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Characterization and classification of soils of Mahabubabad district in Telangana state

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Abstract
Six typical pedons from of Mahabubabad district were studied for physical, physico-chemical and chemical properties of the area. The soils were moderately deep to very deep, reddish brown to dark reddish brown in colour, gravelley sand to clay in texture and had varied structure including granular and sub-angular blocky structure. The clay content in soils varied from 6.1to 61.6 per cent. The clay content increased with depth in all pedons. Silt fraction in the soils 6.5 to 22.9 per cent. The sand content in the soils under investigation varied from 18.6 to 85.3 per cent. Most of the pedons exhibited more or less an increasing trend in bulk density with depth. These soils were near slightly acidic to moderately strong alkaline in reaction, non-saline and very low to medium in organic carbon. The CEC varied from 2.8 to 47.2 C mol (p^+) kg^{-1} soil and dominated by Ca^{+2} followed by Mg^{+2}, Na^+ and K^+. The soils were very low to medium in available nitrogen, low to medium in available phosphorus and potassium. Available zinc was deficient to sufficient in all the horizon. The soils were defficient in available iron, copper and manganese. The soils were classified as Typic Haplusterts, Typic Haplustepts, Vertic Haplustepts and Typic Rhodustalfs.

Keywords: characterization, nutrient status, classification and physical properties

Introduction
Soil is the most important resource for agriculture and needs to be utilized precisely for sustainable crop production. The availability of land for agriculture has been reduced and is likely to touch the limit of 0.10 ha by 2025 (Sekhon and Velayutham, 2002) [23]. Lack of soil characterization becomes obstacle to utilize the soil production potentials and adaptation of better management practice to increase the productivity of the soil (ISSS, 2000) [5]. Soil characterization determines the soil's individual inherent potentials and constraints for crop production besides giving detailed information about the different soil properties. Characterization and systematic classification of dominant soil groups is an essential tool and a pre-requisite for soil fertility evaluation and efficient soil-fertilizer-water management practices and, thus, crop management. The newly formed Telangana state has variable types of soils. Any progress and development in agriculture depends largely on soil resources. Maintaining soil in the state of high productivity on sustainable basis is important for meeting basic needs of the people. Systematic study of soils is important for scientific utilization of these soils and land resources.

Materials and Methods
The pedons from the study area in Mahabubabad district lies in Central Telangana Zone in Telangana state which lies between 17º 33' & 18º 00' North latitude and 79º 36' & 80º 37' East longitude. The study area is characterised by semi arid climatic condition, with the average rainfall of 803.2 mm (decennial average of 2004-13) of which 90.11 per cent is received during southwest monsoon, 4.80 per cent during northeast monsoon and 5.08 per cent during summer season. Mean monthly rainfall is highest in the month of July month (214.4 mm) followed by September (177.5 mm), August (164.1 mm) months. Annual mean maximum and minimum temperatures of the district are 32.44 ºC and 23.31 ºC respectively. The maximum and minimum mean monthly temperature ranges from 17.0 ºC to 40.8 ºC. The mean minimum temperature is recorded during December (17.0 ºC) and maximum in May (40.8 ºC). Mean annual air temperature of the district is 27.78 ºC. Therefore, the temperature regime of the study area was classified as isohyperthermic. Natural vegetation comprises of

Ficus spp, Tamarind (*Tamarindus indica*), neem (*Azadirachta indica*), *Prosopis* and ber (*Zizyphus jujube*) are predominated trees in the study area.

Table 1: Landscape characteristics of pedons

Pedon	Location	Elevation above mean sea level (m)	Physiography	Slope (%)	Drainage	Parent material
1	Warangal	18^{0}00‘57.12”N 79^{0}36‘10.72”E	Slightly eroded pidi plain	< 1.0	Poorly drained	Weathered limestone
2	Kothaguda	17^{0}33‘19.65”N 80^{0}37‘40.16”E	Gently sloping pediment	1-3	Moderately well drained	Calcareous sand stone
3	Khanpur	17^{0}53‘53.46”N 79^{0}59‘17.87”E	Very gently sloping broad vallay	0-5	Moderately well drained	Weathered limestone
4	Narsampet	17^{0}55‘5.62”N 79^{0}52‘09.82”E	Undulating lands	3-6	Well drained	Granite gneiss
5	Chennaraopet	17^{0}53‘5.62”N 79^{0}52‘09.82”E	Undulating lands	3-6	Well drained	Calcareous sand stone
6	Mahabubabad	17^{0}36‘22.58”N 79^{0}59‘39.56”E	Undulating lands	3-6	Well drained	Granite gneiss

Results and Discussion

Soil Morphology

The soil morphological description of the study area will be presented in the table 2.The depth of different pedons of study area of Mahabubabad district ranges from 16cm to 195+cm and found to have deep to very deep solum. pedon 5 were deep and pedon 1,2,3,4 and 6 were very deep depth >100cm respectively. The highest depth was recorded in BSS_3 horizon of pedon 1 and the lowest depth was observed in horizon AP horizon of pedon 4 and 5 respectively. Nasre *et al.*, (2013) [11] noticed that soil depth is related to slope and degree of soil erosion. It was noticed that, soils developed on plateau top, escarpments, isolated hillocks and foot slopes were shallow and soils developed on undulating lands, alluvial plains and valleys were deep.

The colour of the soil pedons of the study area of Mahabubabad district of Warangal district were varied from reddish brown to dark reddish brown in colour. Whereas hue in the range of 2.5 YR, 7.5 YR and 10 YR, value of 3 to 5 and chroma in the range of 1 to 6 respectively. Occurrence of iron oxides at various hydrated forms might have resulted in dark brown colour to the soils (Ramprakash and Seshagiri Rao, 2002) [15].

The texture of the pedons of study area was varied from gravelly sand to clay. Whereas in the pedons in the pedon 1 the texture was clay throughout depth of the profile. However, Decreasing clay content with increasing depth of the pedon was observed in the pedon 1. In pedon 3 the texture was clay loam throughout the depth of the profile but the clay content increased with increasing depth of the profile. In case of pedons 4 and 6 the finer fractions of the increased significantly with the depth of the soil mainly due to eluviation and illuviation processes operated in the pedons. This resulted in the formation of a distinct argillic horizon in the subsurface horizons. Sand content in the soil decreased with increasing depth in these pedons. These variations were caused by topographic position, difference in the nature of parent material, *in-situ* weathering and translocation of clay and age of soils. The variations in texture of soils were mainly associated with the differences in composition of parent material and topography (Sitanggang *et al.* 2006) [28]. The structure of the soil pedons size of aggregate was fine to medium, grade was week to medium, the type of aggregate was granular to sub-angular blocky structure. The blocky structures *i.e.*, sub-angular and angular blocky were attributed to the presence of higher quantities of clay fractions. Similar observations were reported by Meena *et al.* (2012) [10] in Malwa plateau of Banswara district in Rajasthan.

The consistence in the pedons of the study area varied from slightly hard to hard, firm to friable, and non-sticky and non-plastic to very sticky and very plastic in dry, moist and wet conditions, respectively. This qualitative physical behaviour of soils, as influenced by dry, moist and wet conditions was due to the textural make up and type and stability of structure. It is also influenced, to a greater extent, by the type of clay minerals present in these soils. Dry consistency of the soils was slightly hard in the surface horizons. Whereas, moist consistency of the soil was friable to firm; wet consistency was non-sticky, non-plastic to very sticky, very plastic. In the pedons 4 and 6 the wet consistency was non-sticky, non-plastic to slightly sticky and slightly plastic. Whereas in pedons 1 and 3 the consistency was very sticky to very plastic in most of the horizons indicating the predominance of higher content of high active clays. Presence of friable and non-sticky and non-plastic or slightly sticky and slightly plastic consistency might be due to negligible or very small amount of expanding clay minerals. Satyavathi and Suryanarayana Reddy (2003) [22] and Satyavathi and Suryanarayana Reddy (2004) [21] reported similar consistency in soils of Telangana at different soil moisture limits.

Table 2: Soil morphological description of Mahabubabad district of Warangal district in Telangana state.

Horizon	Depth (cm)	Soil colour	Texture	Structure			Consistence			Efferve-scence	Boundary		Concretions $CaCO_3$	
		Moist		S	G	T	Dry	Moist	Wet		D	T	Q	S
Pedon 1														
Ap	0-18	10.0YR 3/1	c	m	2	sbk	sh	fr	sps	eo	c	s	-	-
Bw1	18-42	10.0YR 3/1	c	m	2	sbk	sh	fi	sp	eo	c	s	-	-
Bw2	42-76	10.0YR 3/1	c	m	2	sbk	h	fi	vsvp	eo	c	s	-	-
Bss1	176-105	10.0YR 3/1	c	m	2	sbk	vh	fi	vsvp	eo	c	s	-	-
Bss2	105-165	10.0YR 3/1	c	m	2	abk	h	fi	vsvp	eo	g	s	-	-
Bss3	165-195	10.0YR 4/2	c	m	2	abk	vh	fi	vsvp	e			f	f
Pedon 2														

Ap	0-18	7.5YR 4/4	scl	f	2	gr	sh	fr	sspo	e	c	s	-	-
Bw1	18-46	7.5YR 4/6	gscl	f	2	sbk	s	vfr	sspo	es	d	s	-	-
Bw2	46-75	7.5YR 4/4	gsl	m	1	sbk	s	vfr	sspo	es	c	s	m	f
BC1	75-103	7.5YR 5/6	gls	f	1	sbk	s	vfr	ssnp	es	a	s	c	m
BC2	103-135	7.5YR 4/4	gls	f	1	sbk	s	vfr	ssnp	es	a	s	m	m
Crk	135+	Weathered Parent Material												
Pedon 3														
Ap	0-18	10.0YR 4/2	cl	c	2	sbk	-	fr	sp	e	c	s	f	f
Bw1	18-36	10.0YR 3/3	cl	m	2	sbk	-	fi	sp	e	c	s	m	f
Bw2	36-68	10.0YR 3/3	cl	m	2	sbk	-	fi	sp	e	g	w	f	f
Bw3	68-97	10.0YR 3/3	cl	m	2	sbk	-	fi	sp	e	g	s	f	f
Bw4	97-130	10.0YR 3/3	cl	m	2	sbk	-	fi	sp	e	g	s	m	f
Bw5	130-160+	10.0YR 3/2	cl	m	2	sbk	-	fi	sp	e	g	s	m	f
Pedon 4														
Ap	0-16	7.0YR 4/5	gs	f	1	gr	-	fr	sopo	eo	a	s	-	-
AB	16-35	7.0YR 4/6	gsl	m	2	sbk	-	fr	sssp	eo	g	s	-	-
Bt1	35-65	2.5YR 3/4	gscl	m	2	sbk	-	fr	sssp	eo	g	s	-	-
Bt2	65-98	2.5YR 3/5	gsc	m	2	sbk	-	fr	sp	eo	g	w	-	-
BC	98-112	2.5YR 3/5	scl	m	1	sbk	-	fr	sp	eo	g	W	-	-
Pedon 5														
AP	0-16	2.5YR 4/3	scl	m	2	sbk	sh	fi	sp	es	c	s	m	f
BW1	16-34	10.0YR 3/3	scl	m	2	sbk	h	fi	sssp	ev	d	w	m	m
BW2	34-69	10.0YR 3/4	sc	f	1	cbk	h	fi	sp	ev	d	s	c	f
C	69+	Weathered Parent Material												
Pedon 6														
Ap	0-18	7.0YR 4/5	gls	f	1	gr	-	fr	sopo	eo	a	s	-	-
Bt1	18-58	2.5YR 3/4	scl	m	1	sbk	-	fr	sp	eo	g	s	-	-
Bt2	58-92	2.5YR 3/5	scl	m	2	sbk	-	fr	sp	eo	g	w	-	-
BC	92-110	2.5YR 3/6	scl	m	1	sbk	-	fr	sp	eo	-	-	-	-

Soil physical properties

The detailed Physical properties of the study area of Mahabubabad district presented in table 3. Sand percentage of study area ranged from 18.6 to 85.3 per cent. The highest sand content was noticed in AP horizon of pedon 4 and while the lowest sand percentage was recorded in horizon AP pedon 1. Higher sand content in these surface soils could be attributed loss of finer fractions of soils due to erosion, movement of clay to deeper horizons due illuviation and more active chemical weathering in the lower horizons due to better availability of moisture. Similar findings were also reported by Basavaraju *et al.* (2005) [3].

The silt content varied from ranged from 6.5 to 22.9 per cent. The highest silt content was observed in BSS2 horizon of pedon 1 where as low silt content was observed in BC horizon of pedon of 6. This might be due to variation in weathering of parent material or *in situ* formation. These results were in agreement with the findings of Satish Kumar and Naidu (2012a) [20].

The clay content in soils of the study area ranged from The clay content in soils of the study area ranged from 6.1 to 61.6 per cent. the highest amount of clay was observed in AP horizon of pedon 1 and while the lowest caly was noticed in AP horizon of pedon 4. Where as pedon 1 showed a decreasing trend with depth. The high clay content in soils was due to deposition of finer fractions in the plains from uplands. Similar results were reported by Vara Prasad Rao *et al.* (2008) [30] in soils of Ramachandrapuram mandal in Chittoor district. Increase in clay content with depth might be due to more intensive chemical weathering at deeper layer and eluviation of finer particles from surface horizon leaving behind coarse particles in surface layers. The enrichment of clay in Bw and Bss horizons of pedons 1, 2, 3 and 5 was primarily due to *in situ* weathering of parent material. Sharma *et al.* (2004) [26] observed an increase in clay content in sub-surface horizons as compared to surface horizons in soils of Neogal watershed in north-west Himalayas. The increase in clay content in the Bt horizon in the pedons 4 and 6 is mainly due illuviation of the clay form the upper horizons. Similar enrichment Bt horizons with the clay content was reported by Ramprakash and Rao (2002) [15] in Krishna district of Andhra Pradesh. The bulk density of different pedons varied from 1.32 Mg m^3 to 1.82 Mg m^{-3}. The higher bulk density values in some pedons may be due to high clay content resulting in greater compaction in swelling clay soils. Similar results were reported by Ashokkumar and Jagdish Prasad (2010) [2] who reported higher bulk density values in the soils of Ahmadnagar district of Maharashtra.

The particle density of different pedons varied from 2.59 to 2.65 Mg m^{-3}. Not much variation in the particle density was recorded among different pedons. No regular increasing or decreasing trend was recorded in particle density in any of the pedons studies in the mahabubabad district.

The saturated hydraulic conductivity was ranged from 0.5 cm/hr to 18.21cm hr^{-1}. The highest hydraulic conductivity was recorded in AP horizon of pedon 4 and while the lowest hydraulic conductivity was found in BW_2 horizon of pedon 1. In all the pedons hydraulic conductivity decreased with increasing depth of the soil. Similar results were earlier reported by Ramprakash and Seshagiri Rao (2002) [15] in Vertisols and Alfisols of Krishna district. Increasing compaction of soil with the depth resulting increasing bulk density, decreasing pore density might have resulted in reduction of the hydraulic conductivity with depth in all the studies pedons. Available water content in the study area ranged from 7.3 per cent to 13.2 per cent the highest AWC was observed in AP horizon of pedon 1 and while the lowest AWC was recorded in Ap horizon pedon 4.These differences in water holding capacity were due to variation in the depth, clay, silt and organic carbon content of the pedons. These results match with those of Thangasamy *et al.* (2005) [29] in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh.

Soil physico-chemical properties

The detailed Physico-chemical properties of the study area of Mahabubabad district presented in table 4. The soil reaction of the study area was ranged from 6.2 to 8.9 *i.e.,* slightly acidic to strongly alkaline in reaction. The highest value of pH was observed in pedon 1 of BSS2 horizon and while the lowest pH was found in pedon 6 horizon of Bt2 horizon. The near neutral to very strongly alkaline pH may be attributed to the reaction of applied fertilizer material with soil colloids, which resulted in the retention of basic cations on the exchange complex of the soil. Similar results were also reported by Sharma *et al.* (2011) [24].

The electrical conductivity ranged from from 0.05 to 1.65dSm^{-1}. The lowest value of 0.05dsm^{-1} was registered in BC horizon of pdedon 6 and while the highest EC was observed in the BSS3 of pedon 1 indicating non-saline in nature.

Table 3: Soil physical properties of Mahabubabad district in Telangana State

Pedon No. & Horizon	Depth (cm)	Sand (%) (0.2-0.05 mm)	Silt (%) (0.5 mm)	Clay (%) (< 0.002 mm)	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Hydraulic Conductivity (cm hr^{-1})	Water retention		Available Water Content (%)
								33 Kpa	1500 Kpa	
P 1										
Ap	0-18	18.6	19.8	61.6	1.78	2.62	1.2	38.1	22.9	15.2
Bw 1	18-42	23.4	21.7	54.9	1.81	2.63	1.1	33.3	20.4	12.9
Bw 2	42 - 76	21.7	21.8	56.5	1.81	2.57	0.7	32.8	21	11.8
Bss 1	176-105	27.8	19.5	52.7	1.82	2.65	0.5	30.9	19.6	11.3
Bss 2	105-165	25.6	22.9	51.5	1.82	2.61	0.21	30.2	19.1	11.1
P 2										
Ap	0-18	63.2	6.9	29.6	1.32	2.64	8.65	17.2	11	6.2
Bw 1	18-46	64.9	9.7	25.4	1.38	2.63	6.54	15.5	9.4	6.1
Bw 2	46-75	78.8	9.9	11.3	1.45	2.65	4.85	12.8	7.9	4.9
BC 1	75-103	80.9	9.6	9.5	1.45	2.58	4.21	5.8	2.9	2.9
BC 2	103-135	84.7	8.8	6.5	1.62	2.63	4.51	5.4	2.2	3.2
Crk	135	Weathered Parent Material								
P 3										
Ap	0-18	39.9	22.8	37.3	1.52	2.63	8.51	21.7	14.1	7.6
Bw1	18-36	40.7	19.7	39.6	1.52	2.59	6.54	24.1	15.1	9
Bw2	36-68	39.8	21.9	38.3	1.56	2.63	6.32	25.1	15.8	9.3
Bw3	68-97	38.7	19.8	41.5	1.52	2.65	4.85	25.4	15.4	10
Bw4	97-130	39.8	18.9	41.3	1.54	2.65	6.21	27.4	17.1	10.3
Bw5	130-160+	39.9	19.8	40.3	1.67	2.65	2.22	26.5	15	11.5
P 4										
Ap	0-16	85.3	8.6	6.1	1.45	2.65	18.21	4.1	1.8	2.3
AB	16-35	76	6.9	17.2	1.51	2.59	12.21	9.8	5.1	4.7
Bt1	35-65	54.9	8.3	36.8	1.52	2.64	5.8	19.8	10.9	8.9
Bt2	65-98	43.8	8.8	47.4	1.56	2.6	4.5	26.4	14.1	12.3
BC	98-112	65.7	6.9	27.4	1.54		3.2	15.5	8.1	7.4
P 5										
AP	0-16	58.9	10.7	30.4	1.32	2.63	8.8	18.2	11	7.2
BW1	16-34	47.9	16.9	35.2	1.38	2.62	5.6	21.1	12.9	8.2
BW2	34-69+	44.9	15.9	39.2	1.42	2.64	5.4	26.5	14.5	12
P 6										
Ap	0-18	78.1	13.6	8.3	1.54	2.63	12.4	5.1	2.5	2.6
Bt1	18-58	66.7	11.6	24.6	1.56	2.59	8.9	16.2	7.6	8.6
Bt2	58-92	52.9	8.7	38.4	1.62	2.65	6.4	25.2	12.2	13
BC	92-110+	65.9	6.5	27.6	1.71	2.62	4.2	15.6	8.6	7

The results in the present study indicate the non-saline nature of soils. The lower electrical conductivity in soils was due to excess leaching of salts and due to free drainage conditions which favoured the removal of released bases by percolating and drainage water. Similar results were observed by Ramprasad *et al*. (2013) [17].

The organic carbon content in study area was found to be very low to medium and ranged from 0.15 to 0.72 per cent. The highest Organic carbon content was recorded in AP horizon of pedon 3 and where as the lowest Organic carbon content was recorded in BSS3 horizon of pedon 1. Organic carbon content in all the pedons showed a decreasing trend with depth. Almost all the pedons showed a decreasing trend in organic carbon with depth, which may be due to the fact that the surface horizons showed more organic matter content than sub-surface horizons due to the addition of plant residues and farm yard manure to surface horizons which resulted in higher organic carbon content in surface horizons than in the lower horizons. This observation was in accordance with results of Basavaraju *et al*., (2005) [3] in soils of Chandragiri mandal in Chittoor district of Andhra Pradesh.

The $CaCO_3$ content in soil under study area ranged from 1.1 to 14.1 per cent. The highest value of $CaCO_3$ content was observed in the BW2 horizon of pedon 5 and where as the lowest value of $CaCO_3$ content was found in the AP horizon of pedon 3. Higher contents of $CaCO_3$ observed in the lower horizons of most of the pedons might be due to high clay content which led to impeded leaching, consequently accumulation of $CaCO_3$ in the lower horizons. Similar results

were reported by Ramprakash and Seshagiri Rao (2002) [15] in soils of Krishna district, Andhra Pradesh.

The CEC value of in the study area ranged from 2.8 to 47.2 C mol (p+) Kg^{-1} of soil. The highest CEC was observed in the AP horizon of pedon 1 and while the lowest CEC was found in the horizon of AP horizon of pedon 4. The higher CEC values observed throughout the soil depth in the pedons 1 was due to illuvial accumulation of clay and also because of dominance of smectite clay mineral. These findings were amply supported by the observations of Satish Kumar and Naidu (2012a) [20] and Leelavathi *et al.* (2010a) [8]. Relatively low CEC is the reflection of parent material and higher degree of weathering leading to depletion of bases. Further, it may be due to dominance of clay minerals with low CEC especially illite and kaolinite. Similar findings were observed by Patil and Jagdish Prasad (2004) [13] and Gangopadhyay *et al.* (2001) [4, 18].

Table 4: Soil physico- chemical properties of Mahabubabad district in Telangana State

Pedon No. & Horizon	Depth (cm)	pH (1:2.5)	EC (dS m^{-1})	Organic carbon g kg^{-1}	$CaCO_3$ (%)	CEC [c mol (p+) kg^{-1}]	Exchangeable bases [c mol (p+)kg^{-1}]				Base Saturation (%)
							Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	
Pedon 1											
Ap	0-18	8.2	0.35	0.53	-	47.2	32.5	12.6	1.8	0.3	100
Bw1	18-42	8.5	0.55	0.42	-	44.8	28.8	13.6	2.1	0.3	100
Bw2	42-76	8.8	0.65	0.38	1.9	45.8	26.9	15	3.6	0.3	100
Bss1	176-105	8.9	1.15	0.26	3.9	40.8	20.8	15.3	4.5	0.2	100
Bss2	105-165	8.8	1.5	0.18	4.8	38.9	18.3	14.8	5.6	0.2	100
Bss3	165-195	8.7	1.65	0.15	5.8	39.4	17.6	14.5	7.1	0.2	100
Pedon 2											
Ap	0-18	7.3	1.8	0.7	2.1	17.5	11.8	5.3	0	0.4	100
Bw1	18-46	7.5	1.5	0.35	4.9	15.4	12	3.1	0	0.3	100
Bw2	46-75	7.3	0.9	0.25	7.8	13.8	10.6	2.9	0	0.3	100
Bc1	75-103	7.7	1.1	0.2	9.1	7.7	5.6	1.8	0.1	0.2	100
Bc2	103-135	8.5	1.8	0.18	9.4	8	5.2	2.3	0.3	0.2	100
Crk	135	Weathered Parent Material									
Pedon 3											
Ap	0-18	7.8	0.21	0.72	1.1	24.1	15.8	7.1	0.8	0.4	100
Bw1	18-36	7.9	0.25	0.48	1.8	23.8	16	6.9	0.7	0.2	100
Bw2	36-68	7.7	0.23	0.32	2.1	22.9	16.3	5.8	0.6	0.2	100
Bw3	68-97	7.6	0.19	0.36	2	24.5	16.4	7.4	0.5	0.2	100
Bw4	97-130	8.1	0.21	0.3	1.5	25.9	16.8	8.4	0.5	0.2	100
Bw5	130-160+	8.3	0.29	0.21	1.6	24.2	17	6.7	0.4	0.1	100
Pedon 4											
Ap	0-16	7.3	0.26	0.61	-	2.8	1.1	0.4	0	0.2	62.5
AB	16-35	6.8	0.14	0.48	-	8.3	3.3	1.4	0	0.3	60.36
Bt1	35-65	6.6	0.14	0.52	-	16.4	7.1	2.7	0.1	0.4	62.87
Bt2	68-98	6.4	0.11	0.5	-	20.8	9.4	3.5	0.1	0.4	64.52
BC	98-112	6.9	0.22	0.22	1.2	12.4	4.9	2.8	0.2	0.3	66.61
Pedon 5											
AP	0-16	7.9	0.44	0.55	9.8	17.5	10.9	3.5	0.3	0.3	85.71
Bw1	16-34	8	0.37	0.41	12.4	19.2	12.1	4.9	0.4	0.3	92.19
Bw2	34-69	7.8	0.42	0.32	14.1	21	13.4	5.6	0.6	0.4	95.24
C	69+	Weathered Parent Material									
Pedon 6											
AP	0-18	7.5	0.15	0.45	-	3.8	1.2	0.4	0.2	0.3	56.58
Bt1	18-58	6.6	0.1	0.57	-	11.8	5.4	1.9	0.2	0.2	65.68
Bt2	58-92	6.2	0.09	0.6	-	17.5	8.2	2.7	0.3	0.4	66.34
BC	92-110+	6.3	0.05	0.42	-	14.4	6.8	2.1	0.3	0.3	66.11

The exchangeable bases in all the pedons found to be in the order of $Ca2^{+}$>Mg^{2+}>Na^{+}>K^{+} on the exchangeable complex. The percent base saturation on the exchange complex of soil under investigated area varied from 56.58 per cent to 100 per cent. Comparatively exchangeable bases in the present study were more or less in the order of Vertisols > Inceptisols > Alfisols. The basic cations content was low in Entisols which might be due to less clay and high silica content. Similar observations were earlier made by Sarkar *et al.* (2001) [18] and Arun Kumar *et al.* (2002) [1]. Relatively higher exchangeable Ca was observed in surface horizons of some pedons which might be due to redistribution of Ca^{2+} by the vegetation. These observations were in agreement with the findings of Patil and Jagdish Prasad (2004) [13].

Soil Classification

The detailed classification of the study area of Mahabubabad district presented in table 5. Based on morphological, physical, physico-chemical, mineralogical and meteorological data, the soils in the study area of Mulugu division of Warangal district were classified as Alfisols, Inceptisols and Vertisols.

Table 5: Soil Classification of the study area

Pedon No.	Order	Sub-order	Great group	Sub-group	Family	Tentative soil series
1	Vertisols	Usterts	Haplusterts	Typic Haplusterts	Very fine, smectitic, isohyperthermic Typic Haplusterts	Warangal
2	Inceptisols	Ustepts	Haplustepts	Typic Haplustepts	Loamy-skeletal, mixed, isohyperthermic Typic Haplustepts	Kothaguda
3	Inceptisols	Ustepts	Haplustepts	Vertic Haplustepts	Fine, smectitic, isohyperthermic, Vertic Haplustepts	Khanapur
4	Alfisols	Ustalfs	Rhodustalfs	Typic Rhodustalfs	Clayey-skeletal, mixed, isohyperthermic Typic Rhodustalfs	Narsampet
5	Inceptisols	Ustepts	Haplustepts	Typic Haplustepts	Fine, mixed, isohyperthermic Typic Haplustepts	Chennaraopet
6	Alfisols	Ustalfs	Rhodustalfs	Typic Rhodustalfs	Fine-loamy, mixed, isohyperthermic, Typic Rhodustalfs	Mahabubabad

The pedon 1 had shown the following characteristics, Cracks that are opened and closed periodically, Intersecting slicken-sides and / or wedge shaped aggregates and pressure faces, More than 30 percent clay (weighted mean) in the fine earth fraction of all the horizons, Absence of lithic contact within 100 cm of the mineral soil surface, Absence of calcic, halic, salic and sodic horizons. Hence, pedons were classified as Fine, smectitic, isohyperthermic, Typic Haplusterts at sub-group level. Ramprakash and Seshagiri Rao (2002) [15] and Ramprakash (2005) [16], taxonomically classified some soils of Krishna district in Andhra Pradesh, Soils in Ramannagudem watershed in Nalgonda district.

Presence of these features in the sub-surface horizons within a depth of 69 cm to 160 cm in pedon 2 (with a thickness of >15 cm) were observed. Absence of rock structure. Did not have anthropic, histic, melanic, mollic, plaggen and umbric epipedons. Absence of duripan, fragipan, argillic, calcic, gypsic, natric, oxic, petro-calcic, petro-gypsic, placic and spodic sub-surface horizons. The pedons did not exhibit intergradation with other taxa or an extragradation from the central concept. Hence, pedon 2 was logically classified as Loamy-skeletal, mixed, isohyperthermic, Typic Haplustepts at sub-group level. Niranjana *et al.* (2011) [12] classified banana growing soils in Pulivendla region of Andhra Pradesh as Typic Haplustepts at sub-group level.

Pedon 3 had shown 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 and slicken-sides or wedge shaped aggegates in a layer 15 cm or more thick that has its upper within 125 cm of the mineral soil surface were classified as Fine, smectitic, isohyperthermic, Vertic Haplustept. The presence of cambic sub-surface diagnostic horizon (Bw) in these pedon was recognized by the above features. Jagdish Prasad *et al.* (2001) [6] reported that presence of cambic sub-surface horizon was the diagnostic criteria for Inceptisols.

Presence of argillic horizon and base saturation of more than 50 % in all the sub-surface layers Hue of 2.5 YR or redder and Value, moist, of 3 or less and Dry value no more than 1 unit higher than the moist value were classified as Fine, mixed, isohyperthermic Typic Rhodustalfs (pedon 4 and 6). Satyavathi and Suryanarayana Reddy (2004) [21] and Ramprasad and Goverdhan (2011) classified the Alfisols of Telangana.

Pedon 5 was not having either duripan or calcic horizon or umbric horizon and have free calcium carbonates with in 200 cm of profiles and the base saturation was more than 60 per cent at a depth between 25 to 75 cm from the soil surface which disqualifies them to be categorized as Dystrustepts. These characters indicated that the pedon represented the central concept of Ustepts. So, the pedon 2 was grouped under Haplustepts at great group level. The pedon did not exhibit intergradation with other taxa or an extragradation from the central concept. Hence, pedon 5 was logically classified as Fine, mixed, isohyperthermic Typic Haplustepts at sub-group level. Niranjana *et al.* (2011) [12] classified banana growing soils in Pulivendla region of Andhra Pradesh as Typic Haplustepts at sub-group level.

Soil nutrient status

Macronutrient status

The nutrient status of the study area of Mahabubabad district presented in table 6. The available nitrogen in the soils under present investigation ranged from 150 to 318 kg/ha. The lowest value of 150 kg ha^{-1} soil was observed in BW2 horizon of pedon 2. The highest value of 318 kg ha^{-1} soil was noticed in AP horizon of pedon 3. The available nitrogen was found to be maximum in the surface horizons and decreased more or less with depth of the pedons, which might be due to decreasing trend of organic carbon with depth. This observation was in agreement with the results of Sarkar *et al.* (2002) [19] and Satish Kumar and Naidu (2012a) [20]. The available phosphorus in soils of the study area varied from 2.5 to 25.5 kg ha^{-1} soil. The lowest value of 2.5 kg ha^{-1} soil was observed in BC2 horizon of pedon 2. The highest value of 25.5 kg ha^{-1} soil was noticed in AP horizon of pedon 1. In general, higher available phosphorus was observed in the surface horizons and decreased regularly with depth. The reason for high available phosphorus in surface horizons might possibly be due to the confinement of crop cultivation to the rhizosphere which improves the organic carbon content in surface and supplementing the depleted phosphorus by external sources *i.e.*, fertilizers and presence of small amounts of free iron oxide and exchangeable Al^{3+} in the surface horizons (Thangasamy *et al.* 2005) [29]. The available potassium in soils of the study area ranged from 145 to 395 kg ha^{-1} soil. The lowest value of 145 kg ha^{-1} soil was observed in BC horizon of pedon 4 and the highest value of 395 kg ha^{-1} soil was noticed in AP horizon of pedon 3. Most of the pedons exhibited more or less a decreasing trend with depth. Slow weathering and fixation of released potassium might have resulted in low exchangeable potassium status (Ramprakash and Seshagiri Rao, 2002) [15]. Amount and type of clay, organic carbon, soil pH and CEC significantly affects the K-availability in the soil. Similar observations were also noticed by Sharma and Anil Kumar (2003) [25] a significant and positive correlation between clay content and available K as K availability was largely controlled by clay minerals.

Micro nutrients

The available zinc was ranged for 0.21 to 4.77 mg kg^{-1} soil. The lowest value of 0.21 mg kg^{-1} soil was noticed in BC1 horizon of pedon 2 and the highest value of 4.77 mg kg^{-1} of soil was recorded in AP horizon of pedon 6.

The available copper in soils under study area ranged from 0.32 to11.20 mg kg^{-1} soil. The lowest value of 0.32 mg kg^{-1} soil was observed in BC horizon of pedon 4 and the highest

value of 11.20 mg kg^{-1} of soil was noticed in AP horizon pedon 2.

The available iron ranged from 5.80 to 52.15 mg kg^{-1} soil. The lowest value of 5.80 mg kg^{-1} soil was recorded in BW2 horizon of pedon 5 and where as the highest value 52.15 mg kg^{-1} soil was noticed in AP horizon of pedon 2.

The available manganese in soils of the study area of ranged from 3.20 mg kg^{-1} to 19.20 mg kg^{-1} of soil. The lowest value of 3.2 mg kg^{-1} of soil was noticed in BW5 horizon of pedon 3 and the highest value of 19.20 mg kg^{-1} soil was observed in AP horizon of pedon 2.

The availability of these ions (Zn, Cu, Fe and Mn) increased with increase in organic matter because organic matter acts as a chelating agent for complexation of these micronutrients which reduces their adsorption, oxidation and precipitation into unavailable forms. Similar kind of relationship between Zn and organic carbon was also reported by Mahesh Kumar *et al.* (2011) [9].

Conclusion

Based on morphological, physical and physico-chemical properties of Mahabubabad district were slightly neutral to moderately alkaline, non-saline, low to medium in organic carbon and CEC. The exchangeable bases in all the pedons in the order of $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ on the exchange complex. Whereas, the soils were low to medium in available nitrogen, low to high in available phosphorus and potassium. Available zinc was deficient to sufficient in all the horizon. The soils were sufficient in available iron, copper and manganese. The soils were classified as Typic Haplusterts, Typic Haplustepts, Vertic Haplustepts and Typic Rhodustalfs.

Table 6: Available major nutrients (kg ha^{-1}) and micronutrient content (mg kg^{-1}) of Mahabubabad district in Telangana State

Pedon No. & Horizon	Depth (cm)	Available macronutrients			Available micronutrients			
		N	P	K	Zn	Cu	Fe	Mn
		kg ha^{-1}			mg kg^{-1}			
Pedon 1								
Ap	0-18	283	25.5	285	1.98	2.4	6.99	14.3
Bw1	18-42	261	21	250	1.92	2.35	6.8	12.9
Bw2	42-76	210	11.8	245	1.57	1.86	6.69	12.05
Bss1	176-105	194	9.5	194	1.17	1.53	6.32	5.31
Bss2	105-165	175	8.5	175	0.92	1.17	5.9	5.2
Bss3	165-195	165	6.5	150	0.85	1.16	5.81	4.75
Pedon 2								
Ap	0-18	295	4.5	315	0.39	11.2	52.15	19.2
Bw1	18-46	235	9.5	275	0.36	10.6	48.9	18.91
Bw2	46-75	185	6.5	165	0.23	9.5	30.6	12.64
Bc1	75-103	165	4.8	158	0.21	8.8	28.65	10.2
Bc2	103-135	150	2.5	155	0.31	8.4	24.6	9.8
Crk	135	Weathered Parent Material						
Pedon 3								
Ap	0-18	318	8.5	395	1.28	3.9	10.9	10.06
Bw1	18-36	235	8.5	280	1.23	2.6	9.62	9.22
Bw2	36-68	225	7.5	255	0.86	1.76	7.21	7.18
Bw3	68-97	215	6.9	245	0.79	1.72	6.08	7.05
Bw4	97-130	205	4.5	195	0.48	0.98	12	3.2
Bw5	130-160+	185	3.6	185	0.56	2.08	9.8	3.2
Pedon 4								
Ap	0-16	235	25.3	325	0.58	0.76	13.8	15.2
AB	16-35	175	17.5	295	0.51	0.48	12.1	14.8
Bt1	35-65	215	13.5	185	0.32	0.41	10.4	12.6
Bt2	68-98	185	11.5	150	1.3	0.39	8.69	8.8
BC	98-112	150	10.5	145	0.61	0.32	5.8	11.6
Pedon 5								
AP	0-16	235	18.5	235	0.39	0.52	6.5	15.08
Bw1	16-34	165	14.5	185	0.32	0.49	6.2	14.8
Bw2	34-69	150	12.5	165	0.26	0.44	5.8	12.14
C	69+	Weathered Parent Material						
Pedon 6								
AP	0-18	194	21.5	325	4.77	4.76	13.93	31.16
Bt1	18-58	175	13.5	215	3.1	4.15	10.21	16.23
Bt2	58-92	165	11.5	185	2.2	3.65	7.68	12.67
BC	92-110+	155	9.5	175	1.64	2.75	6.65	10.91

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