV. Genesis, characterization and classification of laterites and associated soils along the east coast of Andhra Pradesh. Journal of the Indian Society of Soil Science. 1995; 43(1):107-112.
4. Bhaskar BP, Baruah U, Vadivelu S, Butte PS. Characterization of soils in the „Bil" environs of Brahmaputra valley in Jorhat district, Assam for land use interpretation. Journal of the Indian Society of Soil Science. 2005; 53(1):3-10.
5. Bhaskar BP, Baruah U, Vadivelu S, Raja P, Sarkar D. Pedogenesis in some subaqueous soils of Brahmaputra valley of Assam. Journal of the Indian Society of Soil Science. 2009; 57(3):237 244.
6. Bipul Deka, Baruah TC, Marami Dutta, Karmakar RM. Landscape-Soil relationships and Pedogenic evaluation of soils in Ghiladhari watershed of the Brahmaputra valley of Assam. Journal of the Indian Society of Soil Science. 2009; 57(3):245-252.

7. Blake GR, Hartze KH. Bulk density In Methods of Soil analysis part I(ed A Klute). American Society of Agronomy Incorporation Wrisconsin USA, 1986, 377-382
8. Centre for Monitoring Indian Economy. Assistant Cane commissioner, Nizam Deccan Sugars Ltd, Sangareddy, Medak 2013-2014. Mandal Wise Plant, Ratoon areas, 2014, 1-25.
9. Chapman HO. Cation Exchange Capacity. In Methods of Soil Analysis Part-II (ed CA Black). American Society of Agronomy Incorporation Wisconsin, USA, 1965, 891-901.
10. Chunale H. Evaluation of different grass species for soil binding and soil aggregation properties under sub-mountane zone of Maharashtra. Indian Journal of Soil Conservation. 2004; 32:24-27.
11. Coughlan KJ, McGarry D, Smith GD. The physical and mechanical characterization of Vertisols. In: First regional seminar on management of Vertisols under semi-arid conditions. IBSRAM proceeding Number 6, Nairobi, Kenya. 1986; 89:106-111.
12. Coulombe CE, Wilding IP, Dixon JB. Over view of Vertisols. Characteristics and impacts on society. Advances in Agronomy. 1996; 57:289-296.
13. Curi N, Franzmeir DP. Toposequence of soils from the central plateau of Brazil. Soil Science Society of American journal. 1984; 48:341-346.
14. Digar S, Barde NK. Morphology, genesis and classification of red and lateritic soils. Review of Soil Research in India, Part - II In: Proceedings of the 12th International Congress of Soil Science, New Delhi, India, 1982, 498-507.
15. Diwakar DP, Singh RN. Characterization of soils of Diara land occurring in Gangetic plains of Bihar. Journal of the Indian Society of Soil Science. 1994; 42(3):420-425.
16. Dutta D, Sha KD, Sarkar D, Reddy RS. Quantitative evaluation of soil development in some Alfisols of Andhra Pradesh. Journal of the Indian Society of Soil Science. 1999; 47:311-315.
17. Gabhane VV, Jadhao VO, Nagdeve MB. Land evaluation for land use planning of a micro-watershed in Vidarbha region of Maharashtra. Journal of the Indian Society of Soil Science. 2006; 54:307-315.
18. Gangopadhyay SK, Das PK, Mukhopadhyay N, Nath S, Banerjee SK. Altitudinal pattern of soil characteristics under forest vegetation in Eastern Himalayan region. Journal of the Indian Society of Soil Science. 1990; 38:93-99.
19. Govindarajan SV, Koppar AL. Improved method for determination of gravels in red clay soils. J Indian Soc. Soil Sci. 1975; 23:138-140.
20. Gupta N, Trivedi SK, Bansal KN, Kaul RK. Vertical distribution of micronutrient cations in some soil series of northern Madhya Pradesh. Journal of the Indian Society of Soil Science. 2003; 51:517-522.
21. Jackson ML. Soil Chemical Analysis-Oxford IBH publishing house, Bombay, 1973, 38.
22. Mahapatra SK, Walia CS, Sidhu GS, Rana KPC, Lal T. Characterization and classification of the soils of different physiographic units in the sub humid ecosystem of Kashmir region. Journal of the Indian Society of Soil Science. 2000; 49:572-577.
23. Manickam TS, Mayalagu K, Velayutham A, Elangovan VE, Palaniappan R, Gothandaraman GV *et al*. Study of the soil profile morphology of a Catema, 1973.
24. Meena HB, Giri JD, Mishra HK. Suitability assessment of soils occurring on different landforms of Chittorgarh district, Rajasthan. Agropedology. 2009; 19(2):75-83.
25. Monday O, Mbila Micheal L, Thompson Mbagwu J, David A. Morphological and chemical properties of selected sludge amended Nigerian soil. Soil Science. 2003; 168:660-669.
26. Mustapha Voncir SN, Umar S, Abdul Hamid NA. Status and distribution of exchangeable micronutrients in Haplic Usterts Akko Local Government Area, Gombe State, Nigeria. International Journal of Soil Science. 2011; 1:200-204.
27. Nagassa W, Gebrekidan H. Influence of land management on morphological, physical and chemical properties of some soils Bako, western Ethiopia. Agropedology. 2003; 13:1-9.
28. Nagelschmidt G, Desai AD, Muir A. The minerals in the clay fraction of a blackcotton soil and red earth from Hyderabad, Deccan state, India. Journal of the Indian Society of Soil Science. 1940; 30:639-653.
29. Nayak DC, Mukhopandhyay S, Sarkar D. Distribution of some available micronutrients in alluvial soils of Arunachal Pradesh in relation to soil characteristics. Journal of the Indian Society of Soil Science. 2000; 8:612-613.
30. Patil RB, Prasad J. Characteristic and classification of some sal (*Shorea rubusta*)-supporting soils in Dindori district of Madhya Pradesh. J Indian Soc. Soil Sci. 2004; 52(2):119-125.
31. Peterschmitt E, Fritsch E, Rajot JL, Herbillon AJ. Yellowing, bleaching and feritisation processes in soil mantle of the Western Ghats, south India. Geoderma. 1996; 4:235-253.
32. Piper CS. Soil and plant analysis. Inter Science publication. Inc. New York, 1966.
33. Rajeshwar M, Aariff Khan MA, Ramulu V. Characterization and classification of soils of Ganapavaram pilot area of Nagarjuna Sagar Left Canal Command Area of Andhra Pradesh. International J. Tropical. Agril. 2009; 27:1-7.
34. Rajeshwar M, Mani S. Nutrients status in the surface and subsurface soils of dryland Agricultural Research Station at Chettinad in Sivaganga district of Tamil Nadu. Asian Journal of Soil Sciences. 2014; 9(2):169-175.
35. Rajeshwar M, Mani S. Soil quality assessment in red laterite soils of Chettinad of Sivaganga district of Tamil Nadu. An Asian Journal of Soil Science. 2013; 8(1):25-33.
36. Rajeshwar M, Aariff Khan MA, Ramulu V. Characterization and classification of soils of Ganapavaram pilot area of Nagarjuna Sagar Left Canal Command Area of Andhra Pradesh. International Journal of Tropical Agriculture. 2009; 27:1-7.
37. Rao BRM, Venkatramaiah K, Sharma SK. Genesis, morphology and classification of soils. In: Soils of Andhra Pradesh Ed. Subba Rao IV, published by Andhra Pradesh Agricultural University and Hyderabad Chapter of Indian Society of Soil Science, 1995, 53-57.
38. Reddy RS, Shivaprasad CR. Characterization and evaluation of the potato growing soils of Karnataka. Journal of the Indian Society of Soil Science. 1999; 47:525-532.

39. Reddy RS, Shivaprasad CR, Harindranath CS. Soils of Andhra Pradesh: Their kinds, distribution, characterization and interpretation for optimizing land use. NBSS publication. 1996; 69:1-94
40. Rudramurthy HV, Dasog GS. Properties and genesis of associated red and black soils in north Karnataka. Journal of the Indian Society of Soil Science. 2001; 49:301-309.
41. Rudramurthy HV, Dasog GS, Vasuki N. Pedogenic features of red and black soils developed from dharwar rock system. Journal of Maharashtra Agricultural University. 1997; 22:147-150.
42. Saha PK, Adhikari S, Chatterjee DK. Available iron, copper, zinc and manganese in some fresh water pond soils of Orissa in relation to soil characteristics. Journal of the Indian Society of Soil Science. 1996; 44:681-684.
43. Sankaram A. A Laboratory Manual for Agricultural Chemsitry. Published by Jaya Singer, Asia publishing house, Bombay, 1966, 56-57.
44. Sarkar D, Baruah U, Gangopadhyay SK, Sahoo AK, Velaytham M. Characteristics and classification of soils of Loktak command areea of Manipur for sustainable land use planning. Journal of the Indian Society of Soil Science. 2002; 50:196-204.
45. Sarkar D, Gangopadhyay SK, Velayutham M. Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau. Agropedology. 2001; 11:29-36.
46. Satish A. Studies on land conditions of vegetable growing belt in Narakoduru area of Andhra Pradesh. M.Sc. (Ag.) thesis submitted to Acharya NG Ranga Agricultural University, Rajendranagar, Hyderabad-500030, 2003.
47. Sharma JP, Landey RJ, Kalbande AR, Mandal C. Characteristics and classification of soils of Kathiawar region of Gujarat as influenced by topography. Agropedology. 2001; 11:83-90.
48. Sidhu PS, Raj Kumar, Sharma BD. Characterization and classification of Entisols in different soil moisture regimes of Punjab. Journal of the Indian Society of Soil Science. 1994; 42(4):633-640.
49. Singh IS, Agrawal HP. Characterization and classification of some rice growing soils of Chandauli district of Uttar Pradesh. Agropedology. 2003; 13:11-16.
50. Singh IS, Agrawal HP. Characterization, genesis and classification of rice soils of eastern region of Varanasi, Uttar Pradesh. Agropedology. 2005; 15:29-38.
51. Soil Survey Staff. Soil Taxonomy (second ed.). Agriculture Hand Book NO. 436 USDA, Natural Resource Conservation Service, Washington. D.C., Soil Survey Staff 2003. 1999, 1-782.
52. Soil Survey Staff. Keys to Soil Taxonomy. U.S. Dept. Agric., Natural Resources Conservation Service, Washington D.C. Oxford & IBH Publishing Co., New Delhi, 2010.
53. Thangasamy A, Naidu MVS, Ramavatharam N, Raghava Reddy C. Characterization, classification and evaluation of soil resources in Sivagiri micro watershed of Chittoor district in Andra Pradesh for sustainable land use planning. Journal of the Indian Society of Soil Science. 2005; 53(1):11-21.
54. Tripathi D, Verma JR, Patial KS, Karansingh. Characteristics, classification and suitability of soils for major crops of Kiar–Nagali micro watershed in North West Himalayas. Journal of the Indian Society of Soil Science. 2006; 54(2):131-136.
55. Veneman PLM, Veprakash MJ, Bouma DJ. The physical significance of soil mottling in a Wisconsin toposequence. Geoderma. 1976; 15:103-118.
56. Walia, CS, Rao YN, Rao YS. Micromorphology of endopedons of some soils of Bundelkhand region. Journal of the Indian Society of Soil Science. 2000; 48:813-818.
57. Walkely AJ, Black CA. An estimation of the digestion method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 1934; 37:29-38.
58. Yadav BR, Guptha RN, Singh BD. Catenary relationship existing among the soils of lower Vindhyan plateau in Uttar Pradesh. Journal of the Indian Society of Soil Science. 1977; 25:253-259.