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Purandhar E
College of Agriculture, Vellanikkara, KAU P.O, Thrissur, Kerala, India

Sreelatha AK
Rice Research Station, Kerala Agricultural University, Vyttila P.O, Ernakulam, Kerala, India

Anil Kumar KS
ICAR-National Bureau of Soil Survey and Land use Planning, Bangalore, Karnataka, India

Nideesh P
College of Agriculture, KAU, Padannakkad P.O, Kasaragod, Kerala, India

Corresponding Author
Purandhar E
College of Agriculture, Vellanikkara, KAU P.O, Thrissur, Kerala, India

Characterization and classification of natural and altered hydromorphic saline soils (Kaipad soils) of North Kerala, India

Purandhar E, Sreelatha AK, Anil Kumar KS and Nideesh P

Abstract
The Kaipad tracts, characterized by the unique saline hydromorphic soils cover the north Malabar districts of Kerala in Kozhikode, Kannur and Kasaragod. As a part of the study, we have excavated two representative soil profiles, one with natural (pedon 1) and another one has altered (pedon 2) Kaipad wetlands. Horizon-wise soil samples were collected for further studies. Natural Kaipad soil profile was deep (100-150 cm), poorly drained, moderate, medium, sub-angular blocky in structure, black to dark grey and then black in colour hues of 10YR and 2.5Y, clayey over coarse loamy in texture, extremely acid surface, strongly to slightly acid control section and slightly alkaline sub-soil and high CEC values ranging from 48 to 67 cmol (p+) kg^{-1} clay and medium to high base saturation (50-57%), with extremely high ESP (41-60) and EMP (18-30). The altered soil profile is also deep, imperfectly drained, weak medium sub-angular blocky in structure, very dark grayish brown to yellowish brown and black in colour hues of 10YR to 5Y, sandy over coarse loamy in texture, strongly acid surface, neutral sub-surface and extremely acid sub-soil and medium to high CEC values ranging from 45 to136 cmol (p+) kg^{-1}clay and medium base saturation values of 23-43 per cent with extremely high ESP of 47 to 62 and EMP of 27 to 38. The natural profile was classified as clayey over coarse-loamy, mixed, active isohyperthermic Typic Halaquepts owing to high ESP and the altered profile was classified as sandy over coarse-loamy, mixed, active, isohyperthermic Typic Sulfaquepts as the soil is having sulfuric horizon resting on a thick layer of extremely acid sulfidic materials.

Keywords: Natural, altered hydromorphic saline soils, Kaipad soils

Introduction
Characterization and classification of soils of a given area are crucial for the determination of its potentials and constraints for enhanced and sustained agricultural production (Alemu Lelago and Tadele Buraka, 2018) [1]. Soil characterization is intended to classify soil and TO determine their physical and chemical attributes (that can reflect the capacity of soil to function) not visible in field examination (Sanchez *et al.*, 2003) [10]. According to Assen and Yilma (2010) [2], soil classification is helpful to identify the most appropriate use of the land, estimate the production and facilitating technology transfer and information exchange between soil scientists, policymakers, planners, researchers, and agricultural extension consultants.
The Kaipad tracts, characterized by the unique acid, saline, sodic, hydromorphic soil cover the north Malabar districts of Kozhikode, Kannur, and Kasaragod. These coastal wetlands are located approximately between the GPS coordinates 11.25° N 75.77° E and 12.5° N 75.0° E. The Kaipad tract covers an area of about 4100 hectares, a major extent of which, about 2500 hectares is located in the Kannur district of Kerala. These are brackish water tracts embellished with high inherent organic matter content and essential nutrients thereby having a high production potential. Pedologically, these soils are dominated by the presence of different iron and sulphur containing minerals like pyrite and jarosite. These natural wetlands are altered for different land uses and the land use changes result in significant changes in soil properties. The study aims at classifying the soils of altered and natural wetlands of Kaipad soils of north Kerala according to USDA soil taxonomy.

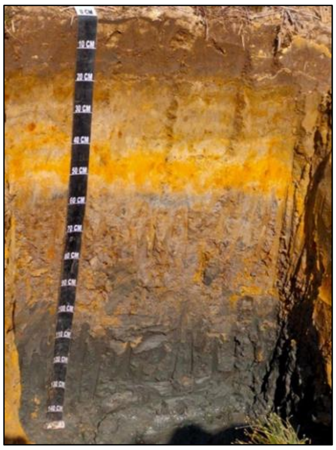
Materials and Methods
Kaipad tracts, comprising the saline hydromorphic soils are coastal wetlands lying between 11.25° N 75.77° E and 12.5° N 75.0° E. As a part of the study, two representative soil profiles (natural and altered) were opened and horizon-wise soil samples were collected from these profiles of Kaipad areas comprising Cherukunnu and Pallikkara (Kalliasseri) of Talipparamba

taluk, Kannur District. Soil horizons were differentiated based on colour, texture, structure and gravel content and horizon-wise samples collected were shade dried, ground, and sieved using a 2 mm sieve. The moisture percentages of the fresh soil samples were estimated gravimetrically. The horizon-wise soil samples were collected and analyzed for pH, electric conductivity (EC), cation exchange capacity (CEC), exchangeable cations and exchangeable sodium percentage (ESP), Exchangeable Magnesium Percentage (EMP) following standard procedures. Soil pH, EC, and CEC were measured as per the procedure described by Jackson (1973). Calcium carbonate ($CaCO_3$) was analyzed by the rapid titration method (Richards, 1954). The soil organic carbon content was determined by the wet digestion method of Walkley and Black (1934) [13]. Based on the studied characteristics soils were classified up to family level by USDA soil taxonomy (Soil Survey Staff, 2003) [11].

Natural Kaipad lands overview

Altered Kaipad lands overview

Natural Kaipad soil profile



Altered Kaipad soil profile

Results and Discussion

Morphological characteristics

The natural and altered soil profiles of Kaipad lands are mostly low lands with very gently sloping up to 1-3 per cantaloupe. These soils are black to dark grey and then black in colour hues of 10YR and 2.5Y (Natural) and very dark grayish brown to yellowish brown and black in colour hues of 10YR to 5Y (Altered) and can be attributed to the presence of organic matter (Dutta *et al.*, 2016) [4] apart from routine tidal inundation of sea water. Sub-surface horizons of altered Kaipad lands exhibit light yellow colour due to oxidized ferric iron oxides. The colour appears to be the function of the chemical and mineralogical composition of the soil (Swarnam *et al.*, 2004) [12].

The bulk density varied from 1.07 Mg m^{-3} to 1.10 Mg m^{-3} in natural and altered wetland ecosystem profiles respectively. The bulk density in soils irrespective of landforms increased with depth, which might be due to more compaction of finer particles in deeper layers caused by the overhead weight of the surface soils (Jewitt *et al.*, 1979) [6]. The texture varied from clay loam to clay then to sandy clay loam and sandy loam in natural wetland ecosystem and loamy sand to sand and then to sandy loam in altered wetland ecosystems of these selected profiles. This wide variation in soil texture is caused by topographic position, nature of parent material, in situ weathering, translocation of clay, and age of soils apart from riverine alluvium churned by marine sediments brought through sea water inundation. Further, the variation in the texture of the soils is also mainly due to the differences in the composition of parent materials (Nayak *et al.*, 2002) [8]. The structure varies from weak or moderate, medium sub-angular blocky, which is showing slow soil structure development and horizonation. Roots on surface showed many fine to common medium on sub-surface and few fine on sub-soil. Pores on surface horizon showed common medium, common fine or very fine on sub-surface and few very fine and/or fine on sub-soil.

Physical and Chemical properties

The altered Kaipad profile exhibited variation in silt content with depth and the content varied from 1.64 to 17.52 per cent. But with respect to the natural Kaipad profile silt content varied from 5.34 to 20.86 per cent and decreased with depth in natural but decreased with depth after surface and then increased with depth in altered except in the last CBg horizon. In altered sand decreased with depth in control section from 95 to 66 and in natural it increased from 30 to 81 per cent.

Clay in altered increased from 1.64 to 17.52, while in natural it reduced from 50 to 14 per cent. Overall clay percentage is more with respect to natural soil profile, when compared to altered profile. The surface horizons of natural have recorded with high electrical conductivity (EC) values ranging from 13.0 dS m^{-1} to 5.8 dS m^{-1} decreasing down the soil profile, while in altered after an initial reduction from 5.95 to 2.10 and an increase down the profile to 17.82 was recorded. This high salinity recorded might be attributed to the extremely high accumulation of salts carried by inundating sea water with marine alluvium during these periods. Similar findings on electrical conductivity of Kaipad soil was reported by Chandramohan and Mohanan (2012) [3]. They reported that the electrical conductivity of these soils ranged from 10.9 to 19.9 dS m^{-1} during the summer months. These salts get washed away during the onset of monsoon and thus cause a reduction in electrical conductivity of soils, which favours rice cultivation. Increased soil pH values showing reduction in acidity from extreme acid condition (3.94) to slightly acid (6.23) in control section and moderately alkaline (7.94) in sub-soil were observed with respect to natural soil profile. But in altered soil, profile pH from strongly acid (5.39) in surface horizon to neutral (7.14) or slightly alkaline (7.42) in control section and extremely acid in sub-soil in contrary to the natural system (3.26) pointing to presence of sulfuric horizon above a thick layer of sulfidic materials. They reported that soil pH of the saline soils of Kerala varied from 3.0 to 6.8. The slightly acid pH noticed in Kaipad soils might be attributed to the presence of lime shell depositions (Iyer, 1989) as a result of frequent saline water intrusions during the monsoon period. Natural soil profile surface layer recorded high OC content compared to sub-surface horizons from very high 3.14 in surface horizon to 0.64 and then increase in sub-soil to 1.55 per cent but with respect to altered soil profile surface was having 0.60 decrease to 0.24 and towards the sub-soil horizon, which registered highest OC content of 3.14 per cent. This is in concordance with the report of Nair and Money (1972) [7]. Among the exchangeable bases, Na content was high in both the soil profiles followed by Mg> Ca>K in contrary to the other soil profiles studied in Kerala, where calcium was seen as the major cation in exchange complex. Here sodium and magnesium shown higher presence having impact in soil physical and chemical properties through high ESP (41-60 in natural and 46-62 in altered) and EMP (18 to 30 in natural and 27 to 38 in altered). The CEC values of sub-surface horizons were high when compared to surface horizons which ranged from high CEC values ranging from 48 to 67 cmol (p+) kg^{-1} clay and medium to high base saturation (50-57%) in natural soil profiles and medium to high CEC values ranging from 45 to136 cmol (p+) kg^{-1} clay and medium base saturation values of 23-43 per cent in the altered soil profile. More or less the exchangeable bases show an increase with respect to the depth ranging from 62.42 to 81.93 cmol (p+) g^{-1} soil in the natural soil profile and 53.23 to 91.44 cmol (p+) g^{-1} soil. High base saturation values were recorded in the sub-surface compared to surface horizons mainly because of the leaching of bases to lower depths and accumulation of these bases in sub-soil.

Soil classification

The classification of natural and altered Kaipad wetlands soil pedons studied was done by referring to the keys to soil taxonomy (Soil Survey Staff, 2014). The natural Kaipad soil pedon was deep poorly drained with an altered B horizon or cambic horizon with lower chroma due to gleying and classified under Inceptisols. At sub-order level, pedon fall under moisture regime aquic, hence the pedon was classified as Aquepts. At great group level, pedon is classified as Halaquepts and at sub-group level Typic Halaquepts. The natural profile was classified as clayey over coarse-loamy, mixed, active iso-hyperthermic Typic Halaquepts. The altered Kaipad soil profile was also deep and imperfectly drained with an altered B horizon or cambic horizon with lower chroma due to gleying and was classified under Inceptisols. At sub-order level, pedon falls under moisture regime aquic, hence the pedon was classified as Aquepts. At great group level, pedon is classified as Sulfaquepts and at sub-group level Typic Sulfaquepts. Altered profile was classified as sandy over coarse-loamy, mixed, active iso-hyperthermic Typic Sulfaquepts.

Table 1: Morphological characteristics of the soils of study area

Horizon	Depth (cm)	Boundary	Mottles	Moist Colour	Texture	Structure	Consistency			Roots	Pores
							Dry	Moist	Wet		
Pedon 1: Natural Kaipad soil profile											
A	0-22	c s	f 1 f	10YR 3/2	cl	2 F sbk	h	fr	ss & ps	m f	c m
Bw1	22-43	c s	f 1 d	10YR 3/3	c	1 M sbk	h	fr	ss & ps	c m	c f
Bw2g	43-74	c s	f 1 d	2.5Y 4/1	scl	2 M sbk	sh	fr	vs & ps	f f	c vf
Bw3g	74-100	c s	m 1 d	2.5Y 5/1	sl	1 M sbk	sh	fr	ms & ps	f f	f vf
BCg	100-128		m 1 d	2.5Y 4/1	sl	1 M sbk		fr	ms & ps		f vf
CBg	128-162+		m 1 d	10YR3/1 (r)	sl	1 M sbk		fr	ms & ps		fvf,f
Pedon 2: Altered Kaipad soil profile											
Ap	0-18	c s	f 1 f	10YR 3/2	ls	1 M sbk		fr	s0 & p0	ff,vf	c f
Bw1	18-38	c s	f 2f	2.5Y 5/3	s	1 M sbk		vfr	s0 & p0	f vf	c f
Bw2g	38-57	c s	f 2d	10YR 5/6	s	1 M gr		vfr	s0 & p0	-	c m
Bw3g	57-90	a s	m 2 d	10YR 4/2	sl	1 M sbk		fr	ms & ps	-	f m
BC1g	90-105	c s	m1 d	2.5Y 4/1	sl	1 M sbk		fr	ms & ps	-	f m
BC2g	105-130	g s	-	2.5Y/2.5/1	sl	1 M sbk/m		fi	vs & vp	-	f f
CBg	130-151	-	-	5Y/2.5/1	sl	m		fr	vs & vp	-	f f
	151+	Water saturated layer									

Table 2: Physical and chemical properties of soils of the study area

Depth (cm)	Particle size distribution			pH (1:2.5)	E.C (dS m^{-1})	OC %	Exchangeable bases					Extractable acidity			CEC	BS by Sum of cations (%)
	Sand	Silt	Clay				Ca	Mg	K	Na	Total	$BaCl_2$- TEA	1.0 N KCl			
	2.0-0.05	0.05-0.002	<0.002										H^+	Al^{3+}		
	% of <2 mm						cmol (p+) g^{-1} soil									
Pedon 1: Natural Kaipad soil profile																
0-22	43.06	18.34	38.59	3.94	13.00	3.14	4.23	11.20	1.79	22.01	39.23	37.0	0.73	0.33	18.62	51.46
22-43	29.56	20.86	49.58	5.18	8.75	1.23	5.95	11.20	2.06	27.75	46.95	36.0	0.09	0	24.02	56.60
43-74	71.65	7.74	20.60	5.58	7.62	0.64	1.98	5.85	0.85	13.47	22.15	25.5	0.07	0	11.13	46.48
74-100	78.20	7.54	14.26	6.23	7.46	1.11	3.48	5.93	1.11	11.86	22.37	20.5	0.07	0	9.57	52.18
100-128	81.01	5.34	13.65	7.94	5.80	0.91	11.00	5.44	1.09	12.36	29.88	30.0	0.05	0	7.80	49.90
128-162+	78.44	4.22	17.35	7.93	6.59	1.55	18.99	7.47	1.36	15.16	42.98	25.0	0.07	0	7.59	63.22
Pedon 2: Altered Kaipad soil profile																
0-18	83.18	6.14	10.68	5.39	5.95	0.595	1.22	3.52	0.28	8.08	13.10	23	0.07	0	4.78	36.29
18-38	95.62	1.64	2.74	7.14	2.41	0.357	0.73	2.12	0.11	3.84	6.80	22	0.05	0	1.46	23.61
38-57	95.99	1.71	2.31	7.42	2.44	0.238	0.52	1.67	0.07	3.34	5.59	21.5	0	0	1.14	26.00
57-90	77.31	6.53	16.16	7.01	4.66	0.357	1.84	5.95	0.46	10.16	18.42	27	0.02	0	7.49	40.55
90-105	75.87	6.42	17.71	6.99	3.04	0.476	2.27	6.69	0.51	11.01	20.48	28.5	0.02	0	8.22	41.81
105-130	66.36	17.52	16.12	3.26	9.93	1.905	4.64	12.16	0.05	14.75	31.60	42	7.98	0	14.66	42.93
130-151	64.53	20.99	14.48	3.44	12.5	3.136	12.87	17.19	0.07	15.99	46.11	44.5	8	0	19.66	50.89
151+	Water saturated layer															

Conclusions

In Kerala, where the humid tropical climate (HTC) predominates, lower positions of the landscape will be recharged through fluvial processes from upper reaches as well rainfall. Same time tidal activity and sea water inundation on a routine basis makes a lot of changes in soil horizonation and development. Pedological approach to studying soils gives an insight into specific characteristics and problems associated with the soils. Natural and altered Kaipad soils belong to the wetlands of north Kerala, where similar agro-climatic conditions exist, even then results of this study have given evidence for differences properties of these soils. The diversity in soils belonging to the same agro-climatic conditions is brought about by variation in local topographic conditions causing erosion, leaching, sedimentation, anthropogenic activities and other pedogenic processes modified by water table.

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