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Characterization of Vertisols in Semi-arid Tropical Region of Chinnapalem Village of Guntur District in Andhra Pradesh

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Eight representative pedons were selected from the study area and the soil samples collected from each horizon in these eight pedons were analysed for physical properties *viz.,* particle size analysis, soil density, water holding capacity, volume expansion, pore space, COLE and LOI; physico-chemical properties like pH, EC and organic carbon; electro-chemical characteristics such as CEC, exchangeable bases, base saturation and ESP and chemical properties such as available macronutrients (N, P_2O_5, K_2O, and S) and micronutrients (Zn, Cu, Fe and Mn). The Pedons 2, 3, 5,

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6, 7 and 8 exhibited an increasing trend in clay content with depth. However, no specific trend with depth was observed in the remaining pedons. Physical constants like water holding capacity, loss on ignition and volume expansion followed the trend of clay content**.** Bulk density showed an increasing trend with depth corresponding to decreasing organic carbon with depth in all the pedons. COLE values not followed any specific trend with depth in any of the pedons. The soils were neutral to moderately alkaline in reaction, non-saline to slightly saline in nature and low to medium in organic carbon. The CEC values were medium to high and exchange complex was dominated by Ca^{2+} followed by Mg^{2+}, Na^{+} and K^{+}. Soils were low to medium in available nitrogen, low to high in available phosphorous, high in potassium and deficient to sufficient in available sulphur. However, the soils were sufficient in DTPA extractable Cu, Fe and Mn and deficient to sufficient in DTPA extractable Zn.

Keywords: Characterization; vertisols; semi-arid tropical.

1. INTRODUCTION

Soil is the indispensable natural resource for the survival of life on the earth. Soil variability within or among the agricultural fields is inherently heterogeneous in nature due to geologic and pedologic factors and some of the variability in soil properties may be induced by management practices. These factors interact with each other across time and space. Characterization, classification and evaluation of soils are the first milestones to develop database for formulating land use models. Systematic study of morphology and taxonomy of soils provides information on nature and type of soils, their constraints, potentials, capabilities and their suitability for various uses [1]. Characterization helps in determining the soil potentials and identifying the constraints in crop production besides giving detailed information about different soil properties [2]. Soil classification, on the other hand, helps to organize our knowledge, facilitates the transfer of technology from one place to another and helps to compare soil properties.

2. MATERIALS AND METHODS

The study area lies in between 160 23' 22.773" to 160 20' 47.612" N latitudes and 800 38' 38.892" to 800 41' 54.958 E longitudes with an average elevation of 16 m mean sea level. Before starting fieldwork, preliminary traverse of the entire village was carried out using 1: 50,000 scale base map and satellite imagery. During the traverse based on geology, drainage pattern, surface features, slope characteristics and land use, landforms and physiographic divisions were identified. After delineating the landform on the satellite image, intensive traversing of each landform was undertaken to select the representative areas for transect study. Transects were located across the slope at right angles to the contours and covers most of the variations observed in a landform. In each selected transect, profiles were located at closely spaced intervals to take care of any change in the land features like break in slope, erosion, gravels and stones *etc.* eight (8) profiles were studied to know the variability in depth, surface and sub-surface texture and color (AIS & LUP, 1970). Horizon-wise soil samples were collected in plastic covers for the purpose of characterization from each pedon for laboratory analysis in the month of May, 2019 (before onset of monsoon). Laboratory analaysis were carried out using standard procedures [3].

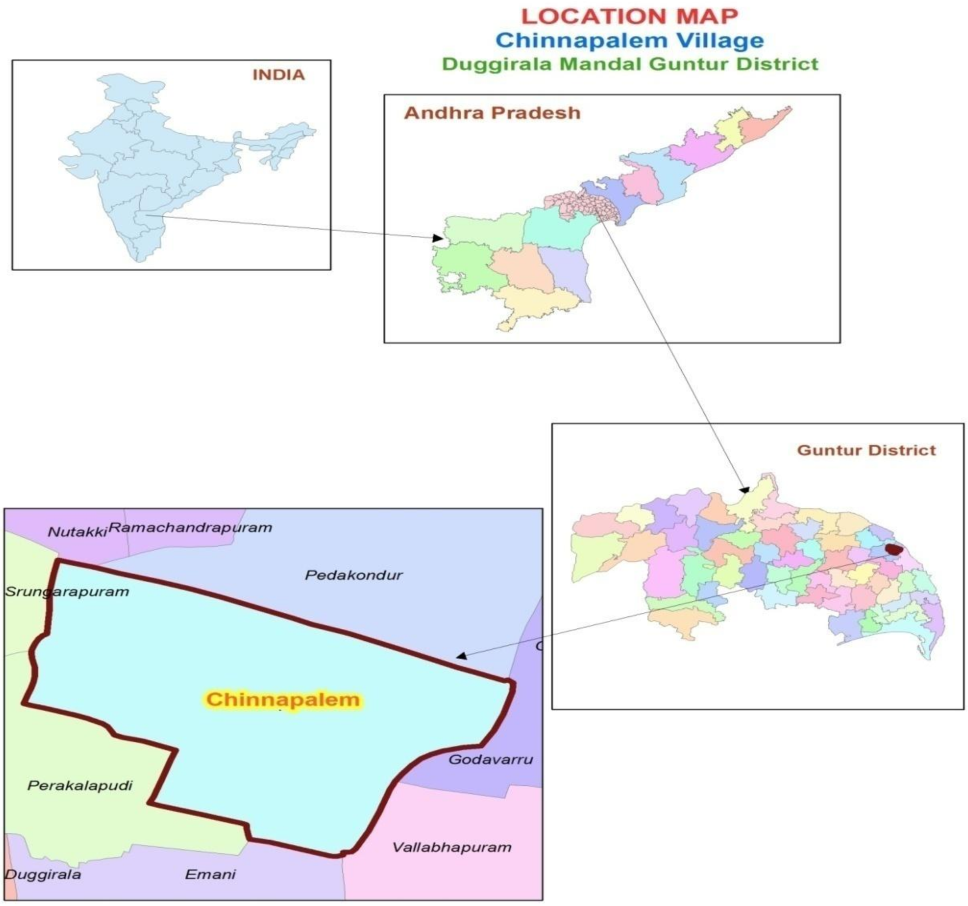
3. RESULTS AND DISCUSSION

3.1 Physical Properties

The results of particle size analysis are presented in Table 1.

3.1.1 Particle size analysis

The clay content ranged from 51.2 to 71.8 per cent. The highest value of clay was observed in Bss5 horizon of pedon 3 and lowest clay content found in Ap horizon of pedon 1. Pedons 2, 3, 5, 6, 7 and 8 showed an increasing trend with depth. However, there is no specific trend in remaining pedons. The mean clay content in all these pedons was 63.21 per cent. The increasing trend of clay with depth was primarily due to illuviation of clay and its accumulation in the sub-soil (Shekar et al. 2014). The silt content varied from 7.3 to 22.3 per cent. The Bss2 horizon of pedon 6 recorded the highest value of



Location map of Chinnapalem village of Guntur district in Andhra Pradesh

22.3 per cent. The Bss6 horizon of pedon 7 registered the lowest value of 7.3 per cent. However, an irregular trend with depth was observed in all the pedons with mean value of 12.6 per cent. The irregular distribution of silt with depth might be due to variation in weathering of parent material or *in situ* formation. A similar result of irregular trend with depth was also reported by Shekar et al. (2014) in black soils of Prakasam district of Andhra Pradesh. The sand content in Chinnapalem village varied from 15.4 (Bss6 horizon of pedon 6) to 34.8 (Ap horizon of pedon 4) per cent. Pedons 4 and 5 showed a decreasing trend with depth. Furthermore, remaining pedons showed an irregular distribution with depth with mean value 24.2 per cent. Higher sand content in surface horizons than those of sub-surface horizons, which was opposite to clay content, was due to surface impoverishment of finer particles by runoff water [4].

The value of sand / silt ratio ranged from 0.84 (Bss6 horizon of pedon 6) to 3.48 (Ap horizon of pedon 4). All the pedons showed an irregular trend with depth. The values of silt / clay ratio ranged from 0.10 (Bss6 layer of pedon 7) to 0.39 (Bss2 of pedon 6). Pedons 2 and 3 showed almost a regular decreasing trend with depth while remaining pedons did not follow any specific trend with depth. The values of Sand / Silt + Clay ratio ranged from 0.18 (Bss6 horizon of pedon 6) to 0.53 (Ap horizon of pedon 4). The pedons 3, 4 and 5 showed almost a regular decreasing trend with depth. However, remaining pedons did not follow any specific trend with depth. Weathering was influenced by varied pedo-environment observations were made by Kumar and Prasad (2010) in sugarcane-growing soils of Ahmadnagar district in Maharashtra.

3.1.2 Physical constants

The results of physical constants are depicted in Table 2. Bulk density in different horizons of pedons ranged from 1.02 to 1.51 Mg m^{-3}. The highest value of 1.51 Mg m^{-3} was recorded in Bss6 horizon of pedon 6 while the lowest value of 1.02

Mg m^{-3} was observed in Ap horizon of pedon 1. All the pedons exhibited an increasing trend with depth with mean value 1.3 Mg m^{-3}. Sub-surface horizons exhibited higher bulk density values as compared to surface horizons. Higher bulk density values in the sub-surface horizons could be ascribed to decreased organic matter and secondary accumulation of illuviated clay in pore space as reported by Kumar and Prasad [5] and Ram et al. [6]. Low bulk density of surface soils could be attributed to relatively higher organic matter content as compared to sub-surface soils. This was evident from the negative correlation (r= - 0.381) of bulk density with organic carbon content.

Particle density of different pedons ranged from 2.40 to 2.72 Mg m^{-3}. The highest value of 2.72 Mg m^{-3} was found in the Ap layer of pedon 8 and the lowest value of 2.40 Mg m^{-3} was observed in Bss2 layer of pedon 2. The mean particle density values in all pedons were 2.5 Mg m^{-3}. Furthermore, particle density in all the pedons did not show any particular trend with depth. Similarly, more or less uniform particle density was reported in soils of Chennur mandal of Kadapa district in Andhra Pradesh [7].

Pore space in all the pedons varied between 37.03 and 60.34 per cent. The lowest value of 37.03 per cent was found in Bss6 layer of pedon 6 and highest value of 60.34 per cent was observed in Ap layer of pedon 1. Almost a decreasing trend was observed in pedons with depth. These results were in conformity with the findings of Walia and Rao [8], who reported a decrease in porespace with depth, which might be due to increase in fine fraction in Vertisols.

The values of water holding capacity varied from 40.71 to 69.56 per cent. The highest value of 69.56 per cent was observed in Bss6 horizons of pedons 8 and the lowest value of 40.71 per cent was observed in Ap horizon of pedon 4. Pedons 3, 4, 5 and 6 showed an increasing trend with depth. The remaining pedons showed no particular trend with depth. Increase in smectite type of clay with depth might have imparted greater water holding capacity in deeper layers of soils [9] in eastern parts of Prakasam district of Andhra Pradesh. Water holding capacity was higher in soils as they were rich in clay as evident from significant and positive correlation between water holding capacity and clay content (r = +0.585**). Similarly, Shasikala et al., (2019) reported that water holding capacity followed the distribution pattern of clay content in the soils.

The per cent volume expansion varied from 17.41 to 41.45 per cent. The lowest value of 17.41 per cent was exhibited by Ap layer of pedon 8 and the highest value of 41.45 per cent was recorded in Bss5 layer of pedon 2. Pedons 1, 3, 4, 7 and 8 exhibited an increasing trend with depth and remaining pedons did not show any particular trend with depth. The volume expansion had a significant and positive correlation (r = +0.444**) with clay content. Increase in volume expansion with increase in clay content was reported by Rajeshwar and Mani (2015) in the soils of Perambalur in Tamil Nadu.

The loss on ignition values varied from 12.3 to 19.3 per cent. The highest value of 19.3 per cent was observed in Bss6 layer of pedon 8 and the lowest value of 12.3 per cent was reported in Ap horizon of pedon 1.

This loss in weight on ignition was attributed to loss of organic matter, crystal lattice water and $CaCO_3$ content. The current study also showed significant and positive correlation between loss on ignition and clay content (r = +0.609**). Similarly, Shasikala et al. (2019) reported that loss on ignition followed the distribution pattern of clay content in the soils.

The COLE values were ranged from 0.04 to 0.18. The highest COLE value (0.18) was observed in Bss4 horizon of pedon1 while the lowest COLE value (0.04) was showed in Ap horizon of Pedons 1. All the pedons exhibited no particular trend with depth. The higher COLE values in pedon might be due to relatively high per centage of smectite in clay fraction. The COLE values of black soils of Vatticherukur mandal of Guntur district [10].

3.2 Physico-chemical Properties

The results of physico-chemical properties are presented in Table 3.

All the pedons studied in study area were neutral to moderately alkaline in reaction and pH values of 1:2.5 soil water suspensions were ranging from 6.82 to 8.27. The lowest value of 6.82 was observed in Ap layer of pedon 1 and the highest value of 8.27 was observed in Bss6 layer of pedon 6. Pedons 2, 3, 4, 7 and 8 showed an increasing trend with depth. The increasing trend of pH with depth might be due releasing of organic acids during decomposition of organic matter and these acids might have brought down the pH in the surface soils. Similar results were obtained by Sanjeev et al. (2005). The pH values of 1:2.5 1 *N* KCl suspension ranged from 5.73 to 6.90. The lowest value of 5.73 was observed in Ap layer of pedon 3 and the highest value of 6.90 was recorded in Bss6 layer of pedon 6. All the pedons showed no particular trend with depth.

Soil pH measured in KCl was low in all the pedons as compared to that measured in water, revealed that the soils contain appreciable quantities of silicate clay minerals with relatively constant surface charges [11]. The KCl-pH values were lower than the water pH values. The Δ pH values in these soils were varying from -1.09 to -1.37 indicating very high negative charge. The difference between pH_{KCl} and pH_{H2O} values (Δ pH = pH_{KCl} - pH_{H2O}) with large negative value (more than -0.5) indicated a high negative surface charge density of these soils. Similar results were reported by Selvaraj and Naidu [12] who reported the existence of net negative charge on colloidal particles.

The electrical conductivity of soil water extract in Chinnapalem village soils varied between 0.48 and 2.06 dS m^{-1}. The highest value of 2.06 was observed in Bss6 layer of pedon 6. The lowest value of 0.48 was recorded in Ap layer of pedon 1. The pedons in the study area showed an increasing trend with depth. The result in the present study indicated that the soils in Chinnapalem village were non-saline to slightly saline. The lower soil electrical conductivity in study area was due to excess leaching of salt sand due to free drainage conditions which favoured the removal of released bases by percolating and drainage water. Similarly, Sireesha and Naidu (2013) and Sathish et al. [4] observed lower EC values in some black soils of Banaganapalle and Brahmanakotkur of Andhra Pradesh, respectively.

The organic carbon content in different horizons of pedons in Chinnapalem village was ranged from 0.15 to 1.02 per cent. The lowest value of 0.15 per cent was observed in Bss6 layer of pedon 7 and the highest value of 1.02 per cent was recorded in Ap layer of pedon 3. The result in the current study indicated that the soils in Chinnapalem village were medium to low organic carbon content. Pedons 1, 7 and 8 showed a decreasing trend with depth which could be attributed to the fact that the surface horizons showed more organic matter content than sub-surface horizons, this might be due to the addition of plant residues and farmyard manure to surface horizons which resulted in higher organic carbon content in surface horizons than in the lower horizons. Similar observations were also made by Thangasamy et al. [13] in the black soils of Sivagiri micro-watershed in Chittor district of Andhra Pradesh.

3.3 Electro-chemical Properties

The results of electro-chemical properties in soils of study area are presented in Tables 4 and 5. The CEC values varied from 40.46 to 63.14 cmol (p^+) kg^{-1} soil indicating considerable variation among and within the Pedons. The lowest value of 40.46 cmol (p^+) kg^{-1} soil was recorded in Bss2 layer of pedon 4 while the highest value of 63.14 cmol (p^+) kg^{-1} soil was observed in Bss5 layer of pedon 3. The increasing trend of CEC values was recorded in pedons 2, 3, 5, 7 and 8. The cation exchange capacity of surface soils in rice growing soils of Guntur district were lower than sub-surface soils which might be due to illuviation of clay from surface to sub-surface horizon. Sudhrani and Jayasree (2014). Statistical analysis revealed a highly significant and positive correlation (r = +0.924 **) between clay and CEC in the current study suggests that clay was the main contributor to CEC in these soils. The per cent base saturation on the exchange complex was in between 88.24 and 98.06. The highest value of 98.06 per cent was observed in Bss6 layer of pedon 7 and the lowest value of 88.24 per cent was observed in Bss1 layer of pedon 3. Pedons 3, 4, 5, 7 and 8 showed an increasing trend with depth. The higher base saturation observed in almost all pedons might be due to higher amount of Ca^{2+} and other basic cations occupying exchange sites on the colloidal complex. Similar results were reported by Shekhar *et al*. (2014) in the soils of Prakasam district of Andhra Pradesh. The BS increased with depth following the trend of clay (r = +0.748 **) and pH (r = +0.597**), which might be due to translocation of clay and basic cations down the depth. The exchangeable bases in all the pedons were in the order of Ca^{2+} > Mg^{2+} > Na^+ > K^+ on the exchange complex. The exchangeable calcium was found to be the dominant cation followed by magnesium on the exchange complex. Similar results were also reported by Shekhar et al. [9] in alluvial plain soils of Prakasam district of Andhra Pradesh. The ESP values ranged from 1.65 to 3.91 per cent indicating considerable variation among and within the Pedons. The highest value of 3.91 per cent was observed in Ap horizon of pedon 1 and lowest value of 1.65 per cent was recorded in Ap horizon of pedon 5. Pedons did not show any specific trend with depth except pedon 1 which was showed a decreasing trend. As the ESP values were less than 15, these soils were considered as non-sodic soil. Contribution of basic cations to base saturation were ranged between 83.02-88.11, 8.70-11.76, 1.81-4.27 and 0.24-2.48 per cent by Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}, respectively. This observation was in accordance with findings of Shekar et al. [9] in soils of Vadamalapeta of Chittoor district. The ratio between CEC and clay varied from 0.72 to 0.92. The highest ratio was observed in Bss3 horizon of pedon 4 and the lowest in Bss3 horizon of pedon 6. Pedons did not show any specific trend down the pedon. The CEC: clay ratio helps in identifying the clay mineralogy. If the ratio is > 0.7, dominant mineral is smectite.

4. AVAILABLE NUTRIENTS STATUS

The results of available macro and micronutrients in horizon samples of different pedons are presented in Table 6.

4.1 Macronutrients

The available nitrogen ranged from 56 to 162 mg kg^{-1} soil and these soils were medium to low in available nitrogen. The lowest value (56 mg kg^{-1} soil) was observed in Bss3 horizon of pedon 3 and the highest value (162mg kg^{-1} soil) was recorded in Ap horizon of pedon 1. All the pedons exhibited a decreasing trend with depth and pedons 2 and 3 showed an irregular trend with depth. The available nitrogen was found to be maximum in the surface horizons and decreased more or less with depth in all the pedons, which might be due to decreasing trend of organic carbon with depth. Further, the available nitrogen was highly significantly and positively correlated (r = +0.654**) with organic carbon. The reason for the maximum available nitrogen observed in the surface horizons could be attributed to the fact that cultivation of crops is mainly confined to the surface horizon (rhizosphere) only and at regular interval the depleted nitrogen is supplemented by the external addition of fertilizers during crop cultivation. This observation was in accordance with findings of Kumar and Naidu [14] and Shekar et al. [9] in soils of Vadamalapeta of Chittoor district and alluvial plain black soils of Prakasam district in Andhra Pradesh. The available phosphorus varied from 9.16 to 75.51 mg P_2O_5 kg^{-1} soil. The highest value (75.51 mg P_2O_5 kg^{-1} soil) was recorded in Ap horizon of pedon4 and the lowest value (9.16 mg P_2O_5 kg^{-1} soil) was observed in Bss4 horizon of pedon7. The pedons 1, 2 and 3 pedons showed a decreasing trend with depth. The highest available phosphorus was observed in the surface horizons than sub-surface horizons. The decreased trend of available phosphorus with depth followed the trend of organic matter (r= +0.811**). The lower phosphorus content in sub-surface horizons as compared to surface horizons could be due to the presence of high organic carbon and fixation of released phosphorus by clay minerals and oxides of iron and aluminium [9]. The available potassium in different soils ranged from 143 to 277 mg K_2O kg^{-1} soil. The lowest value of 143 mg K_2O kg^{-1} soil was recorded in Bss2 layer of pedon 3 and the highest value of 277 mg K_2O kg^{-1} soil was observed in Ap horizon of pedon6. There is no particular pattern with respect to depth in all the pedons. The higher potassium could be attributed to more intense weathering, release of labile K from organic residues, application of K fertilizers and upward translocation of potassium from lower depths along with capillary raise of ground water. Similar results were reported by Vedadri and Naidu [15] in soils of Chillakur mandal of SPSR Nellore district in Andhra Pradesh. Amount of clay, organic carbon, soil pH and CEC significantly affected the K-availability in soils. This is evidenced by the positive and significant correlation of available K with organic carbon (r = +0.426**) in the present study. Similar observations were reported by Sharma and Kumar [16] who observed significant and positive correlation of clay content with available K indicating the availability of K was largely controlled by clay minerals. The available sulphur content varied between 1.8 and 20.6 mg kg^{-1} soil. The lowest value of 1.8 mg kg^{-1} soil was observed in Bss4 horizon of pedon 4 and the highest value of 20.6 mg kg^{-1} soil was observed in Bss5 horizon of pedon 5. All the pedons exhibited more or less a decreasing trend with depth. In General, surface layers contained more available sulphur than sub-surface layers which could be due to higher amount of organic matter in surface layers than in sub-surface layers. A significant and positive correlation (r= +0.410)

Table 1. Particle size analysis of the soils

Pedon No. & Horizon	Depth (m)	Coarse sand	Fine sand	Total sand (%)	Silt	Clay	Textural class	Sand Silt	Silt clay	Sand Silt + Clay
Pedon 1										
Ap	0.00 – 0.20	11.1	20.4	31.5	17.3	51.2	Clay	1.82	0.34	0.46
Bss1	0.20 – 0.60	6.4	23.3	29.7	15.7	54.6	Clay	1.89	0.29	0.42
Bss2	0.60 – 0.90	6.1	28.5	34.6	13.2	52.2	Clay	2.62	0.25	0.53
Bss3	0.90 – 1.30	7.4	24.8	32.2	14.4	53.4	Clay	2.24	0.20	0.47
Bss4	1.30 – 1.70+	9.2	22.4	31.6	9.7	58.7	Clay	3.26	0.17	0.46
Pedon 2										
Ap	0.00 – 0.20	6.7	14.5	21.2	18.2	60.6	Clay	1.16	0.30	0.27
Bss1	0.20 – 0.55	5.8	16.6	22.4	14.4	63.2	Clay	1.56	0.23	0.29
Bss2	0.55 – 0.90	5.7	16.9	22.6	12.7	64.7	Clay	1.78	0.20	0.29
Bss3	0.90 – 1.20	4.3	15.9	20.2	13.6	66.2	Clay	1.49	0.21	0.25
Bss4	1.20 – 1.70+	3.4	16.4	19.8	10.4	69.8	Clay	1.90	0.15	0.25
Pedon 3										
Ap	0.00 – 0.20	8.6	15.5	24.1	11.7	64.2	Clay	2.06	0.18	0.32
Bss1	0.20 – 0.50	7.4	16.3	23.7	9.8	66.5	Clay	2.42	0.15	0.31
Bss2	0.50 – 0.80	6.7	13.2	19.9	10.4	69.7	Clay	1.91	0.15	0.25
Bss3	0.80 – 1.20	8.1	11.6	19.7	9.7	70.6	Clay	2.03	0.14	0.25
Bss4	1.20 – 1.60+	5.9	11.7	17.6	10.6	71.8	Clay	1.66	0.15	0.21

Cont…

Table 1. Contd…

Pedon No. & Horizon	Depth (m)	Coarse sand	Fine sand	Total sand (%)	Silt	Clay	Textural class	Sand Silt	Silt clay	Sand Silt + Clay
Pedon 4										
Ap	0.00 – 0.20	14.3	20.5	34.8	10	55.2	Clay	3.48	0.18	0.53
Bss1	0.20 – 0.42	13.7	19.0	32.7	14.6	52.7	Clay	2.24	0.28	0.49
Bss2	0.42 – 0.92	8.8	21.1	29.9	11.7	58.4	Clay	2.56	0.20	0.43
Bss3	0.92 – 1.34	11.3	15.4	26.7	8.5	64.8	Clay	3.14	0.13	0.36
Bss4	1.34 – 1.65+	9.8	15.9	25.7	12.7	61.6	Clay	2.02	0.21	0.35

Pedon No. & Horizon	Depth (m)	Coarse sand	Fine sand	Total sand (%)	Silt	Clay	Textural class	Sand Silt	Silt clay	Sand Silt + Clay
Pedon 5										
Ap	0.00 – 0.20	12.6	16.7	29.3	10.5	60.2	Clay	2.79	0.17	0.41
Bss1	0.20 – 0.41	13.4	14.3	27.7	9.8	62.5	Clay	2.83	0.16	0.38
Bss2	0.41 – 0.82	10.7	13.9	24.6	8.7	66.7	Clay	2.83	0.13	0.33
Bss3	0.82 – 1.11	11.6	9.9	21.5	10.4	68.1	Clay	2.07	0.15	0.27
Bss4	1.11 – 1.55+	8.4	12.4	20.8	9.8	69.4	Clay	2.12	0.14	0.26
Pedon 6										
Ap	0.00 – 0.15	7.4	18.1	25.5	19.3	55.2	Clay	1.32	0.35	0.34
Bss1	0.15 – 0.42	9.6	11.3	20.9	22.3	56.8	Clay	0.94	0.39	0.26
Bss2	0.42 – 0.80	6.7	14.5	21.2	19.3	59.5	Clay	1.10	0.32	0.27
Bss3	0.80 – 1.30	10.3	9.5	19.8	17.6	62.6	Clay	1.13	0.28	0.25
Bss4	1.30 – 1.60	11.6	9.1	20.7	15.6	63.7	Clay	1.33	0.24	0.26
Bss5	1.60 – 1.90+	8.9	6.5	15.4	18.4	66.2	Clay	0.84	0.28	0.18

Cont…

Table 1. Contd…

Pedon No. & Horizon	Depth (m)	Coarse sand	Fine sand	Total sand (%)	Silt	Clay	Textural class	Sand Silt	Silt clay	Sand Silt + Clay
Pedon 7										
Ap	0.00 – 0.20	13.5	16.1	29.6	11.8	58.6	Clay	2.51	0.20	0.42
Bss1	0.20 – 0.60	11.4	14.7	26.1	10.5	63.4	Clay	2.49	0.17	0.35
Bss2	0.60 – 1.00	8.2	14.6	22.8	12.5	64.7	Clay	1.82	0.19	0.30
Bss3	1.00 – 1.40	9.6	14.9	24.5	8.4	67.1	Clay	2.92	0.13	0.32
Bss4	1.40 – 1.70	7.4	13.3	20.7	10.7	68.6	Clay	1.93	0.16	0.26
Bss5	1.70 – 1.90+	10.2	10	22.2	7.3	70.5	Clay	3.04	0.10	0.29
Pedon 8										
Ap	0.00 – 0.18	12.6	17.2	29.8	10	60.2	Clay	2.98	0.17	0.42
Bss1	0.18 – 0.52	7.4	12.9	20.3	15.3	64.4	Clay	1.33	0.24	0.25
Bss2	0.52 – 0.92	6.9	14.5	21.4	12.4	66.2	Clay	1.73	0.19	0.27
Bss3	0.92 – 1.32	8.3	9.4	17.7	13.6	68.7	Clay	1.30	0.20	0.22
Bss4	1.32 – 1.62	6.2	12.6	18.8	10.8	70.4	Clay	1.74	0.15	0.23

Pedon No. & Horizon	Depth (m)	Coarse sand	Fine sand	Total sand	Silt	Clay	Textural class	Sand Silt	Silt clay	Sand Silt + Clay
				(%)						
Bss5	1.62 – 1.90+	9.1	11.6	20.7	7.7	71.6	Clay	2.69	0.11	0.26
Minimum	**-**	**3.4**	**6.5**	**15.4**	**7.3**	**51.2**	**-**	**0.84**	**0.10**	**0.18**
Maximum	**-**	**14.3**	**28.5**	**34.8**	**22.3**	**71.80**	**-**	**3.48**	**0.39**	**0.53**
Mean	**-**	**8.9**	**15.3**	**24.2**	**12.6**	**63.15**	**-**	**2.1**	**0.2**	**0.3**

Table 2. Physical characteristics of the soils

Pedon No. & Horizon	Depth (m)	Bulk density ($Mg\ m^{-3}$)	Particle density ($Mg\ m^{-3}$)	Waterholding capacity (%)	Pore space (%)	Volume expansion (%)	WHC/ clay	COLE	LOI (%)
Pedon 1									
Ap	0.00 – 0.20	1.02	2.56	51.10	60.3	23.99	1.00	0.04	12.3
Bss1	0.20 – 0.60	1.23	2.46	50.24	50.1	23.34	0.92	0.12	13.2
Bss2	0.60 – 0.90	1.34	2.41	51.58	44.2	27.91	0.99	0.14	13.3
Bss3	0.90 – 1.30	1.37	2.44	54.20	43.9	29.49	1.01	0.18	14.3
Bss4	1.30 – 1.70+	1.37	2.44	55.91	43.7	34.74	0.95	0.10	14.9
Pedon 2									
Ap	0.00 – 0.20	1.15	2.42	50.15	52.4	28.81	0.83	0.15	14.1
Bss1	0.20 – 0.55	1.30	2.40	49.85	45.9	24.39	0.79	0.12	15.8
Bss2	0.55 – 0.90	1.44	2.49	56.13	42.2	32.29	0.87	0.11	15.9
Bss3	0.90 – 1.20	1.48	2.49	63.26	40.6	34.45	0.96	0.17	16.9
Bss4	1.20 - 1.70+	1.47	2.51	68.21	41.3	41.45	0.98	0.09	17.9
Pedon 3									
Ap	0.00 – 0.20	1.28	2.47	49.42	48.0	22.17	0.77	0.08	13.2
Bss1	0.20 – 0.50	1.33	2.42	50.47	45.0	23.23	0.76	0.15	13.6
Bss2	0.50 – 0.80	1.36	2.58	51.30	47.3	23.72	0.74	0.15	13.7
Bss3	0.80 – 1.20	1.25	2.55	51.33	50.8	23.92	0.73	0.15	13.8
Bss4	1.20 – 1.60+	1.39	2.59	52.81	46.3	23.98	0.74	0.12	15.6
Pedon 4									
Ap	0.00 – 0.20	1.36	2.47	40.71	45.0	20.12	0.74	0.08	12.7
Bss1	0.20 – 0.42	1.39	2.55	43.17	45.5	20.38	0.82	0.15	13.0
Bss2	0.42 – 0.92	1.46	2.63	43.49	44.3	20.62	0.74	0.12	13.1

Pedon No. & Horizon	Depth (m)	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Waterholding capacity (%)	Pore space (%)	Volume expansion (%)	WHC/ clay	COLE	LOI (%)
Bss3	0.92 – 1.34	1.41	2.56	46.00	45.1	22.17	0.71	0.15	13.8
Bss4	1.34 – 1.65+	1.48	2.50	48.79	40.7	22.35	0.79	0.13	14.5
Pedon 5									
Ap	0.00 – 0.20	1.22	2.43	44.33	49.7	22.28	0.74	0.14	14.9
Bss1	0.20 – 0.41	1.35	2.55	49.89	46.8	20.93	0.80	0.13	15.9
Bss2	0.41 – 0.82	1.39	2.49	49.95	44.1	26.15	0.75	0.15	16.0
Bss3	0.82 – 1.11	1.41	2.52	50.37	44.1	23.68	0.74	0.13	16.7
Bss4	1.11 – 1.55+	1.47	2.59	57.20	43.1	30.47	0.82	0.14	17.3
Pedon 6									
Ap	0.00 – 0.15	1.33	2.47	48.39	46.1	23.92	0.88	0.14	15.5
Bss1	0.15 – 0.42	1.29	2.51	50.36	48.7	22.96	0.89	0.12	16.2
Bss2	0.42 – 0.80	1.40	2.51	52.70	44.2	27.88	0.89	0.14	16.1
Bss3	0.80 – 1.30	1.41	2.58	54.91	45.1	27.11	0.88	0.13	16.3
Bss4	1.30 – 1.60	1.46	2.42	52.95	39.7	34.32	0.83	0.12	16.8
Bss5	1.60 – 1.90+	1.51	2.40	65.61	37.0	32.31	0.99	0.14	17.3

Cont…

Table 2. Contd…

Pedon No. & Horizon	Depth (m)	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Waterholding capacity (%)	Pore space (%)	Volume expansion (%)	WHC/ clay	COLE	LOI (%)
Pedon 7									
Ap	0.00 – 0.20	1.11	2.48	52.09	55.2	23.28	0.89	0.14	15.1
Bss1	0.20 – 0.60	1.18	2.70	56.83	56.4	24.84	0.90	0.12	15.6
Bss2	0.60 – 1.00	1.26	2.43	57.76	48.1	25.47	0.89	0.12	15.6
Bss3	1.00 – 1.40	1.28	2.51	61.80	48.9	27.97	0.92	0.12	16.0
Bss4	1.40 – 1.70	1.37	2.52	66.07	45.8	32.57	0.96	0.16	16.2
Bss5	1.70 – 1.90+	1.33	2.51	66.74	47.1	33.81	0.95	0.13	18.7
Pedon 8									
Ap	0.00 – 0.18	1.26	2.72	59.29	53.6	17.41	0.98	0.13	13.8
Bss1	0.18 – 0.52	1.30	2.59	56.45	49.9	20.03	0.88	0.10	14.3
Bss2	0.52 – 0.92	1.28	2.49	57.15	48.8	27.00	0.86	0.11	14.4
Bss3	0.92 – 1.32	1.18	2.56	63.33	53.8	34.06	0.92	0.12	15.4

Pedon No. & Horizon	Depth (m)	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Waterholding capacity (%)	Pore space (%)	Volume expansion (%)	WHC/ clay	COLE	LOI (%)
Bss4	1.32 – 1.62	1.40	2.44	65.80	42.3	40.66	0.93	0.15	18.8
Bss5	1.62 – 1.90+	1.40	2.65	69.56	47.0	39.90	0.97	0.12	19.3
Minimum	**-**	**1.02**	**2.40**	**40.71**	**37.03**	**17.41**	**0.71**	**0.04**	**12.30**
Maximum	**-**	**1.51**	**2.72**	**69.56**	**60.34**	**41.45**	**1.00**	**0.18**	**19.30**
Mean	**-**	**1.34**	**2.51**	**54.36**	**46.71**	**27.04**	**0.86**	**0.13**	**15.30**

Table 3. Physico-chemical properties of soils

Pedon No. & Horizon	Depth (m)	Organic carbon (%)	pH 1:2.5		∆ pH	EC (dSm^{-1})
			H_2O	1*N* KCl		
Pedon 1						
Ap	0.00 – 0.20	0.57	7.80	6.85	-0.95	1.00
Bss1	0.20 – 0.60	0.45	7.90	6.59	-1.31	1.06
Bss2	0.60 – 0.90	0.45	7.93	6.72	-1.21	1.16
Bss3	0.90 – 1.30	0.42	7.84	6.65	-1.19	1.25
Bss4	1.30 – 1.70+	0.42	7.98	6.68	-1.30	1.28
Pedon 2						
Ap	0.00 – 0.20	0.59	7.81	6.86	-0.95	0.88
Bss1	0.20 – 0.55	0.41	8.01	6.72	-1.29	0.96
Bss2	0.55 – 0.90	0.42	8.13	6.73	-1.40	1.10
Bss3	0.90 – 1.20	0.42	8.22	6.77	-1.45	1.33
Bss4	1.20 – 1.70+	0.42	8.18	6.82	-1.36	1.82
Pedon 3						
Ap	0.00 – 0.20	1.02	6.82	5.73	-1.09	0.48
Bss1	0.20 – 0.50	0.39	7.74	6.49	-1.25	0.50
Bss2	0.50 – 0.80	0.44	7.77	6.48	-1.29	0.51
Bss3	0.80 – 1.20	0.38	7.78	6.53	-1.25	0.58
Bss4	1.20 – 1.60+	0.38	7.81	6.53	-1.28	0.62
Pedon 4						
Ap	0.00 – 0.20	0.68	7.33	6.37	-0.96	0.55
Bss1	0.20 – 0.42	0.44	7.46	6.26	-1.20	0.58
Bss2	0.42 – 0.92	0.41	7.60	6.51	-1.09	0.64
Bss3	0.92 – 1.34	0.42	7.59	6.47	-1.12	0.66
Bss4	1.34 – 1.65+	0.32	7.60	6.58	-1.02	0.67

Pedon 5						
Ap	0.00 – 0.20	0.75	7.89	6.60	-1.29	0.88
Bss1	0.20 – 0.41	0.41	7.97	6.73	-1.24	0.97
Bss2	0.41 – 0.82	0.33	7.98	6.75	-1.23	1.29
Bss3	0.82 – 1.11	0.33	7.88	6.69	-1.19	1.60
Bss4	1.11 – 1.55+	0.41	7.78	6.69	-1.09	1.80

Cont…

Table 3. Contd…

Pedon No. & Horizon	**Depth (m)**	**Organic carbon (%)**	**pH 1:2.5**		**∆ pH**	**EC (dSm^{-1})**
			H_2O	**1*N* Kcl**		
Pedon 6						
Ap	0.00 – 0.15	0.63	7.57	6.82	-0.75	1.00
Bss1	0.15 – 0.42	0.39	7.97	6.74	-1.23	1.30
Bss2	0.42 – 0.80	0.29	7.96	6.69	-1.27	1.56
Bss3	0.80 – 1.30	0.27	7.97	6.73	-1.24	1.70
Bss4	1.30 – 1.60	0.33	8.13	6.72	-1.41	1.88
Bss5	1.60 – 1.90+	0.27	8.27	6.90	-1.37	2.06
Pedon 7						
Ap	0.00 – 0.20	0.69	7.60	6.64	-0.96	0.80
Bss1	0.20 – 0.60	0.36	7.98	6.67	-1.31	1.02
Bss2	0.60 – 1.00	0.30	8.05	6.66	-1.39	1.06
Bss3	1.00 – 1.40	0.26	8.08	6.67	-1.41	1.25
Bss4	1.40 – 1.70	0.23	8.10	6.69	-1.41	1.46
Bss5	1.70 – 1.90+	0.15	8.19	6.74	-1.45	1.57
Pedon 8						
Ap	0.00 – 0.18	0.57	7.71	6.61	-1.10	0.81
Bss1	0.18 – 0.52	0.41	7.97	6.64	-1.33	0.94
Bss2	0.52 – 0.92	0.32	8.09	6.65	-1.44	0.94
Bss3	0.92 – 1.32	0.29	8.20	6.60	-1.60	1.16
Bss4	1.32 – 1.62	0.29	8.17	6.66	-1.51	1.26
Bss5	1.62 – 1.90+	0.23	8.20	6.77	-1.43	1.48
Minimum	**-**	**0.15**	**6.82**	**5.73**	**-1.60**	**0.48**
Maximum	**-**	**1.02**	**8.27**	**6.90**	**-0.75**	**2.06**
Mean	**-**	**0.42**	**7.88**	**6.64**	**-1.25**	**1.10**

Table 4. Electro-chemical properties of soils

Pedon No. & Horizon	Depth (m)	CEC [cmol (p^+) kg^{-1}]	Exchangeable bases (c mol (p+) kg^{-1})				Base saturation (%)	CEC/Clay	Ca / Mg
			Ca^{2+}	Mg^{2+}	Na^+	K^+			
Pedon 1									
Ap	0.00 – 0.20	40.96	31.3	4.3	1.6	0.25	91.43	0.80	7.28
Bss1	0.20 – 0.60	45.26	35.2	4.1	1.5	0.32	90.85	0.83	8.59
Bss2	0.60 – 0.90	41.31	32.4	4.4	1.3	0.31	92.98	0.79	7.36
Bss3	0.90 – 1.30	47.89	37.7	4.3	1.2	0.28	90.79	0.90	8.77
Bss4	1.30 – 1.70+	49.85	40.5	5.5	0.9	0.22	94.52	0.85	7.36
Pedon 2									
Ap	0.00 – 0.20	50.32	39.8	5.2	1.4	0.89	93.98	0.83	7.65
Bss1	0.20 – 0.55	53.65	43.6	5.6	1.5	0.16	94.80	0.85	7.79
Bss2	0.55 – 0.90	54.51	44.9	5.5	1.3	0.91	96.51	0.84	8.16
Bss3	0.90 – 1.20	55.53	45.4	5.8	1.8	0.99	97.23	0.84	7.83
Bss4	1.20 – 1.70+	58.65	47.5	6.1	1.6	0.87	95.60	0.84	7.79
Pedon 3									
Ap	0.00 – 0.20	55.25	42.2	5.2	1.2	0.15	88.24	0.86	8.12
Bss1	0.20 – 0.50	58.36	46.4	5.5	1.9	0.54	93.11	0.88	8.44
Bss2	0.50 – 0.80	60.21	49.4	5.7	1.4	0.87	95.28	0.86	8.67
Bss3	0.80 – 1.20	62.12	51.5	5.8	1.7	0.8	96.27	0.88	8.88
Bss4	1.20 – 1.60+	63.14	53.7	5.3	1.5	0.45	96.53	0.88	10.13
Pedon 4									
Ap	0.00 – 0.20	45.52	34.6	4.6	1.2	0.45	89.74	0.82	7.52
Bss1	0.20 – 0.42	40.46	30.8	4.3	1.3	0.15	90.34	0.77	7.16
Bss2	0.42 – 0.92	43.23	35.3	4.2	1.3	0.13	94.68	0.74	8.40
Bss3	0.92 – 1.34	59.56	49.5	5.6	1.1	0.64	95.43	0.92	8.84
Bss4	1.34 – 1.65+	54.23	45.8	5.7	1.4	0.14	97.81	0.88	8.04
Pedon 5									
Ap	0.00 – 0.20	54.44	43.3	5.4	0.9	0.12	91.33	0.90	8.02
Bss1	0.20 – 0.41	55.64	44.4	5.5	1.4	0.65	93.37	0.89	8.07
Bss2	0.41 – 0.82	57.23	47.6	5.4	1.2	0.41	95.42	0.86	8.81
Bss3	0.82 – 1.11	59.32	48.8	5.8	1.4	0.64	95.48	0.87	8.41
Bss4	1.11 – 1.55+	60.21	51.4	5.3	1.6	0.57	97.77	0.87	9.70

Pedon No. & Horizon	Depth (m)	CEC [cmol (p$^+$) kg^{-1}]	Exchangeable bases (c mol (p+) kg^{-1})				Base saturation (%)	CEC/Clay	Ca / Mg
			Ca^{2+}	Mg^{2+}	Na^+	K^+			
Pedon 6									
Ap	0.00 – 0.15	43.12	32.5	4.2	1.4	0.97	90.61	0.78	7.74
Bss1	0.15 – 0.42	48.65	37.3	4.9	1.8	0.42	91.31	0.86	7.61
Bss2	0.42 – 0.80	49.74	39.5	4.6	1.9	0.24	92.96	0.84	8.59
Bss3	0.80 – 1.30	45.32	35.2	4.2	1.6	0.12	90.73	0.72	8.38
Bss4	1.30 – 1.60	53.44	41.7	5.8	1.8	0.93	93.99	0.84	7.19
Bss5	1.60 – 1.90+	55.24	45.4	5.6	1.9	0.42	96.52	0.83	8.11

Cont…

Table 4. Contd…

Pedon No. & Horizon	Depth (m)	CEC [cmol (p$^+$) kg^{-1}	Exchangeable bases (c mol (p+) kg^{-1})				Base saturation (%)	CEC/Clay	Ca / Mg
			Ca^{2+}	Mg^{2+}	Na^+	K^+			
Pedon 7									
Ap	0.00 – 0.20	48.35	37.6	4.4	1.1	0.94	91.09	0.83	8.55
Bss1	0.20 – 0.60	50.36	39.8	5.2	1.2	0.84	93.41	0.79	7.65
Bss2	0.60 – 1.00	51.56	41.5	5.5	1.4	0.4	94.65	0.80	7.55
Bss3	1.00 – 1.40	54.24	44.6	5.4	1.5	0.71	96.26	0.81	8.26
Bss4	1.40 – 1.70	55.38	46.2	5.2	1.7	0.84	97.40	0.81	8.88
Bss5	1.70 – 1.90+	59.65	50.3	5.6	1.6	0.99	98.06	0.85	8.98
Pedon 8									
Ap	0.00 – 0.18	49.85	39.5	4.2	1.8	0.76	92.80	0.83	9.40
Bss1	0.18 – 0.52	50.42	39.8	5.4	1.2	0.87	93.75	0.78	7.37
Bss2	0.52 – 0.92	56.52	45.7	5.5	1.6	0.95	95.10	0.85	8.31
Bss3	0.92 – 1.32	59.86	49.5	5.6	1.2	0.84	95.46	0.87	8.84
Bss4	1.32 – 1.62	61.13	51.6	5.4	1.6	0.65	96.92	0.87	9.56
Bss5	1.62 – 1.90+	62.24	52.4	5.7	1.9	0.75	97.61	0.87	9.19
Minimum	**-**	**40.46**	**30.80**	**4.10**	**0.90**	**0.12**	**88.20**	**0.72**	**7.16**
Maximum	**-**	**63.14**	**53.70**	**6.10**	**1.90**	**0.99**	**98.10**	**0.92**	**10.13**
Mean	**-**	**53.07**	**42.86**	**5.17**	**1.46**	**0.57**	**94.14**	**0.84**	**8.28**

Table 5. Per cent of saturation and contribution of basic cations to CEC and PBS

Pedon No. & Horizon	Depth (m)	% Saturation to CEC				% Contribution to PBS			
		Ca^{2+}	Mg^{2+}	Na^{+}(ESP)	K^{+}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
Pedon 1									
Ap	0.00 – 0.20	76.42	10.50	3.91	0.61	83.58	11.48	4.27	0.67
Bss1	0.20 – 0.60	77.77	9.06	3.31	0.71	85.60	9.97	3.65	0.78
Bss2	0.60 – 0.90	78.43	10.65	3.15	0.75	84.35	11.46	3.38	0.81
Bss3	0.90 – 1.30	78.72	8.98	2.51	0.58	86.71	9.89	2.76	0.64
Bss4	1.30 – 1.70+	81.24	11.03	1.81	0.44	85.95	11.67	1.91	0.47
Pedon 2									
Ap	0.00 – 0.20	79.09	10.33	2.78	1.77	84.16	11.00	2.96	1.88
Bss1	0.20 – 0.55	81.27	10.44	2.80	0.30	85.73	11.01	2.95	0.31
Bss2	0.55 – 0.90	82.37	10.09	2.38	1.67	85.34	10.45	2.47	1.73
Bss3	0.90 – 1.20	81.76	10.44	3.24	1.78	84.09	10.74	3.33	1.83
Bss4	1.20 – 1.70+	80.99	10.40	2.73	1.48	84.72	10.88	2.85	1.55
Pedon 3									
Ap	0.00 – 0.20	76.38	9.41	2.17	0.27	86.56	10.67	2.46	0.31
Bss1	0.20 – 0.50	79.51	9.42	3.26	0.93	85.39	10.12	3.50	0.99
Bss2	0.50 – 0.80	82.05	9.47	2.33	1.44	86.11	9.94	2.44	1.52
Bss3	0.80 – 1.20	82.90	9.34	2.74	1.29	86.12	9.70	2.84	1.34
Bss4	1.20 – 1.60+	85.05	8.39	2.38	0.71	88.11	8.70	2.46	0.74
Pedon 4									
Ap	0.00 – 0.20	76.01	10.11	2.64	0.99	84.70	11.26	2.94	1.10
Bss1	0.20 – 0.42	76.12	10.63	3.21	0.37	84.27	11.76	3.56	0.41
Bss2	0.42 – 0.92	81.66	9.72	3.01	0.30	86.24	10.26	3.18	0.32
Bss3	0.92 – 1.34	83.11	9.40	1.85	1.07	87.09	9.85	1.94	1.13
Bss4	1.34 – 1.65+	84.46	10.51	2.58	0.26	86.35	10.75	2.64	0.26
Pedon 5									
Ap	0.00 – 0.20	79.54	9.92	1.65	0.22	87.09	10.86	1.81	0.24
Bss1	0.20 – 0.41	79.80	9.88	2.52	1.17	85.47	10.59	2.69	1.25
Bss2	0.41 – 0.82	83.17	9.44	2.10	0.72	87.16	9.89	2.20	0.75
Bss3	0.82 – 1.11	82.27	9.78	2.36	1.08	86.16	10.24	2.47	1.13
Bss4	1.11 – 1.55+	85.37	8.80	2.66	0.95	87.31	9.00	2.72	0.97

Pedon 6								
Ap	0.00 – 0.15	75.37	9.74	3.25	2.25	83.18	10.75	3.58	2.48
Bss1	0.15 – 0.42	76.67	10.07	3.70	0.86	83.97	11.03	4.05	0.95
Bss2	0.42 – 0.80	79.41	9.25	3.82	0.48	85.42	9.95	4.11	0.52
Bss3	0.80 – 1.30	77.67	9.27	3.53	0.26	85.60	10.21	3.89	0.29
Bss4	1.30 – 1.60	78.03	10.85	3.37	1.74	83.02	11.55	3.58	1.85
Bss5	1.60 – 1.90+	82.19	10.14	3.44	0.76	85.15	10.50	3.56	0.79

Cont…

Table 5. Contd…

Pedon & Horizon No.	Depth (m)	% Saturation to CEC				% Contribution to PBS			
		Ca^{2+}	Mg^{2+}	Na^{+}(ESP)	K^{+}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
Pedon 7									
Ap	0.00 – 0.20	77.77	9.10	2.28	1.94	85.38	9.99	2.50	2.13
Bss1	0.20 – 0.60	79.03	10.33	2.38	1.67	84.61	11.05	2.55	1.79
Bss2	0.60 – 1.00	80.49	10.67	2.72	0.78	85.04	11.27	2.87	0.82
Bss3	1.00 – 1.40	82.23	9.96	2.77	1.31	85.42	10.34	2.87	1.36
Bss4	1.40 – 1.70	83.42	9.39	3.07	1.52	85.65	9.64	3.15	1.56
Bss5	1.70 – 1.90+	84.33	9.39	2.68	1.66	86.00	9.57	2.74	1.69
Pedon 8									
Ap	0.00 – 0.18	79.24	8.43	3.61	1.52	85.39	9.08	3.89	1.64
Bss1	0.18 – 0.52	78.94	10.71	2.38	1.73	84.20	11.42	2.54	1.84
Bss2	0.52 – 0.92	80.86	9.73	2.83	1.68	85.02	10.23	2.98	1.77
Bss3	0.92 – 1.32	82.69	9.36	2.00	1.40	86.63	9.80	2.10	1.47
Bss4	1.32 – 1.62	84.41	8.83	2.62	1.06	87.09	9.11	2.70	1.10
Bss5	1.62 – 1.90+	84.19	9.16	3.05	1.21	86.26	9.38	3.13	1.23
Minimum	**-**	**75.37**	**8.39**	**1.65**	**0.22**	**83.02**	**8.70**	**1.81**	**0.24**
Maximum	**-**	**85.37**	**11.03**	**3.91**	**2.25**	**88.11**	**11.76**	**4.27**	**2.48**
Mean	**-**	**80.52**	**9.78**	**2.78**	**1.06**	**85.52**	**10.40**	**2.96**	**1.13**

Table 6. Available nutrient content of the soils

Pedon No. & Horizon	Depth (m)	Macro nutrients (mg kg^{-1})				Micro nutrients (mg kg^{-1})			
		N	P_2O_5	K_2O	S	Fe	Mn	Cu	Zn
Pedon 1									
Ap	0.00 – 0.20	162	29.1	184	13.27	27.05	25.05	3.30	1.47
Bss1	0.20 – 0.60	123	16.6	146	11.96	23.68	17.93	3.06	0.73
Bss2	0.60 – 0.90	95	16.6	178	9.84	21.72	16.32	3.02	0.75
Bss3	0.90 – 1.30	84	15.8	192	9.74	20.11	15.32	2.75	0.61
Bss4	1.30 – 1.70+	67	15.0	210	8.22	18.91	12.06	0.53	0.51
Pedon 2									
Ap	0.00 – 0.20	134	61.4	236	17.30	28.53	22.93	4.68	2.33
Bss1	0.20 – 0.55	78	22.4	163	11.25	22.49	21.15	3.54	0.93
Bss2	0.55 – 0.90	106	15.8	186	9.23	21.86	19.80	3.70	0.86
Bss3	0.90 – 1.20	84	14.1	189	9.23	20.81	18.22	2.79	0.86
Bss4	1.20 – 1.70+	67	16.6	192	7.01	20.74	13.22	2.87	0.54
Pedon 3									
Ap	0.00 – 0.20	112	58.9	233	6.31	49.65	28.51	4.07	1.73
Bss1	0.20 – 0.50	78	28.2	143	4.39	27.05	27.86	0.38	0.89
Bss2	0.50 – 0.80	67	24.9	152	3.38	22.14	24.61	1.09	0.80
Bss3	0.80 – 1.20	78	14.1	154	3.08	21.51	20.48	2.70	0.72
Bss4	1.20 – 1.60+	78	14.1	184	3.38	20.46	19.99	2.64	0.71
Pedon 4									
Ap	0.00 – 0.20	129	75.5	221	4.69	36.60	33.67	5.59	4.78
Bss1	0.20 – 0.42	112	20.8	218	3.08	27.33	32.48	3.66	4.69
Bss2	0.42 – 0.92	106	15.0	204	2.37	20.46	27.54	3.54	2.97
Bss3	0.92 – 1.34	101	22.4	192	1.76	19.96	22.70	3.38	0.69
Bss4	1.34 – 1.65+	78	29.1	189	2.47	16.04	19.15	3.34	0.65
Pedon 5									
Ap	0.00 – 0.20	95	65.6	233	20.63	44.11	21.48	0.42	3.93
Bss1	0.20 – 0.41	73	21.6	184	16.60	22.14	15.77	0.38	0.93
Bss2	0.41 – 0.82	73	29.1	169	12.86	21.23	15.32	0.69	0.18
Bss3	0.82 – 1.11	73	14.1	184	7.62	19.26	15.03	0.29	0.11
Bss4	1.11 – 1.55+	56	18.3	178	6.51	18.98	14.61	0.19	0.03

Pedon 6									
Ap	0.00 – 0.20	123	53.1	277	20.53	36.60	21.77	4.80	1.34
Bss1	0.20 – 0.60	95	19.9	195	8.83	20.74	19.15	3.93	0.76
Bss2	0.60 – 1.00	84	22.4	198	8.12	17.51	19.12	3.74	0.92
Bss3	1.00 – 1.40	84	14.1	201	7.62	16.46	17.51	2.91	0.10
Bss4	1.40 – 1.70	78	15.0	198	5.60	15.68	17.09	2.71	0.68
Bss5	1.70 – 1.90+	67	10.0	178	4.29	13.86	12.32	2.67	0.94

Cont…

Table 6. Contd…

Pedon No. & Horizon	**Depth (m)**	**Macro nutrients (mg kg^{-1})**				**Micro nutrients (mg kg^{-1})**			
		N	**P_2O_5**	**K_2O**	**S**	**Fe**	**Mn**	**Cu**	**Zn**
Pedon 7									
Ap	0.00 – 0.18	129	52.3	213	7.92	27.06	20.32	4.60	1.24
Bss1	0.18 – 0.52	90	19.9	169	6.91	20.11	17.67	2.67	0.56
Bss2	0.52 – 0.92	78	13.3	184	5.50	16.81	15.74	2.47	0.52
Bss3	0.92 – 1.32	73	9.2	195	5.20	15.26	14.80	2.31	0.49
Bss4	1.32 – 1.62	67	10.8	210	4.29	14.91	14.03	2.27	0.49
Bss5	1.62 – 1.90+	67	10.0	218	3.78	14.49	8.90	0.85	0.46
Pedon 8									
Ap	0.00 – 0.18	129	64.7	216	11.45	22.63	20.41	3.93	0.78
Bss1	0.18 – 0.52	95	33.2	178	10.95	18.63	18.57	2.87	0.73
Bss2	0.52 – 0.92	78	10.8	178	8.63	17.86	17.67	2.75	0.59
Bss3	0.92 – 1.32	78	10.0	207	7.41	16.18	15.93	2.51	0.54
Bss4	1.32 – 1.62	73	15.0	204	6.91	15.12	15.51	2.19	0.44
Bss5	1.62 – 1.90+	73	21.6	189	4.39	13.79	12.28	0.45	0.24
Minimum	**-**	**56**	**9.2**	**143**	**1.8**	**13.8**	**8.9**	**0.2**	**0.03**
Maximum	**-**	**162**	**75.50**	**277**	**20.6**	**49.7**	**33.7**	**5.6**	**4.8**
Mean	**-**	**90**	**25.13**	**193**	**8.01**	**22.01**	**19.07**	**2.39**	**0.97**

between organic carbon and available sulphur confirmed the above trend. Similar findings were reported by Shekhar et al. [9] and Thangasamy et al. [13].

4.2 Micronutrients

The DTPA exctractable zinc ranged from 0.03 to 4.8 mg kg-1 soil. The lowest value (0.03 mg kg-1 soil) was observed in pedon 5 (Bss2) and pedon 6 (Bss2, Bss3, Bss4, Bss5 and Bss6) and the highest value (4.8 mg kg-1 soil) was recorded in Bss2 horizon of pedon 4. All the pedons showed a decreasing trend with depth. The low DTPA exctractable zinc was possibly due to high soil pH values which might have resulted in the formation of insoluble compounds of zinc or insoluble calcium zincate (Prasad *et al.,* 2009). Deficiency of zinc in sub-surface horizons was due to low amount of organic carbon in these deeper layers. These results were in accordance with the results of Murthy et al. [17]. The DTPA exctractable zinc was significantly and positively correlated (r = +0.569**) with organic carbon. DTPA-extractable Zn was higher in surface horizons and decreased with depth generally in most of the pedons. Similar observations were made by Kumar and Naidu [14] in soils of Vadamalapeta mandal of Chittoor district. The DTPA exctractable copper ranged from 0.19 to 5.6 mg kg-1 soil. The lowest value of 0.19 mg kg-1 soil was recorded in pedons 5 (Bss5) and the highest value of 5.6 mg kg-1 soil was observed in Ap layer of pedon4. The pedons 1, 4, 5, 6, 7 and 8 showed a decreasing trend with depth except pedons 2 and 3. DTPA exctractable copper was positively correlated (r = +0.158) with organic carbon. Similar findings were made by Sarkar et al. [18]. The higher concentration of copper in the surface horizons might be due to higher biological activity and the chelating of organic compounds, released during the decomposition of organic matter left after harvesting of crop. Similar findings were made by Shekhar [9] in soils of Prakasam district in Andhra Pradesh. The DTPA exctractable iron varied from 13.8 to 49.7 mg kg-1 soil. The highest value (49.7 mg kg-1 soil) was observed in Ap layer of pedon 3 and the lowest value (13.8 mg kg-1 soil) was recorded in Bss6 horizon of pedon 8. All the pedons showed a decreasing trend with depth. The surface horizons contain more Fe than sub-surface horizons, which might be due to accumulation of organic carbon in the surface horizons. The organic carbon due to its affinity to influence the solubility and availability of iron by chelation effect might have protected the iron from oxidation and precipitation, which consequently increased the availability of iron [19]. These results were further supported by positive correlation of DTPA exctractable iron with organic carbon (r = +0.929**) and significant and negatively correlation with pH (r = -0.729**). These findings were in good agreement with those of Paramasivan and Jawahar [20]. The DTPA exctractable manganese content varied between 8.9 and 33.7 mg kg^{-1} soil. The highest value of 33.7 mg kg^{-1} soil was recorded in Ap horizon of pedon 4 and the lowest value of 8.9 mg kg^{-1} soil was recorded in Bss6 layer of pedon 7. The DTPA exctractable Mn was almost high in the surface horizons and decreased with depth, which might be due to comparatively higher biological activity or organic carbon in the surface horizons. These results were further supported by positive correlation of DTPA exctractable iron with organic carbon (r = +0.618**) and significant. Similar findings were also made by Shekhar et al. [9] in alluvial plain soils of Prakasam district.

5. CONCLUSION

The Pedons 2, 3, 5, 6, 7 and 8 exhibited an increasing trend in clay content with depth. However, no specific trend with depth was observed in the remaining pedons. Physical constants like water holding capacity, loss on ignition and volume expansion followed the trend of clay content. Bulk density showed an increasing trend with depth corresponding to decreasing organic carbon with depth in all the pedons. COLE values didn’t follow any specific trend with depth in any of the pedons. The soils of Chinnapalem village were neutral to moderately alkaline (6.82 to 8.27.) in reaction, non-saline to slightly saline (0.48 and 2.06 dS m^{-1}) and low to medium (0.15 to 1.02 %) in organic carbon. The CEC values were medium to high (40.46 to 63.14 cmol (p+) kg^{-1}) and exchange complex was dominated by Ca^{2+} followed by Mg^{2+}, Na^{+} and K^{+}. The soils were low to medium (56 to 162 mg kg^{-1}) in available nitrogen, low to high (9.16 to 75.51 mg P_2O_5 kg^{-1}) in available phosphorous, high in potassium (143 to 277 mg K_2O kg^{-1}) and deficient to sufficient (1.8 and 20.6 mg kg^{-1}) in available sulphur. However, the soils were sufficient in DTPA extractable Cu, Fe and Mn and deficient to sufficient in DTPA extractable Zn [21-26].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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