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A review on soil physical, physico-chemical, chemical and biological properties of Godavari delta region of Andhra Pradesh

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Abstract
The study was conducted to assess the soil fertility status of Godavari delta region of Andhra Pradesh. Soil samples were drawn from four hundred and thirty nine locations of the study area and analysed for physical, physico-chemical, chemical and biological. The results revealed that overall study area was dominant in clay texture with bulk density lower at surface than subsurface. The water holding capacity followed the reverse trend with higher mean values at subsurface than surface with more values recorded in fine textured soils than coarse textured soils. The soils of the study area were found to be slightly acidic to moderately alkaline in nature, normal to critical for germination in electrical conductivity with medium in organic carbon content. Further the area was low in available N, high in available phosphorus in surface and medium in sub-surface soils. Available potassium, calcium, magnesium and micronutrients (Fe, Cu, Mn, Zn) in the soils were high in both surface and sub-surface soil samples.

Keywords: Surface soils, Sub-Surface soils, Soil fertility status, Nutrient index

Introduction
Soil is the natural dynamic body to give life to all living things in the World (Jones, 2012). In any agricultural operations, soil has the utmost importance as it is the cradle for all crops and plants. Soil fertility is one of the primary constraints to agricultural production in developing countries like India (Gruhn *et al*., 2000) [4]. It comprises not only the nutrient status of soil, but also indicates the nutrient supplying capability; moreover fertility of soil is subject to man's control (Deshmukh, 2012) [3]. Soil fertility management has great challenge now a days because of various intrinsic (parent materials and climate) and extrinsic factors such as soil management practices, indigenous fertility status, crop rotation and nature of standing crop (Cambardella and Karlen, 1999) [2]. The challenge of crop nutrient management is to balance production and economic optimization with environmental impacts.

Soil fertility evaluation is the most basic decision making tool in order to plan a particular land use system efficiently (Havlin *et al*., 2010) [5]. There are several techniques for the evaluation of soil fertility status, among them soil testing is the most popular, as well as more appropriate one. Soil testing provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for economic production of crops. Soil analysis includes physical properties (texture, structure, colour, bulk density *etc.*,), chemical properties (soil pH, organic matter, macro and micronutrients *etc.*,), and biological properties (microbial populations, enzymatic activity *etc.*,) which symbolize prerequisite for sustainable soil management (Panda, 2010) [11].

Godavari delta is one of the major contributors of rice production in the country and also the "Rice bowl of Andhra Pradesh". Rice is cultivated in diverse ecosystems spread over 43.97 million ha in India with a production of 104.32 million tons of milled rice with average productivity of 2372 kg ha^{-1}. In Andhra Pradesh, Paddy is the principal crop extensively cultivated in all the districts of the state both during *Kharif* and *Rabi* seasons. Paddy crop accounted for 34.45 percent of the total cropped area, 79.30 percent of the total food-grains production during 2020-21. The area under Paddy during 2020-21 was 25.52 lakh hectares as against 23.56 lakh hectares in 2019-20, showing an increase of 8.32 percent. West Godavari district is at the top with an area of 4.14 lakh hectares, followed by East Godavari (3.98 lakh hectare) and Krishna (3.38 lakh hectare) and S.P.S.R. Nellore (3.13 lakh hectares). The production of Paddy during 2020-21 was 130.89 lakh tonnes as against 137.10 lakh tonnes in

2019-20, showing a decrease of 4.53 percent (Season and Crop report, 2020-21) [15]. Therefore, the present study was undertaken to know the soil fertility status of Godavari delta region of Andhra pradesh which helps the farmers in better understanding the future scope of nutrient management. This would also help farmers in planning different strategies in farming and irrigation management for overcoming problems and improving the agricultural productivity and to check further degradation of the soils.

Material and methods

Four hundred and thirty nine sampling locations were selected from study area and soil samples were collected at both surface (0-25 cm) and sub-surface (25-50 cm). Soil samples were dried under shade, powdered and ground with a wooden hammer and passed through a 2 mm sieve to obtain a uniform representative sample and stored in air tight polythene bags for analysis. The texture of the soils was determined by Bouyoucos Hydrometer method (Piper, 1966) [13], bulk density by clod method (Black and Hartge, 1986) [1], while water holding capacity and volume expansion was estimated by Keen Raczkowski's method (Piper, 1966). The physico-chemical properties like pH and electrical conductivity were determined in 1:2.5 soil: water suspension using pH meter and conductivity meter, respectively, whereas, organic carbon content was estimated by Walkley and Black method (Jackson, 1973) [6]. Available nitrogen content in the soil samples was estimated by alkaline permanganate method as described by Subbiah and Asija (1956) [17]. Available phosphorus in soils was extracted by employing Olsen's extractant (Olsen *et al.*, 1954) [10] and phosphorus content in the extract was estimated by Murphy and Riley Method (using ascorbic acid as reducing agent) as described by Watanabe and Olsen (1965) [19] using spectrophoto meter at 660nm wave length. Available potassium in the soil samples was determined by using neutral normal ammonium acetate extractant and the extract was directly fed to flame photometer (Jackson, 1973) [6]. Available micronutrients (Fe, Mn, Cu and Zn) were estimated using DTPA extractant of pH 7.3 using atomic absorption spectrophoto meter (Lindsay and Norvell, 1978) [9]. Available Boron was determined using hot water treatment. Soil microbial biomass carbon and microbial biomass nitrogen was estimated by fumigation extraction method according to the procedure of Jenkinson and Powlson (1976). Nutrient index for each soil type were worked out, as per the following formula given by Parker *et al*. (1951). The nutrient indices were classified as low, medium and high, as per following ratings proposed by Ramamoorthy and Bajaj (1969) [14]. Nutrient index is categorised as low when it is <1.67, Medium 1.67-2.33, high >2.33.

3. Results

3.1 Physical properties

Five different textural classes, *viz.* Clay, clay loamy, sandy clay, sandy clay loam and sandy loam were identified in both surface and sub-surface soil samples of the study area. Overall, sand, silt and clay per cent of soils varied from 10 to 84.8, 5.0 to 33.4 and 10.2 to 68.5 at surface (Table.1), while at sub-surface it ranged 4.01 to 76.48, 5.36 to 36.40, 15.62 to 71.81 respectively (Table.2). Textural differences in the study area might be due to fluvial, fluvio-aeolian and fluvio-marine depositional environments in plains while it is fluvial in the upper deltaic plain and along the canals.

The study area was dominant in clay texture because the delta was formed due to river that traversed through the area which was rich in basalt, due to which the finer particles were carried by the river and deposited before it entering into the sea.

Water holding capacity of soils increased with increase in clay content, which can be confirmed through significant positive correlation (r=+0.943*) and ranged from 16.13 to 62.81 and 16.43 to 62.85 per cent with mean value of 53.0 and 52.96 per cent in surface and sub-surface soils, respectively. Volume expansion ranged from 2.70 to 36.0 and 0.10 to 37.94 per cent with mean value of 28.51 and 30.29 per cent in surface and sub-surface soils, respectively. Clay particles due to large surface area and more total pore space when compared to sand, have incredible capacity to retain water. Further, presence of expanding type of clay minerals led to adsorption of water on clay particles thereby, imparting the capacity to retain more water.

Bulk density ranged from 1.20 to 1.69 Mg m^{-3} with mean value of 1.29 Mg m^{-3} at surface and 1.21 to 1.72 Mg m^{-3} with mean value of 1.32 Mg m^{-3} at sub-surface, in the soils of the study area. Particle density ranged from 2.42 to 2.73 Mg m^{-3} with mean value of 2.58 Mg m^{-3} at surface and 2.44 to 2.75 Mg m^{-3} with mean value of 2.59 Mg m^{-3} at sub-surface, in the soils of the study area.

Fine textured soils (black soils) have smaller, but numerous pores resulting higher porosity. Sub-surface soils in general recorded higher bulk density compared surface soils. A significant positive correlation (r = 0.707**) was noticed between sand content and bulk density. The low bulk density in black soils can be attributed to high total pore space increasing the volume of soil. The compaction of finer particles in deeper layers caused by the over-head weight of the surface layers, high clay content with swelling clay and lower organic matter and plant root mass might have resulted in higher bulk density values in lower layers.

3.2 Physico-chemical properties

The study area was divided into five pH classes based on the analysis. Soil reaction in the study was found to be medium acidic to strongly alkaline in nature with pH value varying from 5.68 to 8.23 at surface and 5.95 to 9.00 in sub-surface soils with mean values of 7.30 and 7.65, respectively. The electrical conductivity data revealed that EC of the soils of the study area ranged from 0.11 to 4.26 with mean value 0.97 d Sm^{-1} and from 0.10 to 4.23 with mean value of 0.96 d Sm^{-1} at surface and sub-surface, respectively and was categorized into three classes *viz.* non saline, slightly saline and very slightly saline.

Sub-surface soil samples recorded higher pH than surface which might be due to movement of basic cations to lower layers. Fine textured soils recorded relatively higher pH values than coarse textured soils because of imperfect drainage leading to accumulation of bases and also due to efficient recycling of basic cations (Sumathi, 2012) [18]. The continuous addition of bases through irrigation water or fertilizer material might have resulted in neutral to alkaline pH in majority of soils.

The non-saline category represents the soils might be having well drained conditions, which favored the removal of bases. High electrical conductivity was observed in the soil samples near the aquaponds which might be due to seepage of brackish water from nearby aquaponds.

3.3 Chemical properties
3.3.1 Macro nutrient status
The available nitrogen, phosphorus and potassium content varied from 151 to 406, 25.45 to 113.36 and 288.75 to 1369.5 kg ha^{-1} in the surface soils while, in sub-surface soils ranged from 112 to 375, 7.51 to 98.34 and 235.5 to 1249.5 kg ha^{-1}. The nutrient index values (Table.3) of nutrients in study area revealed that the soils of Godavari delta region of Andhra Pradesh were low in available nitrogen and high in available potassium in both surface and subsurface, whereas the phosphorus status was high in surface soils and medium in subsurface samples. Further, surface samples recorded more available macro-nutrients than sub-surface samples.

Low available nitrogen content in soils might be attributed to more NO_3-N, which must have been lost by leaching (Subbaiah, 2020). As paddy is major crop grown in the study area applied nitrogenous fertilizers are hydrolysed to NH_4^+ and prone to denitrification losses. Medium to high available phosphorus might be due to regular application of inorganic phosphatic fertilizers leading to the build-up in soils. Variation in soil properties such as clay content, exchange capacity, phosphorus fixing capacity might have resulted in variable phosphorus content in soils (Sivajyothi, 2016). The high potassium status could be ascribed to frequent irrigation under rice cropping systems, more weathering of potassium bearing minerals like illite / potassium feldspars, clay content, also sometimes silt particles (Mishra *et al.*, 2015) and high fertilizers use, release of potassium from decomposing organic matter added to the surface through natural vegetation (Sumathi, 2012) [18]. Regular application of potassium-rich fertilizers over long periods can also increase amounts of exchangeable potassium in the soil.

The calcium and magnesium content in the study area was found high in both surface and subsurface samples with their values ranging from 650 to 11750 ppm and 96.36 to 4481.20 ppm in surface and from 650 to 12000 ppm and 90.50 to 4486.22 ppm, respectively.

3.3.2 Available micronutrients
The available iron, manganese, copper, zinc and boron in soils ranged from 5.09 to 39.98, 15.0 to 24.99, 0.41 to 13.98, 0.16 to 3.59 and 1.81 to 4.51 ppm with mean values of 22.14, 19.86, 7.84, 2.02 and 3.61 ppm, respectively, in the surface layer. While, the sub-surface layers recorded values ranging from 2.87 to 36.25, 13.01 to 19.98, 0.33 to 12.35, 0.15 to 3.07 and 1.27 to 4.34 ppm, with mean values of 17.83, 16.45, 5.83, 1.55 and 3.26 ppm, respectively. The available micronutrient status was

Majority of soil samples at surface reported higher cationic micronutrients than sub-surface, which might be due to addition of organic manures and crop residues to surface layers. The chelating action of organic compounds released during decomposition of organic manures forms complexes with micronutrients and improves the availability of nutrients (Sivajyothi *et al.*, 2016). Most of the fine textured soils of the study area recorded higher cationic micronutrients than coarse textured soils due to low retention capacity and excessive leaching.

The higher concentration of Fe in the surface soil might be due to the release of iron from iron bearing minerals and application of fertilizers. The precipitation of ferrous ions as hydroxides ($Fe(OH)_2$ and $Fe(OH)_3$) due to high pH in sub-surface soils might have reduced the available iron content. High manganese in soils, might be attributed to Mn bearing minerals in the parent materiel and also might be less mobility of Mn^{+2} in the soils, which might have contributed for the accumulation of reducible and soluble forms of manganese in the soils (Sumathi, 2012) [18]. High copper content of these soils might be due to the indiscriminate application of copper fungicides for plant protection. Sufficient quantity boron in soils might be due to the presence of tightly bound boron with organic matter and released as available form upon microbial action or the use of irrigation water containing high in soluble salts of boron. Low organic carbon content in coarse textured soils compared to fine texture soils resulted in low boron content in these soils. Higher boron content in sub-surface soils than surface was reported.

3.4 Biological properties
Organic carbon content of soils varied from 1.80 to 9.2 g kg^{-1} at surface with mean value of 6.42 g kg^{-1}while, in sub-surface it varied from 0.54 to 8.83 g kg^{-1} with mean value of 5.65 g kg^{-1}. The data revealed that the study area was medium in organic carbon content (5.0 – 7.5 g kg^{-1}). Significant positive correlation was observed among clay content and soil organic carbon ($r = 0.891^{**}$). The microbial biomass carbon and microbial biomass nitrogen of the study area ranged from 38 to 467 ppm and 2.92 to 54.25 ppm in surface whereas in sub-surface it ranged from 13.2 to 444.3 ppm and 1.20 to 51.70 ppm with the mean values 268.24 and 24.40 ppm in surface while 237.07 and 21.46 ppm in subsurface, respectively. Significantly positive correlation was recorded between organic carbon and microbial biomass carbon (r=+0.960**). The higher organic carbon content in the delta soils might be due to the carrying capacity of river which carries larger amount of organic matter during its path. The inherent higher fertility status and moisture retention capacity of soils supported dense vegetation whose remnants of which are also likely to contribute for the organic carbon content in soils (Zebire *et al.*, 2019). The surface samples showed more organic matter content than sub-surface samples, which might be due to the continuous addition of crop residues as stubbles/ root mass and organic manures like farm yard manure/ green manure.

Table 1: Descriptive statistics of physical, physic-chemical and biological properties of surface soil samples of Godavari delta

Soil properties	Minimum	Maximum	Mean	SD (%)	CV (%)
Clay (%)	10.20	68.50	54.49	9.19	16.86
Silt (%)	5.00	33.40	22.08	4.47	20.25
Sand (%)	10.00	84.80	23.43	11.27	48.09
OC (g/kg)	1.80	9.20	6.42	1.22	19.02
N (kg/ha)	151.00	406.00	267.68	41.91	15.66
P (kg/ha)	25.45	113.36	69.61	25.10	36.06
K (kg/ha)	288.75	1369.50	814.69	285.85	35.09
Ca (ppm)	650.00	11750.00	6444.88	2551.18	39.58
Mg (ppm)	96.36	4481.20	1768.93	826.23	46.71
Fe (ppm)	5.09	39.98	22.14	9.90	44.72
Mn (ppm)	15.00	24.99	19.86	2.96	14.89
Cu (ppm)	0.41	13.98	7.84	3.64	46.44
Zn (ppm)	0.16	3.59	2.02	0.98	48.65
B (ppm)	1.81	4.51	3.61	0.64	17.67
pH	5.68	8.23	7.30	0.53	7.21
EC (d S/m)	0.11	4.26	0.97	0.97	100.45
BD (Mg/m3)	1.20	1.69	1.29	0.09	6.70
PD (Mg/m3)	2.42	2.73	2.58	0.09	3.41
WHC (%)	16.13	62.81	53.00	7.09	13.39
VE (%)	2.70	36.00	28.51	6.37	22.35
MBC(ppm)	38.00	467.00	268.24	71.71	26.73
MBN(ppm)	2.92	54.25	24.40	8.21	33.63

Table 2: Descriptive statistics of physical, physico-chemical and biological properties of sub-surface soil samples of Godavari delta

Soil properties	Minimum	Maximum	Mean	SD (%)	CV (%)
Clay (%)	15.62	71.81	58.16	9.23	15.87
Silt (%)	5.36	36.40	24.51	4.72	19.27
Sand (%)	4.01	76.48	17.33	11.51	66.39
OC (g/kg)	0.54	8.83	5.65	1.28	22.74
N (kg/ha)	112.00	375.00	231.79	43.83	18.91
P (kg/ha)	7.51	98.34	44.52	22.60	50.77
K (kg/ha)	235.50	1249.50	728.86	285.03	39.11
Ca (ppm)	650.00	12000.00	6367.90	2427.67	38.12
Mg (ppm)	90.50	4486.22	1690.64	809.29	47.87
Fe (ppm)	2.87	36.25	17.83	8.79	49.31
Mn (ppm)	13.01	19.98	16.45	1.98	12.03
Cu (ppm)	0.33	12.35	5.83	3.07	52.62
Zn (ppm)	0.15	3.07	1.55	0.83	53.34
B (ppm)	1.27	4.34	3.26	0.65	19.93
pH	5.95	9.00	7.65	0.55	7.13
EC (d S/m)	0.10	4.23	0.96	1.00	104.51
BD (Mg/m3)	1.21	1.72	1.32	0.09	6.61
PD (Mg/m3)	2.44	2.75	2.59	0.08	2.97
WHC (%)	16.43	62.85	52.96	6.91	13.04
VE (%)	0.10	37.94	30.29	6.70	22.11
MBC(%)	13.20	444.30	237.07	69.86	29.47
MBN(%)	1.20	51.70	21.46	8.12	37.84

Table 3: Nutrient index of the soils of Godavri delta region of Andhra Pradesh

S. No.	Parameter	Low	Medium	High	Total	NI	Rating
1	OC-S	27	318	94	439.00	2.15	Medium
2	OC-SS	121	291	27	439.00	1.79	Medium
3	N-S	319	120		439.00	1.27	Low
4	N-SS	377	62		439.00	1.14	Low
5	P-S		145	294	439.00	2.67	High
6	P-SS	91	204	144	439.00	2.12	Medium
7	K-S		42	397	439.00	2.90	High
8	K-SS		9	430	439.00	2.98	High
9	Ca-S	8	11	420	439.00	2.94	High
10	Ca-SS	11	9	419	439.00	2.93	High
11	Mg-S		4	435	439.00	2.99	High
12	Mg-SS		5	434	439.00	2.99	High
13	Fe-S		10	429	439.00	2.98	High
14	Fe-SS	9	20	410	439.00	2.91	High
15	Mn-S			439	439.00	3.00	High
16	Mn-SS			439	439.00	3.00	High
17	Cu-S			439	439.00	3.00	High
18	Cu-SS		1	438	439.00	3.00	High
19	Zn-S	48	59	332	439.00	2.65	High
20	Zn-SS	80	79	280	439.00	2.46	High

S- Surface samples
SS- Sub-surface samples

4. Conclusion

The Godavari delta of Andhra Pradesh which formed due to the deposition of sediments carried by river Godavari before it entering into the sea is dominated by clay soils were slightly acidic to strongly alkaline in reaction and slightly saline to non saline in nature. The soils were medium in organic carbon and low to medium in available nitrogen content. The available phosphorus, potassium and micronutrients (Fe, Cu, Mn, Zn & B) were sufficient in these soils.

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