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Characterization of acid saline rice based wetland ecosystems of Kuttanad, Kerala, and their salinity protection by Thanneermukkom regulator

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Abstract

An evaluation on physical and chemical characterisation of acid saline rice soils of Kuttanad with special reference to salinity protection by Thanneermukkom regulator was attempted by comparing the present soil properties with that of pre-barrage period. About 72 per cent of the tract belong to soil subgroup Typic Sulfaquents and seven per cent each to Typic Tropopsamments, Typic Fluvaquents, Typic Tropofluvents and Fluventic Dystropepts. A definite pattern of distribution of sand, silt or clay was not observed for the pedons belonging to Typic Sulfaquents, Typic Tropofluvents and Fluventic Dystropepts. The other physical properties like apparent and absolute specific gravity, water holding capacity, pore space and hydraulic conductivity did not follow a uniform pattern for most of the soil subgroups. The chemical properties also did not show a definite pattern of variation for Typic Sulfaquents and Typic Tropofluvents. For other soil groups, a general trend was observed. The soils of the area were highly acidic and mildly saline with high organic carbon content. A steep decline in soil pH, organic matter and EC was noted in the area during the post-barrage period. The closure of the regulator during the summer for the past 23 years had altered several soil chemical properties and most of the physical properties remained unaffected.

Additional keywords : Soil properties, evaluation.

Introduction

Kuttanad, the rice bowl of Kerala is a unique agricultural tract lying 0.6 to 2.2 m below the mean sea level on the west coast of India. It has a geographic area of 854 sq. km which represents a deltaic formation traversed by numerous water courses that drain to Vembanad lake. The soils of the area are highly acidic, saline and high in organic carbon content. Several parts of this delta have subsoil layers containing pyrites which on oxidation produce severe acidity. Even though the presence of an aquic moisture regime lessens its intensity, the rice cultivation has to face risks associated with waterlogging, acidity and toxicities of iron and aluminium. The tract is exposed to frequent floods during monsoons and salinity intrusion from sea by tidal action during summer. A regulator was constructed across the Vembanad lake during 1976 to check the salinity intrusion to Kuttanad and thereby to protect the rice crop. Almost entire part of the Kuttanad lies on the southern side of the regulator except the 4000 ha of kari lands (Sulfaquents and Sulfaquepts). The regulator will be kept closed from December to April to prevent salinity intrusion. This transformation from a saline water enviornment to fresh water for four months of the year had initiated several ecological changes. The closure of the regulator had curtailed the water movement in Kuttanad from December to April, which coincides with the major cultivation season of the area. This has resulted in stagnation of water in Kuttanad. With heavy load of fertilizers and pesticides residues released from the rice fields water and pollution reaches alarming proportion. The partial prevention of saline water intrusion to Kuttanad for the past 23 years had considerably altered the characteristics of this agro-ecosystem. During the month of May the regulator will be opened and saline water intrusion will be allowed but by the end of May the south west monsoon commences and the entire area will be changed to a fresh water zone. Hence the available time for natural tidal washing is very much limited which is not sufficient for the removal of toxic materials and the restoration of the soil productivity. The present paper attempts an evaluation on the physical and chemical characterisation of the tract with special reference to salinity protection by regulator by comparing the present data with that of pre-barrage period.

Materials and methods

Representative pedons were selected from 10,000 ha of North Kuttanad during the month of March. Horizonwise soil samples were drawn from each pedon after its morphological examination. About 72 per cent of the tract belong to soil subgroup Typic Sulfaquents and seven per cent each to Typic Tropopsamments, Typic Fluvaquents, Typic Tropofluvents and Fluventic Dystropepts. The physical properties like particle size, apparent and absolute specific gravity and hydraulic conductivity were estimated as per the standard procedures (Black *et al.* 1965). The chemical properties were also estimated according to the standard procedures (Jackson 1958; Hesse 1971; Page 1982).

Results and discussion

The data on the physical properties for a single pedon of each subgroup are presented in table 1. A definite pattern of distribution of sand, silt or clay was not observed for the pedon belonging to Typic Sulfaquents, Typic Tropofluvents and Fluventic Dystropepts. But the pedons belonging to Typic Tropopsamments and

Typic Fluvaquents showed an increase in clay and sand contents with depth and the silt content showed corresponding reduction with depth. The estuarine and fluvial deposits during each year results in the development of strata with varying quantities of sand, silt and clay content.

Table 1. Physical properties of soils

Horizon	Depth (cm)	Sand	Silt	Clay	Specific gravity		WHC	Pore Space	Hydraulic conductivity cm h^{-1}
		----	%	----	Apparent	Absolute	---	% ---	
Pedon 1 - Typic Sulfaquents, Akatheakaripadam, Aropookkara village									
Ap	0–15	64.7	9.0	24.8	1.05	2.04	50.7	56.8	3.2
C1	15–25	93.1	5.1	1.0	1.24	2.51	43.2	49.6	28.9
C2	25–37	79.3	5.6	13.3	0.94	1.75	55.3	49.1	28.9
C3	37–77	20.5	17.3	60.6	0.67	1.60	90.3	66.3	59.7
C4	77–130	22.9	17.2	59.9	1.13	1.96	57.4	58.3	4.5
Pedon 2 - Typic Tropopsamments, Maleekayal, Aymanam village									
Ap	0–15	81.6	10.1	6.3	1.21	2.12	40.6	48.5	38.8
C1	15–25	84.1	8.6	7.1	1.25	2.21	37.0	45.7	20.9
C2	25–120	84.9	3.0	10.2	1.26	2.29	38.8	48.2	17.0
Pedon 3 - Typic Tropofluvents, Thekkepallipadam, Kumarakom village									
Ap	0–15	74.8	2.4	21.1	1.09	2.05	43.3	48.9	17.9
C1	15–36	90.8	3.7	5.2	1.30	2.18	30.6	40.9	25.9
C2	36–120	73.5	15.4	9.7	1.17	2.09	40.8	47.1	6.0
Pedon 4 - Typic Fluvaquents, Keezhimuttathussery, Kumarakom village									
Ap	0–15	54.2	37.2	8.0	1.35	2.47	35.7	47.9	0.4
C1	15–35	57.7	21.0	19.8	1.20	2.12	39.5	47.8	1.2
C2	35–110	58.7	19.0	20.0	1.21	2.22	40.1	48.5	1.4
Pedon 5 - Fluventic Dystropepts, Kadayakolmidavali, Chengalam village									
Ap	0–20	52.0	14.9	31.1	1.21	2.20	42.2	50.4	5.1
Bw1	20–64	47.1	26.4	24.0	1.27	2.17	39.1	49.1	1.1
Bw2	64–130	13.7	54.2	30.5	1.33	2.14	44.9	55.8	1.4

The pedon 2 (Typic Tropopsamments) showed an increase in apparent and absolute specific gravity with depth.

The other physical properties like water holding capacity, pore space and hydraulic conductivity did not follow a uniform pattern except in Typic Tropopsamments. For pedon 2 (Typic Tropopsamments) the above characteristics increased with depth evidently due to the increase in clay and organic carbon content. In pedon 1 (Typic Sulfaquents) the C3 horizon recorded very high value for hydraulic conductivity even though the clay content was very high. This might be evidently due to the large quantity of organic matter in that horizon. The bulk density was also lowest for this layer. The peculiar position of Kuttanad also restricted the profile development in the tract.

As expected sand recorded a highly significant and negative correlation with water holding capacity (–0.657*) and pore space (–0.735**) whereas silt, clay and organic carbon showed significant and positive relationship with above soil properties. Sand was significantly and positively correlated with hydraulic conductivity, absolute and apparent specific gravity, and clay and silt were negatively correlated with the above characteristics.

The soil physical properties were not affected by the soil environmental change from a predominantly saline environment to a fresh water condition, since the present data did not show much variation from the earlier data reported by Money (1961) and Money and Sukumaran (1973). The fluvial deposition during monsoons and impact of tidal intrusion even for the short period might have retarded the changes in physical characteristics.

Chemical properties : The chemical properties also did not show a definite pattern of variation for Typic Sulfaquents and Typic Tropofluvents (Table 2). For other soil groups a general trend was observed. However, in all the cases Ap horizon recorded lesser acidity compared to lower layers. Liming and washing might have washed down a part of acidity from the Ap horizon. The liming and washing induces downward movement of H^+ and they get settled at deeper layers. The saline water intrusion even for the short period was able to remove much of exchangeable acidity from the soils. Van Mensvoort *et al.* (1981) pointed out that in acid sulphate soils Al^{3+} can be substituted by Na^+ and Mg^{++} in salt or brackish water which will help to lower the exchangeable acidity of the soil. For Typic Tropopsamments, Typic Fluvaquents and Fluventic Dystropepts, the pH increases with depth. Among the different soil subgroups Typic Sulfaquents recorded the lowest pH values. The acid release from the sulfuric horizon is attributed to the reason for the extreme acidity of these soils. On comparing the existing acidity parameters with that reported during the pre-barrage period (Money 1961; Kabeerathumma 1969, 1975; Nair and Subramoney 1969; Money and Sukumaran 1973) an increase in soil acidity was observed during the post-barrage period. The prevention of saline water washing slowed the replacement of Al^{3+} from the exchange sites, which resulted in the lowering of soil pH. The frequent cultivation activities and soil drying before harvest had accelerated the development of acidity due to the oxidation of pyrites.

The electrical conductivity was also low for surface layers and subsurface layers showed still higher values due to the accumulation of salts in lower layers. Even though the lower layers showed higher values none of the soil subgroups showed a definite pattern for it. The tidal and fluvial effect varied with the climate in each year and this resulted in variation in chemical characteristics. Considerable reduction in electrical conductivity was noted in the area during the post-barrage period when compared to that of pre-barrage period. The prevention of saline water intrusion from the sea, which was the major source of salts, had decreased electrical conductivity of these soils. Extremely saline soils have changed to mildly saline soils. Nair and Pillai (1990) reported 90 per cent reduction in salinity during the months of March to May compared to that of pre-barrage period.

The organic carbon content of these soils was high and was found to accumulate in lower layers, but a definite pattern was not noticed. The presence of sand layers, differential accumulation of organic matter and sedimentary nature of the parent materials are attributed to be the reason for the heterogeneity in organic carbon distribution. During the post-barrage period a severe depletion in soil organic matter was noted. The continuous monoculture of high yielding rice varieties, without proper organic matter replenishment and the prevention of tidal deposition are the major reasons for organic matter depletion.

Subsurface layers showed an increase in CEC, compared to surface layers for all the pedons. The higher clay and organic matter content of the lower layers were responsible for this. Clay and organic carbon content were significantly and positively correlated with CEC (0.413* and 0.567*).

Table 2. Chemical properties of soils

Horizon	Depth (cm)	Organic carbon %	pH	EC dS m^{-1}	ECEC	CEC	Per cent base saturation
Pedon 1 - Typic Sulfaquents, Akatheakaripadam, Aropookkara village							
Ap	0–15	3.00	4.5	1.39	6.56	19.0	22.9
C1	15–25	1.30	3.3	3.76	5.48	15.9	23.8
C2	25–37	2.82	2.0	8.93	28.59	33.0	34.6
C3	37–77	16.22	2.6	6.18	23.12	62.4	32.2
C4	77–130	8.58	3.3	5.78	19.98	29.5	55.6
Pedon 2 - Typic Tropopsamments, Maleekayal, Aymanam village							
Ap	0–15	0.64	4.6	1.14	7.69	9.6	44.6
C1	15–25	0.62	6.1	2.34	4.02	8.7	40.2
C2	25–120	1.03	5.5	1.52	7.10	11.0	48.1
Pedon 3 - Typic Tropofluvents, Thekkepallipadam, Kumarakom village							
Ap	0–15	0.76	5.0	0.62	9.44	19.1	26.8
C1	15–36	0.79	3.4	1.21	3.70	17.0	10.2
C2	36–120	1.31	4.8	1.00	7.44	19.0	24.5
Pedon 4 - Typic Fluvaquents, Keezhimuttathussery, Kumarakom village							
Ap	0–15	1.32	4.0	0.55	10.25	21.0	40.7
C1	15–35	1.47	4.2	0.47	8.09	22.1	26.0
C2	35–110	1.49	4.2	0.40	7.82	20.2	28.9
Pedon 5 - Fluventic Dystropepts, Kadayakolmidavali, Chengalam village							
Ap	0–20	1.12	4.8	0.33	5.75	15.1	33.7
Bw1	20–64	1.07	4.5	0.39	9.69	15.1	49.0
Bw2	64–130	2.75	3.3	3.06	13.61	32.6	38.0

The influence of organic carbon was more pronounced in these soils as evidenced by higher correlation coefficient. ECEC values were lower than that of CEC. It also followed the same trend as that of CEC and were significantly and positively correlated with clay and organic carbon (0.559* and 0.599*). The percentage base saturation varied widely among the subgroups. The values of CEC and percentage base saturation showed wide variation during pre-barrage and post-barrage period and hence a proper comparison was not possible for these parameters.

The closure of the regulator during summer had altered several soil chemical properties and the physical properties remained unaffected. On comparing the present status with that reported earlier (Money 1961; Kabeerathumma 1969; Nair and Subramoney 1969; Money and Sukumaran 1973) during the pre-barrage period, it was observed that there was a severe depletion of soil organic matter content and an increase in soil acidity. The organic matter depletion and increase in soil acidity were at such a high levels. These are sufficient to interfere with rice growth causing severe deterioration in soil health of Kuttanad.

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