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Soil Physical Properties and Fertility Status of Ayacut Area Under the Thotapalli Irrigation Project of North Coastal Andhra Pradesh

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ABSTRACT

A reconnaissance survey was conducted with 1:50,000 scale in the ayacut area of Thotapalli major irrigation project of North Coastal region of Andhra Pradesh. Based on soil correlation studies six representative soil profiles were selected from Devarapalli, Gujjangivalasa, Patikivalasa, Gangada, Aamiti and Maddivalasa villages under Srikakulam and Vizianagaram districts. Horizon wise soil samples were collected from each profile and analysed for physical, physico-chemical and chemical characters. The data revealed that the soil texture was sandy loam to sandy clay loam in gently sloping uplands, while it was clay loam to clay in cultivated plains. The soil physical constants like bulk density was recorded low at surface horizon compared to subsurface layers, whereas other properties like maximum water holding capacity, pore space and volume expansion were followed the trend as that of clay. The soils were acidic to alkaline in reaction, non saline, low to medium in organic carbon content. The soils in general were low in available nitrogen, low to medium in available phosphorus and medium to high in available potassium status, while the micronutrients were sufficient in respect of manganese and copper however, zinc and iron were deficient to sufficient. Available nitrogen, phosphorous, potassium, zinc, iron, copper and manganese were positively correlated with organic carbon content, while available phosphorous and micronutrients were negatively correlated with soil pH.

Keywords : *Soil physical properties and nutrient status, pH and EC*

The knowledge of soils with respect to their extent, distribution, characteristics and potential use are important for optimising land use. Further the study of soils today has assumed an increased importance due to rapidly declining land area under agriculture, declining soil fertility and increasing soil degradation through unbridled population increase, urbanisation, improper land use policies and irrational use of inputs and information is lacking on these aspects for the ayacut soils under Thotapalli reservoir which comprise parts of Srikakulam and Vizianagaram district. A necessity is always felt for more soil database on ayacut area of proposed irrigation project. Keeping these factors in view, the present investigation has been taken to characterise the soils of Srikakulam and Vizianagaram district under Thotapalli reservoir for its physical and fertility characters to maximise irrigation use efficiency and achieve sustainable crop production.

MATERIAL AND METHODS

The study area comprises parts of Srikakulam and Vizianagaram districts of north coastal region of Andhra Pradesh under Thotapalli reservoir. The study area was located between 18^0 12' 820'' to 18^0 32' 876'' N latitude and 83^0 29' 889'' to 83^0 37' 727'' E longitude. Morphological description was made to diagnostic soil horizons and their depths. In each horizon bulk density was determined by core sampler method. Representative six profiles were dug up to more than 1.0 meter depth during dry period (April, 2018). Horizon wise soil samples were collected, air dried under shade, ground with wooden hammer, passed through 2 mm sieve and the fine earth fraction was used for laboratory analysis of physical and chemical characters of soils by following chemical standard procedure. Particle density was determined by specific gravity bottle method, as described by Black and Hartge (1986). The physical constants such as water holding capacity and volume expansion were determined by following Keen Raczkowski's method as described by Sankaram (1966). Pore space was derived from the values of bulk density and particle density and the results were expressed as percentage. Available nitrogen was determined by modified alkaline potassium permanganate method (Subbiah and Asija, 1956). Available phosphorus in soil was extracted with 0.5 M $NaHCO_3$ of pH 8.5 and measured in spectrophotometer (Olsen *et al*., 1954). Available soil potassium was extracted with neutral normal ammonium acetate and measured in flame photometer(Jackson, 1973). The available zinc, copper, iron and manganese in soils were extracted by DTPA and measured by using atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

RESULTS AND DISCUSSION

Soil physical properties

Among the profiles studied, profile 1and 2 had shown sandy loam texture at surface and sandy clay loam texture in the lower horizons, while profile 3 was sandy clay loam throughout the profile. Profile 4 was sandy clay loam to sandy clay. Profile 5 had shown sandy loam to sandy clay loam and profile 6 had shown sandy clay loam at surface and clayey texture in lower horizons (Table 1). The profiles (1, 4, 5 and 6) exhibited variable texture with depth ranging from coarse to fine, while profile 2 and 3 exhibited uniform texture throughout the profile. These variations were caused by nature of parent material, in-situ weathering, translocation of clay and age of soils. Similar observations made earlier by Geethasireesha and Naidu (2013) and Sreedharreddy and Naidu (2016).

Soil bulk density of different horizons of all the six soil profiles studied were ranged from 1.33 to 1.62 Mg m^{-3} (Table 1). All the profiles had shown an increasing trend of soil bulk density with depth. The increase in bulk density with depth might be due to more compaction of soil in deeper layers caused by over-head weight of the surface soil and decreased organic matter with depth. Similar observations were also made by Prabavathi *et al*. (2017). The statistical data showed a significant negative correlation (r = -0.696**) of bulk density with organic carbon (Table 3).

Particle density of soils of study area ranged from 2.56 to 2.72 Mg m^{-3} (Table 1).The particle density of soils is considered to depend on the mineralogical composition of soils. Since the soils of study area are siliceous and cultivated lands, hence the particle density does not differ much.

The per cent pore space of various horizons of all six profiles studied was ranged from 37.45 to 48.88 per cent (Table 1). In general, the pore space showed decreasing trend with increase in depth in all the profiles, which could be attributed to more compaction in deeper layers which was evident by relatively higher bulk density in deeper layers. The results were in accordance with Varaprasadrao *et al.* (2008). Statistical data showed a significant negative (r = -0.959**) correlation between pore space and bulk density and positive correlation with organic carbon content of soil (r= 0.481*) (Table 3)

The maximum water holding capacity (MWHC) of various horizons in all six profiles studied varied from 34.0 to 50.40 per cent (Table 1). In general, water holding capacity followed an increasing trend with depth. The soils of pedons 4 & 6 recorded high MWHC due to presence of high clay content. Satyavathi and Suryanayanareddy (2004) also reported high water holding capacity in clay soils. Pedons 1, 2, 3 and 5 showed relatively low MWHC.

Statistical data showed a significant positive correlation between MWHC and clay content (r = 0.895**) and a significant negative correlation between MWHC and sand content (r = -0.848**).

The per cent volume expansion in soils of study area varied from 3.10 to 30.1 per cent (Table 1). Volume expansion of the soils showed similar trend of clay and registered significant positive correlation (r = +0.905**) with clay content. Relatively high volume expansion was associated with profiles 4 and 6 (17.5 to 30.10 per cent) are due to swell-shrink nature of soils in these two profiles which was evident by deep and wide surface cracks during summer. Increase in volume expansion with increase in clay content was also observed earlier by Gurumurthy *et al*. (1996). Very low volume expansion in profiles 1, 2 and 5 could be ascribed to relatively low clay content and non expanding nature of clay which was evident by absence of surface cracks during summer.

Fertility characters of soils

Soil reaction

The soil reaction of various horizons of all six profiles studied ranged from 4.87 to 8.71(Table 2). The highest pH was associated with sub surface horizon of profile 4. The lowest pH was observed in surface horizon of profiles 2. Profiles 3, 4 and 6 exhibited slightly alkaline to alkaline pH, profile 2 exhibited acidic pH while profiles 1 and 5 were neutral in reaction. All the profiles in general, showed an increasing trend in soil pH with depth, which could be due to continuous removal of basic cations by crop plants and leaching of basic cations to deeper layers along with percolating water as well as release of organic acids in surface layers during decomposition of organic matter. These findings were in accordance with, Meena *et al*., (2014) and Visalakshidevi *et al*. (2015).

Electrical Conductivity

Electrical conductivity of the soil profiles ranged from 0.11 to 0.60 dS m^{-1}(Table 2). The lowest EC of 0.11 dS m^{-1} was recorded in surface horizon of profile 2, whereas the highest value of 0.60 dS m^{-1} was recorded in lower horizon of profile 6. All the profiles studied were non saline in nature and showed a increasing trend with depth. The profiles 1, 2, 3 and 5 recorded relatively low EC (0.11 to 0.45 dS m^{-1}), while profiles 4 and 5 recorded relatively high EC (0.39 to 0.60 dS m^{-1}). The lower electrical conductivity in profiles 1, 2, 3 and 5 could be due to the coarse texture, which encouraged leaching of soluble salts, while in profiles 4 and 6, fine textured soils caused poor drainage and subsequent accumulating of salts. Similar findings were made by Satyavathi and Suryanarayana Reddy (2004) and Jayaramarao (2012) in soils of Srikakulam, Andhra Pradesh.

Organic carbon

The organic carbon content in different horizons of all the six profiles ranged from 0.110 to 0.619 per cent. The lowest value (0.110 %) was recorded in lower horizons of profile 5 and 6. The highest value (0.619 %) was observed in Ap horizon of profile 6 (Table 2). The organic carbon status of the soils in general was low but in the surface layers of profiles 1, 5 and 6, was medium. Warm climatic conditions of the study area caused rapid decomposition of organic matter resulting low organic carbon content. The organic carbon content showed a decreasing trend with soil depth, which could be due to surface layer enriched with crop residue like left over root mass and added FYM to the surface soil due to cropping activity. Similar observations made by Niranjan *et al* (2013).

Available macro nutrients

The available nitrogen status of the soils was low. The available nitrogen content in the soils studied ranged from 32.9 to 111.3 kg ha^{-1} (Table 2) The values of available nitrogen showed decreasing trend with soil depth in all the six profiles studied which could be attributed to decreasing trend of organic carbon with depth. Stastical data showed a significant positive correlation (r = 0.832*) between available nitrogen and organic carbon (Table 3). This observation was in accordance with the results of Satishkumar and Naidu (2012).

The available phosphorus (P_2O_5) content was ranged from 6.0 to 68.3 kg ha^{-1} and showed a decreasing trend with soil depth (Table 2). The available phosphorus status of all profiles was low except surface horizon of profile 1. In surface horizon addition of organic matter and phosphatic fertilizer might have caused relatively higher available phosphorus. Similar observations were reported by Visalakshidevi *et al.* (2015). Further available P_2O_5 in profiles 4 and 6 was very low owing to high soil pH. A significant positive correlation (r = 0.515**) was recorded between organic carbon and available phosphorus content of soil, while negative correlation (r = -0.687**) between soil pH and available phosphorus content of soil. Rajeswar *et al.* (2009) reported similar findings with respect to available phosphorus content of soils in Garikapadu mandal of Krishna district in Andhra Pradesh.

The available potassium content of the soils ranged from 109.4 to 575.16 kg ha^{-1}. Specific trend was not observed in all the profiles (Table 2). The low available potassium contents in profiles 3, 4 and 6 could be ascribed to less activity of K^+ in relation to Ca^{2+} and Mg^{2+}, while in profile 1, 2 and 5 leaching of potassium due to coarse texture is the reason for low available potassium status. The results corroborated with the findings of Ramalakshmi *et al.* (2001) and Mydhili (2006).

Available micronutrient status of soils

The available zinc content ranged from 0.08 to 0.66 ppm. Irregular distribution of available zinc was observed in all the profiles (Table 2). The soils were deficient in available zinc content except in surface horizon of profiles 1, 5 and 6 considering the critical limit of 0.6 ppm. The available zinc content showed decreasing trend with soil depth, which could be ascribed to decreased trend of organic carbon in soil profiles. In profiles 3 and 4 alkaline pH caused low availability of zinc. The availability of zinc had a negative correlation with soil pH (r = -0.623**) and positively correlated with organic carbon content of soil (r = 0.581**) (Table 3). The results were in conformity with Rajeswar *et al.* (2009) and Sreedharreddy and Naidu (2016).

The available copper content varied from 0.36 to 2.64 ppm (Table 2). All the profiles were found sufficient in available copper status as all the profiles recorded more than critical level (0.2 ppm) of available copper. Available Cu in soils was positively correlated with organic carbon content (r = 0.456*). Verma *et al.* (2005) also reported similar findings earlier.

The available iron content in soils of study area ranged from 2.49 to 9.54 ppm (Table 2). Decreasing trend of available iron content with soil depth was recorded in all the profiles. Considering the critical limit of 4.5 ppm suggested by Lindsay and Norvell (1978), the soil profiles 3, 4 and 6 were deficient and profiles 1, 2 and 5 were sufficient in available iron content. High soil pH in 3, 4 and 6 soil profiles responsible for low available Fe content. The surface horizons contained relatively more available iron than sub-surface horizons, which was ascribed to presence of relatively more 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 (Prasad and Sakal, 1991).

The available manganese content ranged from 6.55 to 22.13 ppm (Table 2). The available manganese status was sufficient in all the profiles. All the profiles in general showed decreasing trend of available manganese with soil depth. Available manganese in soils was relatively high in the surface horizons and almost decreased with depth, which might be due to comparatively higher biological activity and organic carbon content in the surface horizons and the chelating

Table 1. Soil Physical Properties of the ayacut area under Thotapalli irrigation project of North Coastal AndhraPradesh

Horizon	Depth (m)	Soil texture	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Pore space (%)	Maximum Water holding capacity (%)	Volume expansion (%)
Devarapalli profile : Fine loamy, mixed, iso hyperthermic Typic Haplustalf							
Ap	0.00-0.10	Sandy loam	1.42	2.67	46.82	43.46	8.78
Bw	0.10-0.25	Sandy clay loam	1.50	2.64	43.18	45.69	9.81
Bt_1	0.25-0.58	Sandy clay loam	1.52	2.71	43.91	47.36	5.89
Bt_2	0.58-0.70	Sandy clay loam	1.55	2.70	42.59	38.93	10.40
Bt_3	0.70-0.90	Sandy clay loam	1.58	2.68	41.04	39.12	8.70
Bt_4	0.90-1.19+	Sandy clay loam	1.59	2.63	39.54	38.65	9.00
Gujjangivalasa profile : Fine loamy, kaolinitic, iso hyperthermic Typic Haplustults							
Ap	0.00-0.10	Sandy loam	1.40	2.71	48.34	45.36	3.10
Bw	0.10-0.22	Sandy loam	1.52	2.68	43.28	45.15	4.56
Bt_1	0.22-0.40	Sandy clay loam	1.59	2.65	40.00	42.89	3.56
Bt_2	0.40-0.70	Sandy clay loam	1.61	2.62	38.55	43.56	4.16
Bt_3	0.70-0.98+	Sandy clay loam	1.62	2.59	37.45	36.30	3.25
Patikivalasa Profile : Fine loamy, mixed, iso hyperthermic Typic Ustochrepts							
Ap	0.00-0.10	Sandy clay loam	1.42	2.64	46.21	43.00	12.80
Bw_1	0.10-0.30	Sandy clay loam	1.49	2.68	44.40	42.56	14.40
Bw_2	0.30-0.50	Sandy clay loam	1.55	2.66	41.73	41.14	15.00
Bw_3	0.50-0.80	Sandy clay loam	1.60	2.59	38.22	38.56	11.40
Bw_4	0.80- 0.95+	Sandy clay loam	1.61	2.61	38.31	36.60	9.30
Gangad Profile : Clayey , montmorrilonitic, iso hyperthermic Vertic Ustochrepts							
Ap	0.00-0.09	Sandy clay loam	1.37	2.68	48.88	47.70	20.00
Bw_1	0.09-0.40	Sandy clay	1.40	2.64	46.97	49.00	19.60
Bw_2	0.40-0.62	Sandy clay	1.45	2.60	44.23	50.40	17.50
Bw_3	0.62-0.82	Sandy clay loam	1.46	2.61	44.06	46.00	24.60
Bw_4	0.82-1.02+	Sandy clay loam	1.51	2.56	41.02	42.10	17.50
Aamiti Profile : Fine loamy, mixed, iso hyperthermic Typic Ustochrepts							
Ap	0.00-0.16	Sandy clay loam	1.48	2.72	45.59	39.10	9.20
Bw_1	0.16-0.30	Sandy clay loam	1.51	2.70	44.07	42.10	12.40
Bw_2	0.30-0.48	Sandy clay loam	1.55	2.66	41.73	40.10	14.80
Bw_3	0.48-0.70	Sandy clay loam	1.60	2.70	40.74	38.40	11.20
Bw_4	0.70-0.90+	Sandy loam	1.61	2.66	39.47	34.00	9.80
Maddivalas Profile : Clayey, montmorrilonitic, iso hyperthermic Chromic Haplustert							
Ap	0.00-0.13	Sandy clay loam	1.33	2.58	48.45	44.10	26.50
Bw	0.13-0.32	Clay	1.41	2.64	46.59	49.60	28.60
Bss_1	0.32-0.55	Clay	1.45	2.60	44.23	46.60	30.10
Bss_2	0.55-0.74	Clay	1.41	2.58	45.35	44.60	28.00
Bss_3	0.74-1.15+	Clay	1.52	2.60	41.54	42.60	29.00

Table 2. Soil fertility characters of the soils ayacut area under Thotapalli irrigation project of North Coastal AndhraPradesh

Horizon	Depth (m)	Soil pH	EC (dSm^{-1})	Organic carbon (%)	Available macronutrients (kg/ha)			Available micronutrients (mg/kg)			
					N	P_2O_5	K_2O	Zn	Cu	Fe	Mn
Devarapalli profile : Fine loamy, mixed, iso hyperthermic Typic Haplustalf											
Ap	0.00-0.10	6.23	0.13	0.53	94.10	68.30	488.16	0.66	2.40	7.68	22.13
Bw	0.10-0.25	6.61	0.17	0.30	81.50	39.30	240.90	0.27	1.56	4.94	11.32
Bt_1	0.25-0.58	7.34	0.17	0.23	70.60	46.20	266.28	0.12	2.56	6.23	16.85
Bt_2	0.58-0.70	7.41	0.21	0.22	70.60	18.50	318.15	0.14	1.32	5.16	16.85
Bt_3	0.70-0.90	7.35	0.23	0.22	64.30	23.90	300.06	0.09	2.06	4.88	13.66
Bt_4	0.90-1.19+	7.48	0.23	0.21	64.30	16.20	290.90	0.11	2.06	4.59	14.87
Gujjangivalasa profile : Fine loamy, kaolinitic, iso hyperthermic Typic Haplustults											
Ap	0.00-0.10	4.87	0.11	0.38	70.60	18.00	227.54	0.33	1.87	7.82	10.85
Bw	0.10-0.22	5.43	0.13	0.26	70.60	14.50	157.53	0.14	1.32	7.45	14.11
Bt_1	0.22-0.40	5.51	0.15	0.25	69.00	7.70	192.54	0.09	1.09	6.39	15.64
Bt_2	0.40-0.70	5.96	0.20	0.14	66.00	12.00	196.91	0.08	1.32	5.06	13.26
Bt_3	0.70-0.98+	5.50	0.26	0.12	64.30	12.00	205.66	0.09	1.18	7.13	9.86
Patikivalasa Profile : Fine loamy, mixed, iso hyperthermic Typic Ustochrepts											
Ap	0.00-0.10	7.23	0.19	0.33	111.30	36.80	206.95	0.38	2.13	4.60	18.69
Bw_1	0.10-0.30	7.48	0.20	0.23	103.40	18.00	109.40	0.14	1.56	4.29	12.33
Bw_2	0.30-0.50	7.54	0.22	0.20	76.80	12.00	148.78	0.31	1.95	1.95	7.16
Bw_3	0.50-0.80	7.91	0.23	0.18	72.10	12.80	190.03	0.13	1.06	3.24	6.55
Bw_4	0.80- 0.95+	8.28	0.31	0.14	50.20	12.80	131.27	0.13	1.63	2.49	6.55
Gangad Profile : Clayey , montmorrilonitic, iso hyperthermic Vertic Ustochrepts											
Ap	0.00-0.09	7.88	0.39	0.45	81.50	24.00	343.89	0.30	2.64	3.94	13.04
Bw_1	0.09-0.40	8.04	0.43	0.32	39.20	9.10	475.16	0.11	2.41	4.12	12.31
Bw_2	0.40-0.62	8.26	0.44	0.29	32.90	12.40	497.04	0.09	2.00	3.56	9.28
Bw_3	0.62-0.82	8.50	0.47	0.25	36.10	10.00	300.80	0.09	0.86	2.90	8.00
Bw_4	0.82-1.02+	8.71	0.58	0.21	40.80	6.00	453.28	0.10	0.43	2.69	9.89
Aamiti Profile : Fine loamy, mixed, iso hyperthermic Typic Ustochrepts											
Ap	0.00-0.16	6.53	0.24	0.52	67.40	32.00	575.16	0.75	2.34	9.54	11.86
Bw_1	0.16-0.30	7.20	0.26	0.38	61.20	25.40	306.40	0.39	1.31	8.62	9.23
Bw_2	0.30-0.48	7.61	0.31	0.23	56.40	21.00	227.54	0.24	1.96	6.54	14.90
Bw_3	0.48-0.70	7.14	0.39	0.11	61.20	18.20	332.56	0.15	0.38	7.14	10.20
Bw_4	0.70-0.90+	7.10	0.45	0.11	48.60	10.80	244.40	0.09	0.36	5.12	9.60
Maddivalas Profile : Clayey, montmorrilonitic, iso hyperthermic Chromic Haplustert											
Ap	0.00-0.13	7.80	0.48	0.62	94.10	20.50	379.41	0.93	2.56	4.23	9.36
Bw	0.13-0.32	8.16	0.56	0.30	64.30	12.60	270.61	0.32	2.42	4.10	12.66
Bss_1	0.32-0.55	8.12	0.45	0.23	64.30	8.50	275.10	0.18	1.92	3.16	10.20
Bss_2	0.55-0.74	8.04	0.53	0.11	40.80	12.00	253.40	0.12	0.65	4.54	8.52
Bss_3	0.74-1.15+	7.91	0.60	0.11	50.20	6.50	235.50	0.12	0.39	3.94	6.81

Tabale 3. Correlation coefficients between various soil properties

S.No	Variables	Correlation coefficient (r)
1	Soil pH vs available phosphorus content of soil	-0.665**
2	Soil pH vs available zinc content of soil	-0.623**
3	Soil pH and available iron	-0.697**
4	Soil pH vs available copper content of soil	-0.436*
5	Soil pH vs available manganese content of soil	-0.574*
6	Soil organic carbon content vs available nitrogen content of soil	0.832**
7	Soil organic carbon content vs available phosphorus	0.515*
8	Soil organic carbon content vs available potassium	0.561*
9	Soil Organic carbon content vs available zinc	0.580*
10	Soil organic carbon content vs available copper	0.456*
11	Soil organic carbon content vs available manganese	0.429*
12	Soil organic carbon content vs available iron	0.623**
13	soil organic carbon content vs bulk density	-0.696**
14	Pore space vs bulk density	-0.959**

of Mn by organic compounds, released during the decomposition of organic matter. The observations are in confirmation with the findings of Sreedharreddy and Naidu (2016).

CONCLUSION

Soils of Thotapalli irrigation project ayacut were gently slopping cultivated uplands to nearly level cultivated plains. The soils were sandy loam to clayey texture, bulk density showed increasing trend with depth while reverse is the trend of porespace. Volume expansion and maximum water holding capacity was higher in fine textured soils (profiles 4 and 6), medium in profile 3 and 5 and low in coarse textured soils (profile 2). The soils were acidic to alkaline in reaction, soil pH showed increasing trend with depth. Non saline and EC of soil showed increasing trend with soil depth. Organic carbon status of soils was low to medium and showed decreasing trend with depth. Available nitrogen content was low and followed the trend of organic carbon. Available phosphorous status of soils was low to medium, available potassium status was medium to high. Presence of calcium carbonate in soil profiles 3, 4 and 6 influenced potassium activity ratio and caused low status. In respect of available micronutrients, the soils were deficient in Zn and sufficient in manganese and copper, however soil profiles 3,4 and 6 showed low available iron status due to alkaline soil reaction, while profiles 1, 2 and 5 showed sufficiency in available iron status. Available nitrogen, phosphorous, potassium, zinc, iron, copper and manganese were positively correlated with organic carbon content, while available phosphorous and micronutrients were negatively correlated with soil pH.

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