International Journal of Plant & Soil Science

Volume 36, Issue 12, Page 425-435, 2024; Article no.IJPSS.128362
ISSN: 2320-7035

Assessment of Morphological, Physical and Physico-chemical Properties of Selected Soil Series in Cauvery Delta Zone, Tamil Nadu, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i125216

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/128362

Original Research Article

Received: 17/10/2024
Accepted: 19/12/2024
Published: 23/12/2024

ABSTRACT

An assessment of soil morphology, physical and physico-chemical properties was conducted in the Cauvery Delta zone in the selected soil series encompassing in Thanjavur and Pudukottai Districts in Tamil Nadu, India. The heterogeneity of topography and terrain features in selected area featured

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Cite as: *K.M.Sellamuthu, R.Santhi, D.Selvi, K.Sivakumar, R.Jegadeeswaran, P.Malathi, and P.Balasubramaniam. 2024. "Assessment of Morphological, Physical and Physico-Chemical Properties of Selected Soil Series in Cauvery Delta Zone, Tamil Nadu, India". International Journal of Plant & Soil Science 36 (12):425-35. https://doi.org/10.9734/ijpss/2024/v36i125216.*

in three dominant soil series viz., Mangalathupatty, Pattukottai, and Kalathur series. The representative pedons were examined for their morphological, physical and physico-chemical properties. The soils were deep, with drainage varying from well-drained to moderately poor-drained. The soils were yellowish brown to black in most condition. Overall, in surface soils clay content varied from 24.15 to 41.15 per cent where Kalathur series recorded higher clay content followed by Mangalathupatty followed by Pattukottai soil series. Clay content increased up to subsurface layer then decreased towards parent material. Soil pH varied from 5.34 to 8.9 among the soil series Soils are slightly acidic to moderately alkaline. Electrical conductivity varied from 0.06 to 0.74 dSm^{-1}. Soil samples were non saline. Free calcium carbonate content varied from 0 to 3.75 per cent and it indicate the calcareousness of the soils. The cation exchange capacity (CEC) of the threesoil series varied from 8.0 to 46.0 C mol $(p+)Kg^{-1}$. Higher CEC was found in Kalathur series followed by Mangalathupatty and Pattukottai.CEC also exhibited similar trend as that of clay. The sequence of abundance for exchangeable cations follows the order of Ca^{2+}> Mg^{2+}> Na^{+}> K^{+}. The high base saturation in these soils ranging from 80.0 in Mangalathupatty soil series to 100.3 % in Kalathur soil series. The exchangeable sodium percentage (ESP) varied from 0.81 per cent in Pattukottai series to 26.62 per cent in Mangalathupatty soil series.

Keywords: Soil morphology; plant growth; agro technology;Cauvery Delta zone.

1. INTRODUCTION

Soil is a basic entity on which plants grow, takes essential nutrients to survive and complete their life cycle. On agricultural point of view soil is a medium for plant growth. But the performance of soil largely depends on its properties such as physical, physico-chmical, chemical and biological properties. Soil properties are so important part of study for agricultural point of view or a different discipline. Because soil is a limited, scarce, and non-renewable resource, there are some restrictions on how much it can grow crops. An in-depth insight on soil is a prerequisite for planning, monitoring and development of strategies like optimum land, water, fertilizer use and management aiming at high returns. Through technological means, soil's carrying capacity can only be increased to a limited extent (Tefera et al., 2000). The restrictions are imposed by inherent qualities, agro-ecological environments, land use, and management. Soils should be maintained sustainably in order to execute suggested improvements to satisfy developmental demands without compromising the possibility for further utilisation (Varade, 1994).

Generally, benchmark soils are taken into account Yilmaz et al., 2000; for a state or country. However, for scientific soil management, regional agroclimatic zones and land use must be considered. Comprehensive knowledge on Tamilnadu soils representing agroclimatic zones and land use, as well as their characterization, is required to understand their properties, genesis, and development of management strategies. In Tamil Nadu, there are approximately 458 dominant soil series. The chosen soil series should have a large amount of research data to allow for the transfer of agro technology.

Researchers have used a variety of methods to investigate various geographical areas. Soil survey is one of these methods for offering a thorough scientific resource inventory which may be employed for a long-term planning and management of any region. To make predictions about the characteristics and potentialities of different soil types, soil surveys provide an accurate and thorough database of those soil types, their nature, and the extent of their dissemination (Tumbal and Patil, 2015). In turn, by integrating the fundamental principles of soil science into agriculture, forestry, and engineering, soil surveys could be used to forecast how soil will behave under specified uses, management, or alteration. Characterization, categorization, land evaluation, mapping, and suggestions for appropriate land use planning are all key components of a soil survey.

Knowledge of potentials and constraints are critical for scientific soil management. Systematic analysis of the soils is necessary before suggesting effective management practices for profitable cropping. A soil test involves analysing a soil sample to ascertain soil properties including salinity, acidity, alkalinity, and level of calcareousness. Soil tests are carried out to determine the soil's expected potential in terms of crop growth. This study specifically conducted to assess the potentials and constraints of three

Table 1. Geographical distribution of study area

District	Village	Block	Taluk	Latitude	Longitude	Soil series
Pudukottai	Thenipatti	Arimalam	Thirumayam	$10^0$26’44.5”N	$78^0$50’37.7”E	Mangalathupatty
Thanjavur	Veppankulam	Madukkur	Pattukottai	$10^0$28’3.9.5”N	$79^0$22’13.8”E	Pattukottai
Thanjavur	Aduthurai	Papanasam	Kumbakonam	$11^0$01’4.7”N	$79^0$28’54.4”E	Kalathur

Table 2. Parameter analysed, techniques adopted for soil analysis

Particulars	Techniques	References
Physical parameters		
Bulk Density Particle Density Porosity	Cylinder Method	Tan (1998)
Colour	Munsell Colour Chart	Soil Survey Staff (1970)
Texture	Robinson Pipette Method	Piper (1966)
Physico-chemical parameters		
pH	Water (1:2.5)	Jackson (1973)
Electrical Conductivity	Electrical Conductivity Meter	Jackson (1973)
Free $CaCO_3$	Rapid Titration Method	Piper (1966)
Cation Exchange Capacity	Neutral Normal Ammonium acetate method (soil pH <8.2)	Schollenberger and Dreibelbis, (1930)
	Sodium Acetate method (Soil pH>8.2)	Schollenberger and Dreibelbis (1930)
Exchangeable Ca and Mg	Versenate titration	Jackson (1973)
Exchangeable K and Na	Flame photometry	Sanford and English (1949)

representative soil series of Thanjavur and Pudukottai districts of Cauvery Delta zone of Tamil Nadu to suggest proper management practices for profitable farming.

2. MATERIALS AND METHODS

2.1 Study Area

This study covers soil series comes under Cauvery Delta zone of Tamil Nadu and covers Thanjavurand Puduckottai districts. Geographical distribution of study areas are given in Table 1.

2.2 Climate

This zone is located between 100 and 200 metres above sea level. The average annual maximum temperature is 33.2°C, and the average annual minimum temperature is 24.47°C. The highest maximum temperature is recorded during the pre-monsoon season (summer), and the lowest maximum temperature is recorded during the winter season.

The average annual rainfall is 984 mm, with the majority of it coming from the northeast monsoon. The northeast monsoon accounts for about 67% of the annual rainfall, while the southwest monsoon accounts for about 25%. Rainfall in the area has become more erratic in recent years.

Major crops grown are rice, cumbu, maize, cholam, ragi, black gram, green gram, coconut, gingelly, castor, groundnut, banana, onion, cashew, betel vine, citrus, jack and other vegetables (Soil and Land Use Survey of India 2022).

3. METHODOLOGY

In order to determine the selected soil series, a survey was conducted using cadastral maps from 1:3000 to scales of 1:5000. According to the soil survey handbook, three pedons were left exposed in benchmark sites and their morphological parameters were examined. Horizon wise samples were collected, air-dried, sieved through a 2 mm sieve, and weighted separately for the amount of gravel present. The samples were analyzed for physical parameters like soil texture (Robinson pipette method), Bulk Density, Particle Density, Colour (Munsell colour chart), porosity, Physico-chemical properties like pH, EC, CEC, exchangeable cations, free $CaCO_3$ were determined. (Table 2).

4. RESULTS AND DISCUSSION

Three dominant soil series present in Cauvery Delta zone of Tamil Nadu viz. Mangalathupatty series (287092 ha), Pattukottai series (162624 ha) and Kalathur series (180104 ha), were identified for assessing the morphological (Table 3), physico-chemical properties (Table 4).

4.1 Morphological Properties

Morphological properties of soils are depicted in Table 3. The depth of the soil varies with pedon, ranged from 130 to 160 cm which coming under deep category (>100 cm).

Table 3. Morphological and physical characteristics of selected soil series in the study area

Depth(cm)	Horizon	Colour (Moist)	Mechanical Analysis (%)			Texture	BD(gcm^{-3})	PD(gcm^{-3})	Porosity
			Sand	Silt	Clay				
Pedon1.Mangalathupatty Series									
0-18	Ap	10YR4/4	50.83	16.00	32.90	Sandy clay loam	1.33	2.40	44.4
18-40	B1	10YR5/4	48.73	12.50	38.40	sandy clay	1.23	2.52	51.0
40-90	B2	7.5YR3/3	48.23	14.50	37.15	sandy clay	1.25	2.09	40.3
90-130	Bc	7.5YR5/4	58.42	18.50	22.40	sandy clay loam	1.18	1.86	36.8
>130	C	10YR5/6	74.24	14.25	10.65	sandy loam	1.25	2.09	40.3
Pedon 2.Pattukottai series									
0-15	Ap	10YR4/4	54.07	21.50	24.15	sandy clay loam	1.43	2.27	36.9
15-70	B1	10YR4/4	54.34	21.75	23.90	sandy clay loam	1.43	2.33	38.7
70-155	B2	10YR5/4	47.97	23.25	28.65	sandy clay loam	1.33	2.26	41.1
>155	B3	7.5YR5/6	57.14	19.75	22.65	sandy clay loam	1.29	2.20	41.3
Pedon 3.Kalathur Series									
0-20	Ap	10YR2/1	18.09	40.75	41.15	Silty Clay	1.41	2.23	36.9
20-42	Bw	10YR2/1	17.65	40.68	41.23	Silty Clay	1.42	2.24	36.6
42-63	Bss1	10YR2/1	16.60	41.50	43.65	Silty Clay	1.43	2.02	29.3
63-90	Bss2	10YR3/2	15.79	40.50	41.90	Silty Clay	1.33	2.43	45.2
90-111	Bss3	10YR3/2	18.50	41.00	40.15	Silty Clay	1.27	2.10	39.3
111-160	Bss4	10YR3/3	19.06	40.00	40.90	Silty Clay	1.28	2.56	50.0
>160	Bss5	10YR3/2	18.83	41.00	40.15	Silty Clay	1.27	2.56	50.6

Table 4. Physico-chemical and exchangeable properties of selected soil series in the study area

Depth	Horizon	pH	EC(dSm^{-1})	Free $CaCO_3$ (%)	Exch. Bases (C mol (p+) kg^{-1})					CEC(C mol (p+) kg^{-1})	BSP(%)	ESP(%)
					Ca	Mg	K	Na	Total			
Pedon1. Mangalathupatty Series												
0-18	Ap	5.91	0.06	0.00	9.2	4.0	0.07	0.17	13.4	16.8	80.0	1.26
18-40	B1	6.20	0.12	0.00	10.1	5.1	0.05	1.31	16.6	18.2	91.0	7.91
40-90	B2	8.22	0.74	0.12	9.1	4.2	0.06	4.47	17.8	19.4	91.9	25.07
90-130	Bc	8.78	0.43	0.50	7.2	4.2	0.07	4.16	15.6	17.2	90.9	26.62
>130	C	8.90	0.33	0.63	6.1	3.1	0.04	3.23	12.5	14.2	87.8	25.90

Depth	Horizon	pH	EC(dSm^{-1})	Free $CaCO_3$ (%)	Exch. Bases (C mol (p+) kg^{-1})					CEC(C mol (p+) kg^{-1})	BSP(%)	ESP(%)
					Ca	Mg	K	Na	Total			
Pedon 2. Pattukottai series												
0-15	Ap	6.16	0.29	0.00	5.1	2.2	0.04	0.06	7.4	8.4	88.1	0.81
15-70	B1	6.39	0.24	0.12	6.2	2.1	0.02	0.09	8.4	9.6	87.6	1.07
70-155	B2	5.72	0.22	0.37	7.0	4.0	0.06	0.10	11.2	11.8	94.6	0.90
>155	B3	5.34	0.34	0.63	5.2	2.1	0.06	0.13	7.5	8	93.6	1.74
Pedon 3. Kalathur Series												
0-20	Ap	6.83	0.50	1.25	29.1	15.0	0.34	1.29	45.7	46.0	99.4	2.82
20-42	Bw	7.27	0.26	1.75	26.0	14.2	0.27	1.21	41.7	42.2	98.8	2.90
42-63	Bss1	7.31	0.19	2.37	28.0	13.1	0.19	1.06	42.4	43.2	98.0	2.50
63-90	Bss2	7.45	0.18	2.88	26.2	14.0	0.17	1.07	41.4	41.8	99.1	2.58
90-111	Bss3	7.53	0.17	3.37	26.0	12.2	0.19	1.2	39.6	40.6	97.5	3.03
111-160	Bss4	7.67	0.16	3.75	24.1	15.1	0.15	1.02	40.4	41.2	98.0	2.53
>160	Bss5	7.71	0.18	3.75	26.1	12.0	0.18	1.42	39.7	39.6	100.3	3.58

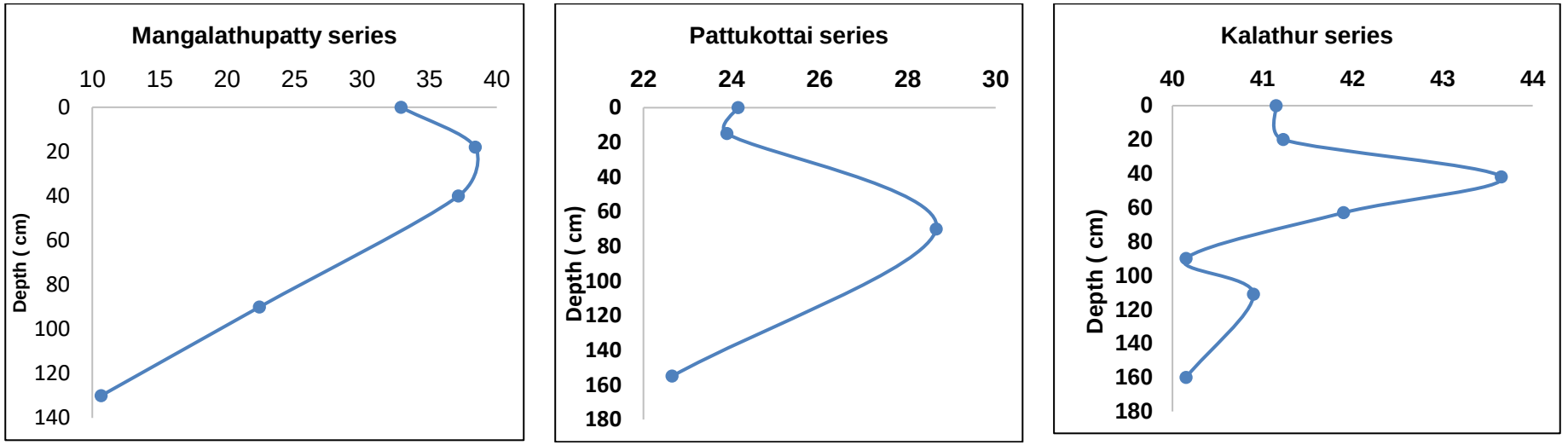

Fig. 1. Distribution of clay in selected soil series of Cauvery Delta zone

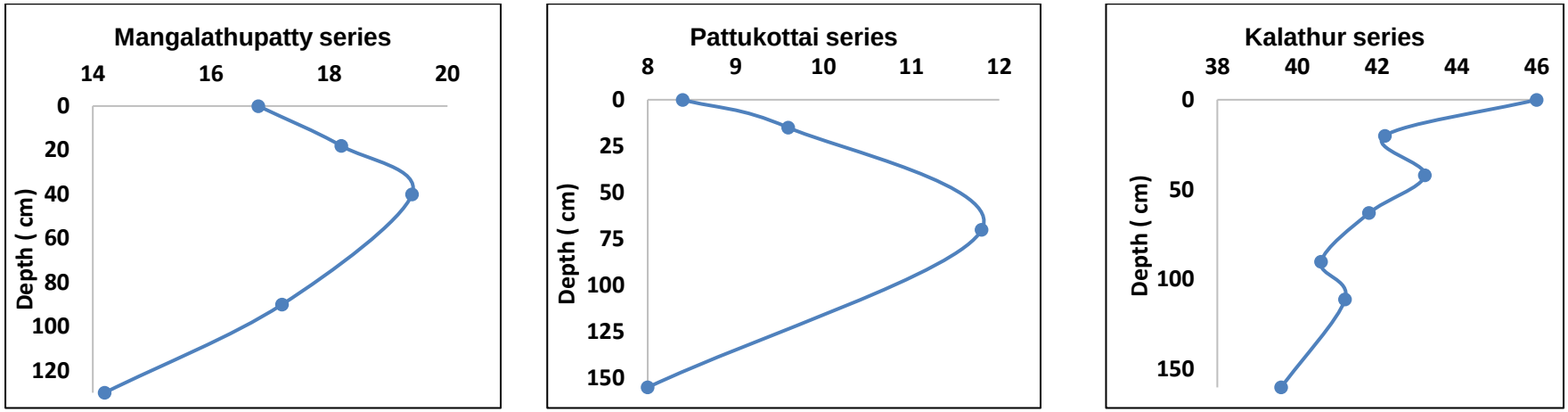

Fig. 2. Cation exchange capacity in selected soil series of Cauvery Delta zone

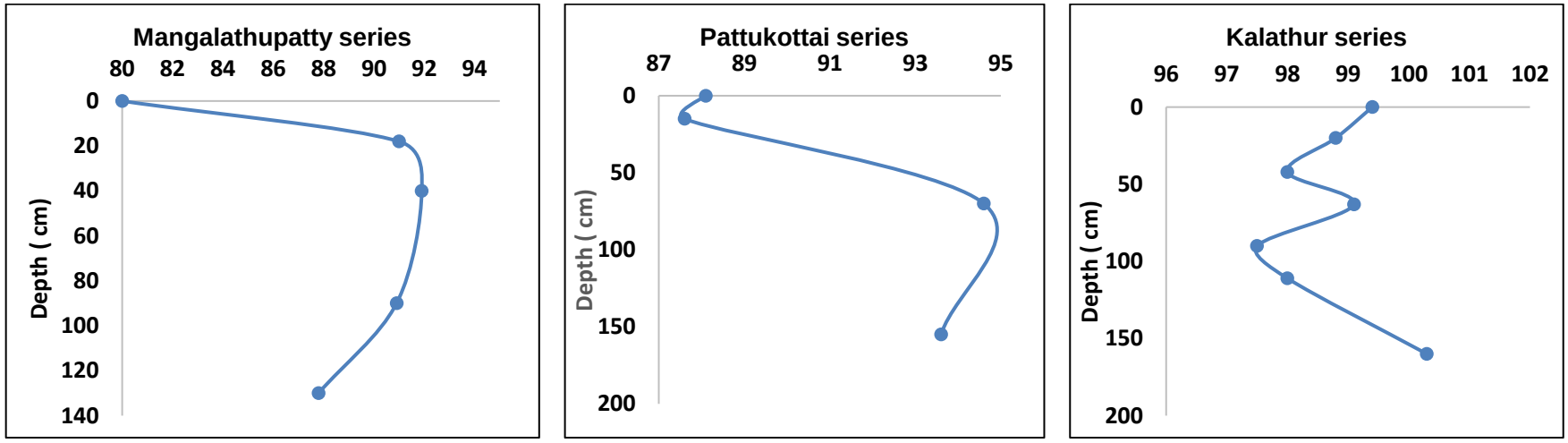

Fig. 3. Base saturation per cent in selected soil series of Cauvery Delta zone

The moist soil colour of the Mangalathupatty series varies from 10 YR 4/4 in surface to 7.5 YR 3/3 in subsurface soil. In Pattukottai series, soil colour (moist) varies from 10 YR 4/4 in surface to 7.5 YR 5/6 in subsurface soil. In Kalathur soil series, soil colour (moist) varies from 10 YR 2/1 in surface to 10 YR 3/2 in subsurface soil. Mohekar and Chella (2000) expressed that the nature and kind of soil formation processes are responsible for the variance in hues of the soil.

Soil texture varies from Sandy clay loam to Silty clay. In sub surface, soil texture vary from sandy loam to silty clay. Mangalathupatty soil series distributed in 1-3% slope. In surface, soils are sub angular blocky in structure; loose, non-sticky, non-plastic, many fine roots; few medium pores; very rapid permeability; clear wavy boundary. Subsurface soils are with sub-angular blocky in structure; slightly hard; friable; slightly sticky and slightly plastic; common very fine roots; common very fine tubular pores; rapid permeability; gradual wavy or irregular boundary.

Pattukottai soil series also distributed in 1-3% slope with sub angular blocky in structure; hard; friable; non-sticky and non-plastic; few fine roots; abrupt smooth boundary in surface soils while strong coarse sub-angular blocky in structure; very hard; firm; slightly sticky and nonplastic; clear smooth boundary recorded in subsurface horizons.

Kalathur soil series found to have sub angular blocky structure; very hard; firm; sticky and plastic; common fine roots, calcareous with moderate effervescence; clear smooth boundary in surface followed by sub-angular blocky in structure; very hard firm; sticky and slightly plastic; very few fine roots, distinct pressure faces distinct intersecting slicken sides; calcareous; moderate slow permeability; clear prominent boundary in subsurface layers.

4.2 Physical Properties

Physical characteristics of the soils are given in Table 4. Overall, in surface soils clay content varied from 24.15 to 41.15 per cent where Kalathur series recorded higher clay content followed by Mangalathupatty followed by Pattukottai soil series.

In Mangalathupatty soil series, clay content varied from 10.65 per cent in C horizon to 32.90 per cent in surface. Silt content varied from 12.5 to 18.5 per cent. Sand content ranged from 48.23 to 74.24 per cent. Soil texture found to be sandy loam to sandy clay loam. Pattukottai soil series exhibited with variations in clay from 22.65 to 28.65 per cent. Silt content vary from 19.75 to 23.25 per cent. While sand content ranged from 47.97 to 57.14 per cent. All the layers are found to have sandy clay loam texture. In Kalathur soil series clay content vary from 40.15 to 43.65 per cent. Clay content increased with depth then decreasing trend was noted in the pedons (Fig.1). Silt and sand content ranged from 40.0 to 41.50 per cent and 15.79 to 19.06 per cent respectively. All the horizons found to record silty clay texture. Sand content was dominated in Mangalathupatty and Pattukottai series while clay and silt in Kalathur soil series. This may be caused by variations in the way soil forms and the effects of different weathering processes. Sandy soils have poor nutrient retention and water-holding capacity, which restricts the amount of moisture available to the crop. In order to increase agricultural output, these soils must be carefully maintained. Soil texture and its correlation has been evaluated by Enang et al. (2020).

The soils' bulk densities (BD) ranged from 1.18 to 1.43 Mg m^{-3}. In Mangalathupatty series, BD varies from 1.18 to 1.25 Mg m^{-3} where as in Pattukottai and Kalathur series BD varies from 1.29 to 1.43 Mg $m^{-3}$and 1.27 to 1.43 Mg m^{-3} respectively. Particle density (PD) of soils varied from 1.86 to 2.52 Mg m^{-3}. In Mangalathupatty series, PD varies from 1.86 to 2.52 Mg m^{-3} where as in Pattukottai and Kalathur series PD varies from 2.20 to 2.33 Mg $m^{-3}$and 2.02 to 2.56 Mg m^{-3} respectively. Soil porosity ranged from 29.3 per cent in Kalathur to 51.0 per cent in Mangalathupatty series. Mangalathupatty soil series have more pores followed by Pattukottai and Kalathur series. The distribution of pores in all soil series profiles is inconsistent and varies sharply. There's a direct positive relationship between porosity and clay content. This means that as the clay content increases in the soil, the porosity of the soil also tends to increase. This relationship can be attributed to the fact that clay particles are finer and pack closely together, creating micro-pores that contribute to overall soil porosity. Haoet al. (2008) reported similar findings.

4.3 Physico-Chemical and Exchangeable Properties

Soil pH is a measure of the acidity or alkalinity of the soil. It's an important parameter because it

affects the availability of essential nutrients to plants and the activity of soil microorganisms, among other things. Soil pH varied from 5.34 to 8.9 among the soil series. Soil pH of the Mangalathupatty, Pattukottai and Kalathur soil series ranged from 5.91 to 8.90, 5.34 to 6.39 and 6.83 to 7.71 respectively. Soils are slightly acidic to moderately alkaline. Increasing pH in subsurface horizons has been documented by Singhet al. (2017) and Jenaet al. (2016), confirming that this is a recognized phenomenon in soil profiles. This extensive variation in pH among all soil series was attributed to the properties of the parent material, capacity of leaching, free $CaCO_3$ as well as exchangeable cations. The depth of the carbonate accumulation horizon is a suitable index of the soil moisture environment (Maki et al., 2007).

Electrical conductivity varied from 0.06 to 0.74 dSm^{-1}. Soil EC of the Mangalathupatty, Pattukottai and Kalathur soil series ranged from 0.06 to 0.74 dSm^{-1}, 0.29 to 0.34 dSm^{-1} and 0.16 to 0.50 dSm^{-1} respectively. All the soils are non-saline. Such observations align with the studies carried out by Nayaket al. (2000). The low electrical conductivity in the soils across all series could be attributed to the significant leaching of salts. This process could also be influenced by the nature of the parent material from which these soils have developed. The correlation between enhanced drainage conditions and reduced soil salinity, as evidenced by low electrical conductivity, has been documented in a study by Narsaiahet al. (2018), lending further support to these observations.

Free calcium carbonate content indicate the calcareousness of the soils. It varied from 0 to 3.75 per cent. Free calcium carbonate content of Mangalathupatty and Pattukottai soil series it varied 0 to 0.63 per cent. In Kalathur series, it ranged from 0 to 1.25 to 2.88 per cent. First, the deposition of concretionary nodules by water activity and, second, the precipitation of calcium carbonate from solutions rich in carbonate. This precipitation process is enhanced by the elevated pH values present in these soils, a phenomenon previously documented by Walia and Rao (1997).

Exchangeable calcium content of Mangalathupatty, Pattukottai and Kalathur soil series ranged from 6.1 to 10.1 C mol (p+) kg^{-1}, 5.1 to 7.0 C mol (p+) $kg^{-1}$and 24.1 to 29.1 C mol (p+) kg^{-1} respectively. Higher eexchangeable calcium was recorded in Kalathur series when compared to Mangalathupatty and Pattukottai. Exchangeable magnesium content of Mangalathupatty, Pattukottai and Kalathur soil series varied from 3.1 to 5.1 C mol (p+) kg^{-1}, 2.1 to 4.0 C mol (p+) kg^{-1} and 12.0 to 15.0 C mol (p+) kg^{-1} respectively. Higher exchangeable magnesium was recorded in Kalathur series when compared to Mangalathupatty and Pattukottai. Exchangeable sodium content varied from 0.17 to 4.47 C mol (p+) kg^{-1}, 0.06 to 0.13 C mol (p+) kg^{-1} , and 1.06 to 1.42 C Cmol (p+) kg^{-1}respectively in Mangalathupatty, Pattukottai and Kalathur soil series. Exchangeable potassium content varied from 0.04 to 0.07 C mol (p+) kg^{-1}, 0.02 to 0.06 C mol (p+) kg^{-1}, and 0.15 to 0.34 C mol (p+) kg^{-1} respectively in Mangalathupatty, Pattukottai and Kalathur soil series.The cation exchange capacity (CEC) of the threesoil series ranged from 8.0 to 46.0 C mol (p+) kg^{-1}. Higher CEC was found in Kalathur series followed by Mangalathupatty and Pattukottai. In all the pedons, the sequence of abundance for exchangeable cations was as follows: Ca^{2+}> Mg^{2+}> Na^{+}> K^{+}. Variations in CEC can be linked to the presence of organic matter and the quantity and nature of the clay within the soil. These observations align with findings from previous studies conducted by Sankar and Dadhwal (2009) and Naitamet al. (2016). As CEC is directly correlated with clay content of the soil the changes is clay percentage lead to changes in CEC also across the soil profiles.

The high base saturation in these soils ranging from 80.0 in Mangalathupatty soil series to 100.3 % in Kalathur soil series that can be attributed to the exchangeable Ca^{2+} and Mg^{2+}. Free calcium carbonate also contributes in exchangeable calcium and overall exchangeable cations with depth. In all horizon base saturation is having a direct correlation with free calcium carbonate content. CEC and BSP followed similar trend in Mangalathupatty and Pattukpttai with depth (Figs. 2 and 3) while Kalathur found to have irregular pattern of CEC and BSP with respect to depth. (Figs. 2 and 3). Similar observations were recorded by Pervinet al. (2023)

The exchangeable sodium percentage (ESP) varied from 0.81 per cent in Pattukottai series to 26.62 per cent in Mangalathupatty soil series. Due to the Na ions moving from the surface to the subsurface, the exchangeable sodium percentage increased with depth. Comparatively speaking, the Soils of Tulukkanur series has more ESP than other series. The

Mangalathupatty series' subsurface horizons have higher ESP than the soils on the surface. The results corroborate those from Mahapatraet al. (2019) and Pandey and Kumar (2014).

5. CONCLUSION

Soils of Cauvery delta zone of Thanjavur and Pudukottai Districts of Tamil Nadu recorded slightly acidic to moderately alkaline pH, non saline, low to medium CEC, high base saturation percentage. The soils soils are having level land to gentle slope and having no to slight erosion. All the pedons found to have the sequence of abundance for exchangeable cations in the order of Ca^{2+}> Mg^{2+}> Na^{+}> K^{+} with high base saturation. The exchangeable sodium percentage (ESP) in Pattukottai and Kalathur were found to be significantly below the crucial threshold of 15% while Mangalathupatty series found to have sodium accumulation in subsurface horizons. Calcareousness in Kalathur series, low CEC in Pattukottai series, sodium accumulation in Mangalathupatty indicate high probability for nutrient deficiency are the salient constraints to be addressed. Implementing suitable site-specific techniques is essential for attaining sustainable productivity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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