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Mahesh C
Dept. of Soil Science and Agricultural Chemistry, College of Agriculture, PJTSAU, Hyderabad, Telangana, India

Rajeshwar Naik Malavath
Dept. of Soil Science and Agricultural Chemistry, College of Agriculture, PJTSAU, Hyderabad, Telangana, India

Balaguruvaiah D
Dept. of Soil Science and Agricultural Chemistry, College of Agriculture, PJTSAU, Hyderabad, Telangana, India

Vidyasagar GECH
Dept. of Soil Science and Agricultural Chemistry, College of Agriculture, PJTSAU, Hyderabad, Telangana, India

Correspondence
Mahesh C
Dept. of Soil Science and Agricultural Chemistry, College of Agriculture, PJTSAU, Hyderabad, Telangana, India

Genesis, classification and evaluation of some sugarcane growing black soils in semi arid tropical region of Telangana

Mahesh C, Rajeshwar Naik Malavath, Balaguruvaiah D and Vidyasagar GECH

Abstract
The morphological, physical and physico-chemical characteristics of some sugarcane growing black soils of Medak district of Telangana State have been studied for proper appraisal of their productivity potential and their rational use. The soils were formed at nearly level and plain topography on granitic gneiss parent material mixed with calcareous murram. The soils are deep to very deep. The textural class of fine earth fraction was clay loam and clayey and had angular blocky structure. The colour varied from very dark grayish brown (10 YR3/2) to dark yellowish brown (10YR 4/4) under dry condition. The clay content ranged from 38.7 to 71.4 percent in surface and 37.2 to 76.2 percent in subsurface horizons. The silt clay ratio was found to be less than 0.5 indicating the moderate weathering. The soil pH was neutral to strongly alkaline in range (6.5 to 9.2) and non saline in nature. The organic carbon content was medium to high (4.3 to 8.4 g kg^{-1}) in surface horizons. The soils are moderately calcareous with $CaCO_3$ ranges from 1.3 to 7.8 percent with high in cation exchange capacity. The exchangeable bases were in the order of $Ca^{+2} > Mg^{+2} > Na^{+} > K^{+}$ on the exchange complex. The CEC /clay ratios soils were high (0.58 to 0.86). It indicates the presence of smectitic type of clay minerals. The soils have been classified as Typic Haplusterts and Vertic Haplustepts based on the morphological, physical, physico-chemical, and chemical properties. The study area classified into 'III swef' land capability sub-class due to the limitations of drainage, texture, erosion and soil fertility limitations. The soils were moderately suitable to highly suitable for cultivation of sugarcane.

Keywords: Genesis, classification, evaluation, sugarcane growing black soils, semi arid tropical

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 which results the reduction forests 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. Sugarcane is cultivated in the Medak district in an area of 22076 hectares producing 1721 thousand tonnes with an average productivity of 74.41 t ha^{-1}.

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 percent (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 extending over an area of 9,519 km^2. It forms a part of Deccan Plateau under Godavari basin and lies between North Latitudes 17^0 27' and 18^0 18' and East longitudes 77^0 28' and 79^0 10' falling in topographical sheet nos. 56 F, G, J and K of Survey of India. 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 divided into 12 agricultural divisions.

Based on the morphological characteristics and physiography, four geo-referenced pedon were selected in Medak district such as Aroor (Pedon 1), Budera (Pedon 2), Andole (Pedon 3) and Pulakurty (Pedon 4). Physiographically, 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. It has been divided into three physiographic regions, *viz.*, granite and granite-gneiss landform, basalt landform and laterite landform. The important rock types are Peninsular Gneissic complex, Dharwar super group associated with Younger intrusive of Achaean age separated unconformably with overlying Basaltic flows of late Cretaceous to early Eocene age with sub-Recent to Recent alluvium along the stream courses. The Archaean or Peninsular gneisses occur all over the district in 6, 86,853 ha area (70.7%). They are partially metamorphosed igneous rocks. They remained stable as a "Shield" area for a very long time. The rocks are composed of grey or pink feldspars, quartz and muscovite mica (NBSS&LUP, 2005).

The climate is semi-arid. The mean annual rainfall is 870 mm of which 76 percent is received during the southwest monsoon (June to September), 14 percent during the northeast monsoon (October to December) and 8 percent during the premonsoon period (March to May). The rainfall is highest in the month of August. The climate of Medak district is comparatively equitable and although it is very hot in May with mercury rising up to 42 ºC. The temperature dips to 12ºC in winters during the months of December and January. The mean maximum and minimum temperature vary from 40° to 26 °C. Mean humidity varies from 65 percent in July to 74 percent 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 tomertose 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 black soil pedons were selected on the basis of soil heterogeneity and land forms in different locations of sugarcane growing areas of the district. The profiles were dug up to parent rock and studied for their morphological characteristics. Soil samples were collected from each horizon of four representative pedons for laboratory analysis. The samples were air dried and ground to pass through 2 mm sieve. 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) [15]; cation exchange capacity (Chapman, 1965) [7]; organic carbon (Walkly and Black, 1934) [46]; free CaCO3 (Piper 1966) [26]; bulk density (Blake and Hartze 1986) [5]; moisture retention at 33 and 1500 kPa (Richards, 1954) [32]; COLE (Soil Survey Staff, 2010) [40]; water holding capacity and volume expansion gravel by gravimetry method (Govindarajan and Koppar, 1975) [14]; Soil texture by International Pipette Method (Piper, 1966) [26]. The soils were characterized and classified as per Keys to Soil Taxonomy (Soil Survey Staff, 2010) [40].

Results and discussion

Morphological properties

Major part of the study area is coming under nearly level to gently sloping. The details of the morphological properties of the soils were presented in Table 1. The drainage condition of the pedon 1, 2, 3 and 4 was poorly drained with irregular $CaCO_3$ concretions. Soil depth of the pedons 1, 3 and 4 were very deep (>150 cm) and deep soils were found in nearly level to very gently sloping plain. The pedon 2 was moderately deep (75-100 cm), 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 results obtained in the present study are in agreement with the findings of Ramprakash and Seshagiri Rao (2002) [30]. All the pedons were characterized as A- B-C horizons. The thickness of the surface horizons varied from 14.0 (pedon 2) to 27.0cm (pedon 4) cm and sub surface horizons ranged from 17.0 (pedon 2) to 40.0 cm (pedon 3). Pedon 1, 3 and 4 showed slicken sides (Bss). The surface horizon was designated as 'Ap' horizon at all the location because of the ploughed and disturbed condition due to cultivation. Similar observation was made by Rajeshwar *et al* (2009) [29] and Ashok kumar and Jagadish Prasad (2010) [1] to represent ploughed condition of the soils.

The 'B' horizon of soils (pedon 1, 9 and 12) exhibited prominent, well-formed distinct slickensides. Hence the symbol 'ss' (sub-ordinate distinction) was suffixed to the master horizon symbol 'B'. Similar type of designation was represented by Chinchmalatpure *et al.* (2005) [8]; Ashok kumar and Jagadish Prasad (2010) [1]; Rajeshwar and Mani (2015) [28]. The boundary between the sub-horizons of 'Bss' horizon was described as diffuse because of the presence slickensides and the clay content was high enough for clay textural class. Similar finding was noticed by Balapande *et al.* (2007) [2]. The soil colour varying from very dark grayish brown (10 YR3/2) to dark yellowish brown (10YR 4/4) under dry condition and very dark gray (10 YR3/1) to dark yellowish brown (10YR 4/4) under moist condition. The dark colour appears due to the presence of iron and manganese oxide in combination with the organic complex (Srinivasan *et* *al.*, 1969) [41] and parent material, topography, high clay content, clay-humus complex, smectite type of clay, moisture *etc.*, were the factors responsible for the dark colour of the soils (Santsingh, 1987) [34].

The surface horizons and subsurface horizons had blocky structure (sub-angular and angular) and the peds were medium to coarse in size with strong grade (strength). The pedality of black soils was more strongly developed because of the high clay content, CEC, BSP and dominance of montmorillonite type of clay. Stronger pedality of soils at lower topographic positions might be due to finer fractions (Shyampura *et al.*, 1994) [38]. The textural class of fine earth fraction was clay loam (pedon 2) to clay (pedon 1, 3 and 4) throughout the depth. The uniformity in texture was due to the argillopedoturbation operating in the black soil profiles (Buol *et al.*, 1998) [6]; Marathe *et al*. (2003) [17] and Balapande *et al.* (2007) [2]. The horizons of soils exhibited sticky to plastic to very sticky to very plastic, firm and hard to very hard in wet, moist and dry conditions, respectively, which might be due to high clay content. Similar observations made by Sarkar *et al.* (2001) [35] in soils of lower outlier of Chhotanagpur plateau and Rajeshwar and Mani (2013) [27].

Vertic properties like surface cracks ranging from 3-8 cm wide, slickensides, microknolls and microridges were developed in the soil pedons (1, 3 and 4). The soil pedons (1, 2, 3 and 4) 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 slickensides in the deeper horizons and mounds and depressions on the surface. Similar observations were made by Subbaiah and Manickam (1992) [42]; Ashok kumar and Jagadish Prasad (2010) [1]. Pressure faces were common in sub-surfaces horizon of pedon 1, 3 and 4 and slickensides were observed from 52 and 55 cm of depth, respectively and their thickness is more than 40 cm. Moderately strong to violent effervescences were observed with dilute HCl. Many calcium carbonate nodules (calcrets) were formed in lower horizons of the pedons of 1, 2, 3 and 4. The colour of $CaCO_3$ concretions vary from pale brown to light grayish white, small to bigger size (0.2 mm to 8.0 cm diameter), hard irregular outlined found in surface layers. The soft and easily separable lime nodules developed a zone of accumulation below 150 to 178 cm (Pedon 1, 3 and 4). 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*. (1982) [20]. Sub surface hard pan with high bulk density was observed in sugarcane growing black soil pedon 1 and 4 where the penetration and proliferation roots are very few within 20-40 cm depth due to decades of cultivation practices of shallow ploughing and migration of finer clays to deeper layers resulted in sub soil hard pan to some extent.

Physical properties

The clay content varied from 37.2 percent (pedon 2) to 76.2 percent (pedon 4). Increase of clay up to certain depth and a decrease was observed in pedon 1, 7, and 9 due to the illuviation process occurring during soil development (Table 2). Similar observations were also made by the clay content was found gradually increased in pedon 4. The increased clay content with depth was an evidence of pedogenic development as their formation and distribution is time dependent (Bhaskar *et al.*, 2009) [4] and also these variations could be attributed to the parent material, topography, *in situ* weathering and / or pedogenesis (Rudramurthy and Dasog, 2001) [33]. The silt content varied from 16.5 (pedon 3) to 19.8 (pedon 1) percent, where as in sub surface horizons ranged from 16.9 (pedon 9) to 20.1 (pedon 4) percent. There was a gradual increase in silt content with depth in pedon 4 and no uniform trend was observed in the distribution pattern of silt content with depth in all other pedons**.** The silt content in most of the pedons showed an irregular trend with soil depth. It might be due to coarse nature of silt than clay, which restricts its movement with percolating water (Sharma *et al.*, 2001) [37].

The sand content varied from 10.3 (pedon 4) to 41.2 (pedon 2) percent in surface horizon whereas, in subsurface horizon 3.6 (pedon 4) to 43.2 (pedon 2) percent. A decreasing trend in sand content with depth was observed in pedon 1, 3 and 4 due to the translocation / migration of finer particles into the lower layers and surface erosion. These observations were in agreement with those of Bhaskar and Subbaiah (1995) [3], Sarkar *et al.* (2001) [35] and Monday *et al.* (2003) [19]. 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 ratios of sand / silt (0.18 (pedon 4) to 2.45 (pedon 2)), silt / clay (0.25 (pedon 4) to 0.50 (pedon 2)) and sand / (silt + clay) (0.04 (pedon 4) to 0.77 (pedon 2)). The silt clay ratio was found to be less than 0.5 in black soils indicating the moderate weathering (Rajeshwar and Mani, 2013) [27].

The bulk density of the soils ranged from 1.43 Mg m^{-3} (pedon 2) to 1.56 Mg m^{-3} (pedon 1) in surface horizons whereas in subsurface horizons ranged from1.50 Mg m^{-3} in (pedon 2) to 1.68 Mg m^{-3} in (pedon 1). Bulk density increased with increasing depth in all pedons might be due to decrease in organic matter content, more compaction, and less aggregation (Singh and Agarwal, 2005 and Rajeshwar and Mani, 2013) [39, 27] except (pedon 2) showed irregular trend with soil depth. The Bss horizon of pedon 1, 3, and 4 had higher bulk density than the surface and sub-surface horizons which may be due to high clay content resulting in greater compaction in swelling clay soils (Ashok kumar and Jagadish Prasad, 2010) [1]. The higher water-holding capacity was recorded and varied from 32 percent (pedon 2) to 53.0 percent (pedon 3). The water holding capacity showed increasing trend with soil depth in pedon 4. The other pedons were exhibited an irregular trend with depth. In all the locations these values showed increasing trend with increasing clay content (Rudramurthy and Dasog, 2001) [33]. The pore space varied from 45.0 percent (pedon 12) to 62.0 percent (pedon 2). A reduction in porosity with depth was observed in pedon 1 due to soil compaction whereas reverse trend was noticed in pedon 9 and 12 (Rajeshwar and Mani, 2013) [27].

The higher volume of expansion was varied from 23.1 percent (pedon 1) to 30.4 percent (pedon 3). The volume expansion was high in black soil pedons due to presence smectite type of clay minerals (Rajeshwar and Mani, 2013) [27]. The shrinkage and swelling phenomenon was exhibited by black soils, coefficient of linear extensibility (COLE) was determined and ranged from 0.13 (pedon 3) to 0.21 (pedon 1). The studied black soils fall in the category of very high (greater than 0.09) swell-shrink class (Nayak *et al.*, 2006) [22] might be due to increased amount of clay (Ashok kumar and Jagadish Prasad, 2010 and Rajeshwar and Mani, 2013) [1, 27].

Physico-Chemical Properties

The pedon wise physico-chemical properties are described in table 3). The pH value of soils (pedon 1, 2, 3 and 4) found to vary from 6.5 (pedon 2) to 8.2 (pedon 1) in surface horizons (neutral to moderately alkaline) whereas in subsurface horizons ranged from 6.7 in pedon 2 to 9.2 in pedon 3 (neutral to strongly alkaline). The pH increased with depth in the pedon 3 might be due to increase in bases with depth and their complete downward leaching. The distribution was irregular in pedon 1, 2 and 4 which might be due to downward movement of bases and they get adsorbed at different layers irregularly (Rajeshwar and Mani, 2013) [27]. The EC was non saline, values found to vary from 0.16 dS m^{-1} (pedon 4) to 0.24 dS m^{-1} (pedon 1) in surface horizons whereas in subsurface horizons ranged from 0.18 dS m^{-1} in (pedon 4) to 0.40 dS m^{-1} in pedon 3. The EC gradually increased with depth might be due to the leaching of electrolytes to the lower depth and also due to foraging of nutrient ions by the vegetation in the surface layer (Renukadevi, 2003) [31].

The organic carbon content found to vary from 6.6 g kg^{-1} (pedon 2) to 8.4 g kg^{-1} (pedon 4) in surface horizons whereas in subsurface horizons ranged from 1.7 g kg^{-1} in pedon 1 to 6.7 g kg^{-1} in pedon 4. The organic carbon content relatively higher in surface horizons than sub-surface horizons in all the pedons and it decreased with depth except pedon 2. This was attributed 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. These observations are in accordance with results of Rajeshwar *et al.* (2009) [29].

The $CaCO_3$ content was varying from 2.8 percent (pedon 2) to 7.8 percent (pedon 4) in surface horizon and 3.2 percent (pedon 2) to 11.6 percent (pedon 1) in subsurface horizon. The content was relatively higher in deeper layers than in surface layers might be due to the downward movement of it along with percolating water (pedogenic and lithogenic) in soils of semi-arid regions (Pal *et al.*, 2000) [24]. Increase in the calcium carbonate content down the depth was attributed to the leaching of bicarbonate from upper layer during rainy season and their subsequent precipitation as carbonate in the lower layer (Maji *et al.*, 2005) [16].

Exchangeable properties

The cation exchange capacity was higher and varied from 24.4 c mol (p^+) kg^{-1} (pedon 2) to 56.2 c mol (p^+) kg^{-1} (pedon 4) in surface layers and 24.5 c mol (p^+) kg^{-1} (pedon 2) to 65.2 c mol (p^+) kg^{-1} (pedon 4) in sub surface layers. The high CEC of the black soils was attributed to the high clay content and smectitic clay mineralogy (Pal and Deshpande, 1987). The CEC/clay ratios were found to vary from 0.58 (pedon 7) to 0.86 (pedon 12). The CEC values are indicating that the black soils are less weathered. Higher values of CEC/clay ratio indicate the less weathered nature of the soils with weatherable primary minerals (Buol *et al.*, 1998) [6]. Soil exchange complex was dominated with Ca in all the pedons compared to other exchangeable cations and varied from 11.4 c mol (p^+) kg^{-1} (pedon 2) to 25.2 (pedon 4) in surface layers and 12.2 (pedon 2) to 30.9 (pedon 4) in sub surface layers. In general, exchangeable Ca content increased with depth in pedons 2 and 4 and decreased with depth in pedon 3. There was no regular pattern of distribution with depth was noticed in pedon 1.

The Mg was varied from 6.0 c mol (p^+) kg^{-1} (pedon 2) to 16.3 c mol (p^+) kg^{-1}(pedon 4) in surface layers and 8.4 c mol (p^+) kg^{-1} (pedon 3) to 20.6 c mol (p^+) kg^{-1}(pedon 4) in sub surface layers. Pedons 1, 2 and 4 showed increasing trend with soil depth. The exchangeable Na varied from varied from 0.7 c mol (p^+) kg^{-1} (pedon 3) to 0.81 c mol (p^+) kg^{-1} (pedon 4) in surface layers and 0.8 c mol (p^+) kg^{-1} (pedon 3) to 1.13 c mol (p^+) kg^{-1} (pedon 4) in sub surface layers. The exchangeable Na content increased with depth in pedons 1 and 7 and in the rest of the pedons, the depth wise distribution was irregular.

The K in soils varied from 0.5 c mol (p^+) kg^{-1} (pedon 3) to 0.80 c mol (p^+) kg^{-1} (pedon 4) in surface layers and 0.2 c mol (p^+) kg^{-1} (pedon 3) to 1.6 c mol (p^+) kg^{-1} (pedon 1) in sub surface layers. The pedon 4 shows that the exchangeable K content decreased with depth. The remaining pedons showed inconsistent pattern with depth. The exchangeable bases in soil pedons were in order of $Ca^{+2} > Mg^{+2} > Na^+ > K^+$ on the exchange complex. From the distribution of Ca^{+2} and Mg^{+2}, it is evident that Ca^{+2} shows the strongest relationship with all the species, comparing these ions (Ca^{+2}, Mg^{+2}, K^+ and Na^+) it was clear that Mg^{+2} was present in low amount than Ca^{+2} because of its higher mobility. These results are in conformity with findings of Thangasamy *et al.*, (2005) [44]. The base saturation percentage was higher in black soil pedons ranged from 75.0 percent (pedon 2) to 87.4 percent (pedon 3) in surface layers and 60.69 percent (pedon 3) to 87.40 percent (pedon 3) in sub surface layers might be due to the dominance of smectitic type of clays and moderate to strongly alkaline reaction (Singh and Agarwal, 2005 and Gabhane *et al.*, 2006) [39, 13]. The SAR ranged from 0.04(pedon1) to 0.14 (pedon 4) in surface layers and 0.04 (pedon 2) to 0.28 (pedon 3) in sub surface layers. The pedons 1 and 4 found to follow an increasing trend with the increase in depth. All other 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) [40]. At the highest category (order), the presence or absence of diagnostic horizons which are indications of pedogenic processes are considered. At sub-order level, the moisture and temperature regimes were used. At lower categories (great group, family *etc.*) mineralogy, texture, soil chemical properties and drainage are considered. The soils of the study area were characterized and classified into two soil orders *viz.*, Vertisols and Inceptisols.

The pedons 1, 3 and 4 were classified under Vertisols because of the following features. A layer of 25 cm or more thick, with an upper boundary with in 100 cm of the mineral soil surface; clayey texture, more than 30 percent clay in fine earth fraction throughout the depth; gilgai micro-relief (micro-knolls and micro-ridges) on the surface; distinct intersecting slickensides in lower horizons; cracks of greater than 1 cm width which remained open and close periodically to the surface from a depth of more than 40 cm and Absence of lithic or paralithic contact, duripan, petrocalcic horizon within 50 cm from the surface. Based on these characters, the soils were grouped under order “Vertisols”. The pedon 2 was classified under the order Inceptisols based on the presence of cambic subsurface horizon due to the following features. A texture of loamy very fine sand or finer; absence of rock structure in one half or more of its volume. In these pedons the subsurface horizons were recognized as cambic horizons (Thangasamy *et al.*, 2005) [44]. As the moisture regime is Ustic, the pedons 1, 3 and 4 were classified as Usterts at sub order level. The pedons 1, 3 and 4 were further placed under the Haplusterts at great group level and Typic Haplusterts at sub group level because these pedons had deep cracks that remained open for more than 150 cumulative days most years (Surekha *et al*., 1997) [43]. The pedon 2 was classified as Haplustepts at great group level and Vertic Haplustepts at sub group level because of the base saturation is more than 60 percent at a depth between 0.2 to 0.6 m from the soil surface and due to presence of cracks within 125 cm of the mineral soil surface that are 5 mm or more wide through a thickness of 30 cm or more for some time in normal years.

The pedon 1 and 4 had clay content more than 60 percent on weighted average in fine earth fraction. Hence, it was qualified for "Very fine" particle size class. The pedon 3 had clay content less than 60 percent on weighted average in fine earth fraction which is qualified for "fine" particle size class and showed relative dominance of smectite mineral. Hence the clay mineralogical class of these pedons was "smectitic" (Rajeshwar and Mani, 2015) [28]. The pedon 2 had showed clay content more than 35 percent on weighted average in fine earth fraction and it was qualified for "fine" particle size class (Ramprakash and Rao, 2002) [30]. The difference between mean summer and winter temperatures was less than 6 ^{0}C and the mean annual soil temperature was more than 22 ^{0}C. Therefore, the study area was classified as "iso-hyperthermic" temperature regime (Sehgal, 1996) [36].

Pedogenesis

Eastern Ghats (south) of Deccan trap had been divided into three landforms *viz.*, granite and granite - gneiss, dharawars, and cuddapahs and kurnools. In the very gently sloping lands and valleys, the finer factions and calcium carbonate were accumulating with weathered granitic gneiss. Hence, the parent material for the development of these black soils was weathered granite - gneiss at higher elevations and it was mixed with calcareous murram in very gently sloping lands, plains and valleys. The black soils (pedon 1 and 3) were derived from weathered granite-gneiss mixed with calcareous murram whereas pedon 4 was derived from weathered basalt mixed with calcium carbonate nodules. Similar occurrence of black soils on granite-gneiss was reported earlier by Paramasivam and Gopalaswamy (1993) [25]; Subbaiah and Manickam (1992) [42]; Vijay Kumar *et al.* (1994) [45]. The black soils (pedon 1, 2, 3 and 4) were developed on nearly level to very gently sloping lands with slope percent varying between 1 and 3. Many scientists in different locations also reported formation of black soils on lower elements of topography. Similar results were reported by Nagelschmidt *et al.* (1940) [21] in deccan state of India*;* Curi and Franzmeir (1984) [10] in central plateau of Brazil in Bako soils of Ethiopia and Gabhane *et al.* (2006) [13] in Vidarbha region. The soils of the study area might have been formed during Archean period about 3800 million years back. Digar and Barde (1982) [11] reported that it was during Archean period, the black soils were developed during Cenozoic era, which included tertiary and quaternary period (Coulombe *et al*., 1996) [9].

Soil Forming Processes

The black soils of sugarcane growing area (pedon 1, 3 and 4), prominent or distinct slickensides were noticed in the lower layers. Slickensides were originated due to sliding of one soil mass over the other due to swelling and expansion of clay minerals in wet season. They were seen as polished smooth surfaces in dry period when profile was opened up to the deeper layers. The pedogeneic process was nothing but argillo pedoturbation. Similar reports were earlier given by Mermut *et al.* (1996) [18] and Maji *et al.* (2005) [16]. In the black soil locations, narrow to wide cracks were noticed revealing the shrinking nature of the clay minerals in dry period. The soil particles particularly clay which were loose on the surface, due to slight disturbance, wind and / or rain migrate to the deeper layers along the sides of the cracks. This type of mechanical migration of inorganic particles in the profile was described as lessivage (Buol *et al.,* 1998) [6]. The 'B' horizon in the pedon 2 was exhibiting features of altered horizon and thereby resulted in structural / colour 'B' horizon (cambic horizon, a sub-surface diagnostic horizon). The colour of the soil was darker in dry and moist conditions due to release of iron oxides from weathering of rocks and minerals and their accumulation in the solum.

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. Based on soil properties, soils were classified into land capability classes III with 'III swef' land capability sub-class due to the limitations of drainage, texture, erosion and soil fertility limitations Table 6). Similar interpretation was also made by Sarkar *et al.* (2001) [35] and Rajeshwar and Mani (2013) [27].

Soil Site Suitability Evaluation for Sugarcane

Soil Site suitability evaluation for any crops forms an essential part of every land use planning programme. The soils of the study area were evaluated for their suitability for growing sugar cane by the following criteria outlined by Important parameters *viz*., maximum and minimum temperature, relative humidity, slope, erosion, drainage, texture, coarse fragments, depth, soil reaction, EC, $CaCO_3$, organic carbon, CEC, ESP and BSP were taken into consideration for evaluating the suitability of crops (Table 7). The land suitability order and classes were assigned to the soils as per the guidelines given in the Frame Work of Land Evaluation (FAO, 1976) [12].

The land is given a suitability rating depending on how well its properties meet the requirement of the crop. If all the properties match well with the crop requirements, the land is considered highly suitable: otherwise less suitable (moderate and marginal) and even not suitable depending upon the deviation of the land properties from the optimal growth requirement of the crops. The studied sugar cane growing soils vary in their suitability, according to the criteria for the determination of land suitability classes (Table 8).

The suitability for sugarcane cultivation in black soil pedons (1,2,3 and 4) were found moderately suitable to highly suitable with limitation of poor drainage, texture, runoff, erosion and $CaCO_3$, high pH, sub surface hard pan, Slope, medium OC and N and Low Zn (Table 9) with slow permeability and low hydraulic conductivity. In the black soil area, improved management practices have good potential to enhance productivity on these soils. If the improvements could be done such as addition of river sand @ 100 t ha^{-1} and application of 100 cartloads of red loam soil; deep ploughing the field with mould board plough or disc plough during summer to enhance the infiltration and percolation will help to enhance moderately suitable to highly suitable for the cultivation of sugarcane.

Table 1: Morphological characteristics of Sugarcane growing 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						
	Sadasivpet division															
1	Aroor	Very-Fine Smectitic Calcareous Superactive Isohyperthermic Typic Haplusterts (Latitude º N 17 º 37'42.34" Longitude º E 77 º 53'10.33" Altitude 539 m)														
		Ap	0-25	10YR3/2	10YR3/2	c	m1abk	sh	fi	vs&vp	ms	ff	mf	cs		Gilgai relief; surface cracks (5-8 cm wide); slickensides; sub surface hard pan with high B.D
		BA	25-52	10YR3/2	10YR3/1	c	m2abk	h	vfi	vs&vp	ms	ff	cf	gs		
		Bss1	52-79	10YR3/2	10YR3/2	c	m2abk	h	vfi	vs&vp	ms	ff	-	cd		
		Bss2	79-115	10YR4/2	10YR3/2	c	m2abk	h	vfi	vs&vp	s	ff	-	cd		
		Bss3	115-155	10YR4/2	10YR3/2	c	m2abk	h	fi	vs&vp	vs	ff	-	cd		
		C	155+	Mixed with calcareous murram												
2	Budera	Fine Smectitic Superactive Non calcarious Isohyperthermic Vertic Haplustepts (Latitude º N 17 º 38'37.18" Longitude º 77 º 50'35.00"Altitude 585 m)														
		Ap	0-14	10YR3/2	10YR3/1	cl	f1sbk	sh	fr	s&p	ms	ff	mf	cs	-	subsurface cracks(3-4cm) &slickensides
		Bw1	14-41	10YR3/2	10YR3/1	cl	m1sbk	h	fr	vs&p	ms	ff	ff	cw	-	
		Bwss1	41-58	10YR4/2	10YR4/1	cl	m1sbk	h	fr	vs&p	ms	ff	ff	cw	-	
		Bwss2	58-79	10YR4/2	10YR4/2	cl	m1sbk	h	fi	vs&p	ms	ff	-	cw		
		BC	79-100	10YR4/4	10YR4/4	cl	m1sbk	h	fi	s&p	ms	ff	-	cw		
	Jogipet division															
3	Andole	Fine Smectiti Calcareous Superactive Isohyperthermic Typic Haplusterts (Latitude º 17 º 49'34.54" Longitude º 78 º 05'07.31" Altitude 492 m)														
		Ap	0-25	10YR3/2	10YR3/2	c	m2sbk	h	fi	vs&vp	ms	ff	mf	cs	-	Gilgai relief surface cracks (5-8 cm wide) and subsurface cracks (3-5cm) slickensides conca
		BA	25-65	10YR3/2	10YR3/2	c	c2abk	h	fi	vs&vp	ms	ff	ff	cs	-	
		Bss1	55-85	10YR3/2	10YR3/2	c	c2abk	h	vfi	vs&vp	ms	ff	ff	cd	-	
		Bss2	85-117	10YR3/2	10YR3/2	c	c2abk	h	vfi	vs&vp	ss	ff	-	cd	-	
		Bss3	117-145	10YR3/2	10YR3/2	c	c2abk	h	vfi	vs&vp	ss	ff	-	cd	--	
		Bss4	145-178	10YR3/2	10YR3/2	c	c2abk	h	vfi	vs&vp	ss	ff	-	cd		
	Narayankhed division															
4	Pulkurty	Very- Fine Smectitic, Calcareous Superactive Isohyperthermic Typic Haplusterts (Latitude º 17 º 56'45.77" Longitude º 77 º 42'43.82" Altitude 527 m)														
		Ap	0-27	10YR3/2	10YR3/2	c	m2sbk	h	fi	vs&vp	-	ff	cf	cs		Gilgai relief surface cracks (5-7 cm wide); slickensides; sub surface hard pan with high B.D.
		BA	27-55	10YR3/2	10YR3/2	c	c2abk	h	fi	vs&vp	ms	ff	cf	cs		
		Bss1	55-87	10YR3/2	10YR3/2	c	c2abk	h	fi	vs&vp	ms	ff	ff	cs		
		Bss2	88-124	10YR3/2	10YR3/2	c	c2abk	h	fi	vs&vp	s	ff	-	cd		
		Bss3	124-150	10YR3/2	10YR3/2	c	c2abk	h	fi	vs&vp	s	ff	-	cd		

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

Table 2: Physical characteristics of Sugarcane growing 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 (%)	COLE
					Sand	Silt	Clay					
	Sadasivpet division											
1	Aroor	Very-Fine Smectitic Calcareous Superactive Isohyperthermic Typic Haplusterts (Latitude º N 17 º 37'42.34" Longitude º E 77 º 53'10.33" Altitude 539 m)										
		Ap	0-25	11.50	20.1	19.8	59.6	1.56	55.0	48.0	23.1	0.14
		BA	25-52	10.50	19.0	18.4	62.1	1.59	53.0	51.0	23.7	0.16
		Bss1	52-79	9.00	17.3	17.3	63.9	1.61	50.0	49.0	25.5	0.18
		Bss2	79-115	9.50	16.8	17.2	64.3	1.65	48.0	46.0	26.4	0.19
		Bss3	115-155	8.30	16.4	20.0	61.1	1.68	46.0	45.0	28.4	0.21
		C	155+	Mixed with calcareous murram								
2	Budera	Fine Smectitic Superactive Non calcarious Isohyperthermic Vertic Haplustepts (Latitude º N 17 º 38'37.18" Longitude º 77 º 50'35.00"Altitude 585 m)										
		Ap	0-14	12.30	41.2	18.6	38.7	1.43	46.0	32.0	23.10	-
		Bw1	14-41	14.00	42.3	17.3	40.1	1.52	52.0	38.0	26.24	-
		Bwss1	41-58	14.50	43.2	18.6	37.2	1.50	55.0	36.0	27.13	-
		Bwss2	58-79	17.00	42.5	17.9	39.3	1.61	61.0	38.0	29.14	-
		BC	79-100	17.60	39.9	17.2	42.1	1.62	62.0	39.0	29.10	-
	Jogipet division											
3	Andole	Fine Smectiti Calcareous Superactive Isohyperthermic Typic Haplusterts (Latitude º 17 º 49'34.54" Longitude º 78 º 05'07.31" Altitude 492 m)										
		Ap	0-25	10.9	28.2	16.5	54.2	1.51	45.0	44.0	22.8	0.13
		BA	25-65	10.4	25.4	16.9	57.6	1.50	48.0	47.0	23.7	0.14
		Bss1	55-85	11.1	23.2	17.4	58.9	1.54	51.0	49.0	25.8	0.16
		Bss2	85-117	12.6	20.1	18.0	61.7	1.58	52.0	51.0	26.8	0.18
		Bss3	117-145	12.3	19.0	17.7	63.1	1.58	52.0	48.0	30.4	0.18
		Bss4	145-178	12.5	18.8	19.6	61.4	1.60	55.0	53.0	30.1	0.17
	Narayankhed division											
4	Pulkurty	Very- Fine Smectitic, Calcareous Superactive Isohyperthermic Typic Haplustrets (Latitude º 17 º 56'45.77" Longitude º 77 º 42'43.82" Altitude 527 m)										
		Ap	0-27	10.0	10.3	17.5	71.4	1.49	45.0	46.0	23.5	0.14
		BA	27-55	9.4	8.2	18.1	73.4	1.55	48.0	47.0	24.6	0.15
		Bss1	55-87	8.9	6.3	18.4	75.1	1.62	51.0	49.0	26.8	0.17
		Bss2	88-124	10.1	4.3	19.5	75.7	1.66	53.0	51.0	28.6	0.19
		Bss3	124-150	10.5	3.6	20.1	76.2	1.66	53.0	52.0	30.1	0.20

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)
	Sadasivpet division								
1	Aroor	Very-Fine Smectitic Calcareous Superactive Isohyperthermic Typic Haplusterts (Latitude º N 17 º 37'42.34" Longitude º E 77 º 53'10.33" Altitude 539 m)							
		Ap	0-25	39.9	79.4	1.02	0.33	0.50	0.25
		BA	25-52	37.4	80.5	1.03	0.30	0.51	0.24
		Bss1	52-79	34.6	81.2	1.00	0.27	0.50	0.21
		Bss2	79-115	34.0	81.5	0.98	0.27	0.49	0.21
		Bss3	115-155	36.4	81.1	0.82	0.33	0.45	0.20
		C	155+	Mixed with calcareous murram					
2	Budera	Fine Smectitic Superactive Non calcarious Isohyperthermic Vertic Haplustepts (Latitude º N 17 º 38'37.18" Longitude º 77 º 50'35.00"Altitude 585 m)							
		Ap	0-14	59.8	57.3	2.22	0.48	0.69	0.72
		Bw1	14-41	59.6	57.4	2.45	0.43	0.71	0.74
		Bwss1	41-58	61.8	55.8	2.32	0.50	0.70	0.77
		Bwss2	58-79	60.4	57.2	2.37	0.46	0.70	0.74
		BC	79-100	57.1	59.3	2.32	0.41	0.70	0.67
	Jogipet Division								
3	Andole	Fine Smectiti Calcareous Superactive Isohyperthermic Typic Haplusterts (Latitude º 17 º 49'34.54" Longitude º 78 º 05'07.31" Altitude 492 m)							
		Ap	0-25	44.7	70.7	1.71	0.30	0.63	0.40
		BA	25-65	42.3	74.5	1.50	0.29	0.60	0.34
		Bss1	55-85	40.6	76.3	1.33	0.30	0.57	0.30
		Bss2	85-117	38.1	79.7	1.12	0.29	0.53	0.25
		Bss3	117-145	36.7	80.8	1.07	0.28	0.52	0.24
		Bss4	145-178	38.4	81.0	0.96	0.32	0.49	0.23
		C	90+	Weathered granite- gneiss					
	Narayankhed division								
4	Pulkurty	Very- Fine Smectitic, Calcareous Superactive Isohyperthermic Typic Haplustrets (Latitude º 17 º 56'45.77" Longitude º 77 º 42'43.82" Altitude 527 m)							
		Ap	0-27	27.8	88.9	0.59	0.25	0.37	0.12
		BA	27-55	26.3	91.5	0.45	0.25	0.31	0.09
		Bss1	55-87	24.7	93.5	0.34	0.25	0.26	0.07
		Bss2	88-124	23.8	95.2	0.22	0.26	0.18	0.05
		Bss3	124-150	23.7	96.3	0.18	0.26	0.15	0.04

Table 4: Physico-chemical characteristics Sugarcane growing 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 $CaCO_3$ (%)	ESP (%)	SAR	CEC/ Clay ratio
							Ca	Mg	Na	K							
	Sadasivpet division																
1	Aroor	**Very-Fine Smectitic Calcareous Superactive Isohyperthermic Typic Haplusterts (Latitude º N 17 º 37'42.34" Longitude º E 77 º 53'10.33" Altitude 539 m)**															
		Ap	0-25	8.1	0.24	7.5	18.6	11.6	0.55	1.70	32.45	80.32	40.4	5.6	1.36	0.11	0.68
		BA	25-52	8.2	0.28	5.4	21.4	12.4	0.66	1.52	35.96	84.61	42.5	7.4	1.55	0.13	0.68
		Bss1	52-79	8.3	0.33	5.1	22.4	12.5	0.73	1.53	37.13	78.83	47.1	8.3	1.55	0.14	0.74
		Bss2	79-115	7.9	0.33	3.7	22.1	12.8	0.75	1.55	37.25	77.28	48.2	9.3	1.56	0.14	0.75
		Bss3	115-155	8.5	0.34	1.7	22.4	13.1	0.81	1.50	37.81	76.69	49.3	11.6	1.64	0.15	0.81
		C	155+	Mixed with calcareous murram													
2	Budera	**Fine Smectitic Superactive Non calcarious Isohyperthermic Vertic Haplustepts (Latitude º N 17 º 38'37.18" Longitude º 77 º 50'35.00"Altitude 585 m)**															
		Ap	0-14	6.5	0.21	6.6	11.4	6.0	0.14	0.76	18.30	75.00	24.4	2.8	0.57	0.04	0.63
		Bw1	14-41	6.8	0.26	4.5	12.2	6.0	0.15	0.52	18.87	66.68	28.3	3.2	0.53	0.04	0.71
		Bwss1	41-58	7.0	0.29	5.0	13.1	6.2	0.15	0.51	19.96	66.98	29.8	3.9	0.50	0.04	0.80
		Bwss2	58-79	6.7	0.31	3.5	13.2	6.4	0.20	0.55	20.35	81.08	25.1	4.7	0.80	0.05	0.64
		BC	79-100	7.0	0.34	2.4	13.3	6.5	0.21	0.55	20.56	83.92	24.5	4.7	0.86	0.05	0.58
	Jogipet division																
3	Andole	**Fine Smectiti Calcareous Superactive Isohyperthermic Typic Haplusterts (Latitude º 17 º 49'34.54" Longitude º 78 º 05'07.31" Altitude 492 m)**															
		Ap	0-25	8.2	0.21	7.9	24.6	8.2	0.7	0.5	34.00	87.40	38.9	5.5	1.80	0.13	0.72
		BA	25-65	8.2	0.29	5.1	21.3	11.6	0.8	0.3	34.00	87.40	38.9	6.3	2.06	0.15	0.68
		Bss1	55-85	8.4	0.28	4.5	20.4	10.9	0.9	0.3	32.50	79.08	41.1	6.5	2.19	0.18	0.70
		Bss2	85-117	8.4	0.34	3.3	19.1	11.3	1.2	0.3	31.90	75.06	42.5	6.6	2.82	0.24	0.69
		Bss3	117-145	8.9	0.36	3.3	18.3	12.3	1.0	0.2	31.80	70.51	45.1	7.8	2.22	0.20	0.71
		Bss4	145-178	9.2	0. 40	2.9	18.1	8.4	1.3	0.3	28.10	60.69	46.3	9.9	2.81	0.28	0.75
	Narayankhed division																
4	Pulkurty	**Very- Fine Smectitic, Calcareous Superactive Isohyperthermic Typic Haplustrets (Latitude º 17 º 56'45.77" Longitude º 77 º 42'43.82" Altitude 527 m)**															
		Ap	0-27	7.9	0.16	8.4	25.2	16.3	0.81	0.80	43.11	76.71	56.2	7.8	1.44	0.14	0.79
		BA	27-55	8.1	0.18	6.7	26.6	18.5	0.86	0.60	46.56	82.85	60.2	8.4	1.43	0.14	0.82
		Bss1	55-87	8.0	0.20	4.8	29.2	19.6	0.89	0.60	50.29	83.54	64.7	8.6	1.38	0.14	0.86
		Bss2	88-124	8.2	0.22	4.6	30.5	20.1	1.11	0.60	52.31	80.85	64.2	10.1	1.73	0.17	0.85
		Bss3	124-150	8.4	0.23	3.6	30.9	20.6	1.13	0.50	53.13	82.76	65.2	11.2	1.73	0.18	0.86

Table 5: Available nutrient status of Sugarcane growing soil pedons of the Medak district

Pedon	Location	Horizon	Depth (cm)	Available Macronutrients (kg ha^{-1})			Available S (mg kg^{-1})	Available Micronutrients (mg kg^{-1})				
				N	P	K		Zn	Cu	Mn	Fe	B
	Sadasivpet division											
1	Aroor	**Very-Fine Smectitic Calcareous Superactive Isohyperthermic Typic Haplusterts (Latitude º N 17 º 37'42.34" Longitude º E 77 º 53'10.33" Altitude 539 m)**										
		Ap	0-25	289	41.8	401	44.6	0.86	2.63	7.69	8.94	1.85
		BA	25-52	210	24.1	383	31.1	0.73	2.32	7.25	7.05	1.12
		Bss1	52-79	189	19.6	281	26.2	0.54	2.60	6.65	5.52	0.56
		Bss2	79-115	168	15.2	241	16.2	0.51	1.89	5.24	4.85	0.39
		Bss3	115-155	101	10.2	222	13.3	0.36	1.48	5.44	3.27	0.42
		C	155+	Mixed with calcareous murram								
2	Budera	**Fine Smectitic Superactive Non calcarious Isohyperthermic Vertic Haplustepts (Latitude º N 17 º 38'37.18" Longitude º 77 º 50'35.00"Altitude 585 m)**										
		Ap	0-14	277	21.03	310	30.56	0.88	0.94	12.36	15.8	1.94
		Bw1	14-41	184	20.62	281	18.52	0.80	0.86	10.60	11.6	1.86
		Bwss1	41-58	152	14.80	267	15.47	0.42	0.66	10.25	14.4	1.51
		Bwss2	58-79	96	11.23	210	10.75	0.36	0.39	9.57	12.6	1.36
		BC	79-100	92	8.11	181	9.23	0.31	0.38	10.98	11.1	1.22
	Jogipet division											
3	Andole	**Fine Smectiti Calcareous Superactive Isohyperthermic Typic Haplusterts (Latitude º 17 º 49'34.54" Longitude º 78 º 05'07.31" Altitude 492 m)**										
		Ap	0-25	296	42.1	415	48.56	1.36	1.05	10.60	10.2	1.99
		BA	25-65	253	39.3	395	31.98	0.69	1.02	10.23	8.1	1.84
		Bss1	55-85	165	29	336	24.52	0.48	0.96	9.63	5.2	1.74
		Bss2	85-117	168	18.91	358	19.23	0.37	0.62	9.51	6.2	1.58
		Bss3	117-145	96	18.52	321	9.65	0.34	0.61	8.86	6.6	1.41
		Bss4	145-178	88	16.4	294	6.23	0.23	0.61	5.45	5.2	1.23
	Narayankhed division											
4	Pulkurty	**Very- Fine Smectitic, Calcareous Superactive Isohyperthermic Typic Haplustrets (Latitude º 17 º 56'45.77" Longitude º 77 º 42'43.82" Altitude 527 m)**										
		Ap	0-27	289	58.94	404	51.21	0.96	2.34	13.8	9.5	1.89
		BA	27-55	178	27.66	384	26.25	0.72	2.14	11.1	9.1	1.74
		Bss1	55-87	165	20.02	348	18.29	0.52	2.51	6.5	8.3	1.68
		Bss2	88-124	129	16.56	334	15.52	0.41	1.63	5.2	8.2	1.51

Table 6: Land capability classification of Sugarcane growing 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.sur.coarse fragments	Soil Depth		CEC	BS	OC	
Pedon 1	Aroor	II	II	IV	III	II	II	I	I	I	III	II	IIIwef
Pedon 2	Budera	III	II	III	II	II	II	II	I	I	I	III	IIIwef
Pedon 3	Andole	II	II	IV	III	II	II	I	I	I	I	II	IIIwef
Pedon 4	Pulkurty	II	II	IV	III	II	II	I	I	I	I	II	IIIwef

Table 7: 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	Aroor	855	40.0	26.2	74.0	1-3	Moderate	Poor	155	11.5	c	8.1	7.5	40.4	80.32
Pedon 2	Budera	980	40.0	26.2	74.0	1-3	Moderate	Poor	100	12.3	cl	6.5	6.6	24.4	75.00
Pedon 3	Andole	855	40.0	26.2	74.0	1-3	Moderate	Poor	178	10.4	c	8.2	7.9	38.9	87.40
Pedon 4	Pulakurty	855	40.0	26.2	74.0	1-3	Moderate	Poor	150	10.0	c	7.9	8.4	56.2	76.71

Table 8: Actual and potential soil suitability for Sugarcane growing Soils of Medak District

Pedon No	Location	Max. temp ©	Min.Temp ©	RH ©	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	Aroor	S1	S1	S1	S1	S3	S3	S1	S1	S1	S1	S2	S1	S1	S1	S2	S1
Pedon 2	Budera	S1	S1	S1	S1	S2	S1	S1	S2	S1	S1	S2	S1	S1	S2	S2	S1
Pedon 3	Andole	S1	S1	S1	S1	S3	S3	S1	S1	S1	S1	S2	S1	S1	S1	S2	S1
Pedon 4	Pulakurty	S1	S1	S1	S1	S3	S3	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1

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

Table 9: Comparative evaluation of productivity of soils in the study area along with the management options

Soil type	Pedon	Location	Suitability	Major limitations	Management suggested
Black Soils					
	1	Aroor	Moderately suitable to highly suitable	Drainage, texture, runoff, erosion and $CaCO_3$, high pH, sub surface hard pan	Addition of river sand at 100 t ha^{-1}; application of 100 cart loads of red loam soil; summer deep ploughing; furrow system to manage the surface drainage; raised beds should be 1.2 m wide and 15 cm hight with two furrows of 30 cm width on either side to drain out excess of water; pre monsoon sowing of green manures; application of farmyard manures, composted coir pith or press mud at 25 t ha^{-1} per year and crop rotation. Follow site-specific nutrient management.
	2	Andole	Moderately suitable to highly suitable	Drainage, texture, runoff, erosion and high $CaCO_3$, high pH in subsurface horizon	
	3	Pulakurty	Moderately suitable to highly suitable	Drainage, texture, runoff, erosion and high $CaCO_3$, high pH, sub surface hard pan	
	4	Budera	Moderately suitable to highly suitable	Slope, medium OC and N and Low Zn	Pre monsoon sowing of green manures; application of farmyard manures, composted coir pith or press mud at 25 t ha^{-1} per year and crop rotation. Follow site-specific nutrient management.

References

1. Ashok Kumar HP. Prasad J. Some typical sugarcane-growing soils of Ahmadnagar district of Maharashtra: Their characterization and classification and nutritional status of soils and plants. Journal of the Indian Society of Soil Science. 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, 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.
5. Blake GR, Hartze KH. Bulk density In Methods of Soil analysis part I(Ed A Klute). American Society of Agronomy Incorporation Wisconsin USA, 1986, 377-382.
6. Buol SW, Hole FD, Mc Cracken RJ, Southard RJ. Soil Geneis and Classification. 4th edition, Panima publishing corporation, New Delhi, 1998, 110.
7. Chapman HD. Cation exchange capacity. In C. A. Black et al. (ed.) Methods of soil analysis. Agronomy Am. Soc. of Agron., Inc., Madison, Wis. 1965; 9:891-901.
8. Chinchmalatpure AN, Nayak AK, Rao GG. Soil survey interpretation of salt affected black soils of Jambusar taluk of Bharuch district of Gujarat state for suggested land use planning. Agropedology. 2005; 15:22-28.
9. Coulombe CE, Wilding IP, Dixon JB. Over view of Vertisols. Characteristics and impacts on society. Advances in Agronomy. 1996; 57:289 -296.
10. Curi N, Franzmeir DP. Toposequence of soils from the central plateau of Brazil. Soil Science Society of American journal. 1984; 48:341-346.
11. 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.

12. FAO. A frame work of land evaluation. Soils bull., Food and Agricuture Organization of the United Nations, Rome, 1976, 22.
13. 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.
14. Govindarajan SV, Koppar AL. Improved method for determination of gravels in red clay soils. Journal of the Indian Society of Soil Science. 1975; 23:138-140.
15. Jackson ML. Soil Chemical Analysis – Oxford IBH publishing house, Bombay, 1973, 38.
16. Maji AK, Obireddy GP, Thayalan S, Walke NJ. Characterization and classification of landforms and soils over basaltic terrain in sub humid tropics of central India. Journal of the Indian Society of Soil Science. 2005; 53(2):154-162.
17. Marathe RA, Mohanty S, Singh S. Soil characterization in relation to growth and yield of Nagpur Mandarin (*Citrus reticulata* Blanco). Journal of the Indian Society of Soil Science. 2003; 51(1):70-73.
18. Mermut AR, Padmanabham E, Eswaran H, Dasog GS. Pedogenesis. *In* Vertisols and technologies for their management developments in soil science, Ed. N Ahmad and A Mermut, Elsevier, Amsterdam, 1996, 32.
19. 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.
20. Murthy RS, Bhattacharjee JC, Landey RJ, Pofali RM. Vertisols and rice soils of tropics. 12th international congress of soil science, New Delhi, 1982, 3-22.
21. 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.
22. Nayak AK, Chinchmalatpure AR, Rao GG, Kandelwal MK, Verma AK. Swell-shrink potential of Vertisols in relation to clay content and exchangeable sodium under different ionic environment. Journal of the Indian Society of Soil Science. 2006; 54:1-6.
23. Pal DK, Deshpande SB. Characteristics and genesis of minerals in some benchmark Vertisols of India. Pedology. 1987; 37:259-275.
24. Pal DK, Dasog GS, Vadivelu S, Ahuja RL, Bhattacharyya T. Secondary calcium carbonate in soils of arid and semi-arid rigions of India - global climate change and pedogenic carbonate. Lewis publishers, 2000, 149-185.
25. Paramasivam P, Gopalaswamy A. Charactersitics and classification of some soils of lower Bhavani project command area, Tamilnadu. Agropedology. 1993; 3:105-109.
26. Piper CS. Soil and plant analysis. Inter Science publication. Inc. New York, 1966.
27. Rajeshwar M, Mani S. Soil quality assessment in black soils of Veppanthattai Sivaganga district of Tamil Nadu. An Asian Journal of Soil Science. 2013; 8(1):108-121
28. Rajeshwar M, Mani S. Genesis, Classification And Evaluation Of Cotton Growing Soils In Semi Arid Tropics Of Tamil Nadu. An Asian Journal of Soil Science. 2015; 10(1):13-22
29. 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.
30. Ramprakash T, Seshagiri Rao M. Characterization and classification of some soils in a part of Krishna district, Andhra Pradesh. The Andhra Agriculture Journal. 2002; 49:228-236.
31. Renukadevi A. Soil resource and land evaluation studies using remote sensing and GIS techniques in western Parambikulam Aliyar project area, Ph.D., Thesis, Tamil Nadu Agricultural University, Coimbatore, 2003.
32. Richards LA. Diagnosis and improvement of saline and alkali soils. USDA Handbook, 60, USDA, Washington. D.C., USA, 1954.
33. 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.
34. Santsingh S. Colouration and formation of black soils. Journal of Agricultural and food Chemistry. 1987; 20:201-222.
35. Sarkar D, Gangopadhyay SK, Velayutham M. Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau. Agropedology. 2001; 11:29-36.00
36. Sehgal JL. Pedology: Concepts and Applications. Kalyani publishers, New Delhi, 1996, 176-185.
37. 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.
38. Shyampura RL, Giri JD, Das K, Singh SK. Soil physiographic relationships on a transect in southern Rajsthan. Journal of the Indian Society of Soil Science. 1994; 42:622-625.
39. Singh IS, Agrawal HP. Characterization, genesis and classification of rice soils of eastern region of Varanasi, Uttar Pradesh. Agropedology. 2005; 15:29-38.
40. 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.
41. Srinivasan TR, Balu YP, Tamhane RV. Placement of black soils of India in the comprehensive soil classification system-7th approximation. Journal of the Indian Society of Soil Science. 1969; 17:323-332.
42. Subbiah GV, Manickam TS. Genesis and morphology of Vertisols developed on different parent materials. Journal of the Indian Society of Soil Science. 1992; 40:150-155.
43. Surekha K, Subbarao IV, Rao AP, Shantaram MV. Characterization of some Vertisols of Andhra Pradesh. Journal of the Indian Society of Soil Science. 1997; 45:338-343.
44. 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.
45. Vijaya Kumar T, Reddy MS, Gopalakrishna V. Characteristics and classification of soils of northern Telangana zone of Andhra Pradesh. Agropedology. 1994; 4:31-43.
46. 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.