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Characterization of soils from the Coastal Rural Area of Bengkulu, Indonesia for Agricultural Land

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Abstract

Conversion of productive land to other uses requires the utilization of marginal land for agricultural purposes, such as coastal areas. The coastal environment has disadvantages of high salinity, high acidity, and low nutrient availability for plant growth. The study aimed to characterize the current status of soil from a coastal rural area of Bengkulu for agricultural land. The study was in Pondok Kelapa SubDistrict, The District of Central Bengkulu, Indonesia. Two soils were purposely selected for description based on the area's highest acreages, namely Entisols and Inceptisols. The soil profile was constructed and described in early July 2022. Soil samples were collected from each soil depth and analyzed for physical and chemical characteristics. The result showed that Entisols were more significantly affected by seawater intrusion than Inceptisols, as indicated by higher exchangeable Ca and Mg at the bottom of the soil profile. The Electrical Conductivity and Exchangeable Sodium Percentage for both soils were constantly low throughout the depths of the profile and less than 4 dS m⁻² and 15%, respectively. This current status of both soils has potential for agricultural land expansion.

Keywords: Characterization of soils, Coastal Rural Area, Agricultural Land

Introduction

Agricultural land conversion to other use obliges the agricultural land expansion to marginal land such as less fertile soils in the coastal area. According to Ray et al. (2014), a coastal area is an interface between land and sea that is reciprocally influenced by both. It consists of a coastal line ecosystem and upland watershed draining to the shoreline. Bengkulu Province has approximately 525 km of coastal line, dominated by hilly topography instead of plain shore. This kind of agroecosystem will highly affect agricultural activities in the area. In general, the coastal area has disadvantages for agricultural use, such as soil salinity, soil acidity, high soil conductivity, sand content, and waterlogging (Wang et al., 2014; Masum et al., 2017; Zhang et al., 2018; Thiam et al. 2021).

The soil characteristics of the shoreline are different depending on the soil formation. Coastal soils are diverse depending on the parent materials, climate, physiography, geomorphic process, hydro-chemical characteristics, and tidal marine water (Ray et al. 2014). Arulmathi and Porkodi (2020) study indicates that electrical conductivity (EC) ranges from 0.5-25 dS m⁻¹ with various soil textures, ranging from sandy loam to clay and soil pH 3.0-8.8. Sajitha et al. (2017) collected 10 seashore soils samples from the west coast of Kanyakumari District, Tamilnadu, and found the soil pH ranging from 7.2-8.2, EC 0.7-2.0 dS m⁻¹ with different content of macro and micro plant nutrients. The studies show that soils from other coastal plains have different characteristics.

Characteristics of soil will affect the interaction among nutrients in the soil and their availability for plant growth. Most saline soils exhibit high soluble Na⁺, to which most plant is hypersensitive (Qadir et al., 2007), causing accumulation of Na⁺ and Cl⁻ in plant tissue and lower other mineral uptakes such as Ca, K, N, and P (Kaya et al. 2001). Higher organic matter in saline soils improves soil structure, increases CEC, and lowers EC

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and salt content (Wang et al., 2014). The study intended to characterize the current status of soil in the coastal rural area of Bengkulu for agricultural land.

Material and Methods

Study Site and Soil profile description

The study located in Pondok Kelapa Subdistrict, The District of Central Bengkulu, Bengkulu Province, Indonesia. It is positioned at 102°12'20"-102°19'50" East dan 3°37'13" - 3°45'8" South (Figure 1), covering 100.867 km². The study was started by preparing the soil type by ArGis 4.0 using an RBI map of Central Bengkulu, satellite image sheet 0912, map of the village boundary. Inceptisols and Entisols dominated the soil order according to USDA Classification and were purposely selected for soil profile identification, as shown in Figure 1. Both soils were selected based on the closeness to the shoreline. The soil profiles were located in the latitude of 3°43'35" S and longitude of 102°14'14" E for Enstisols profile and latitude of 3°42'35" S and longitude of 102°15'32" E for Inceptisols.

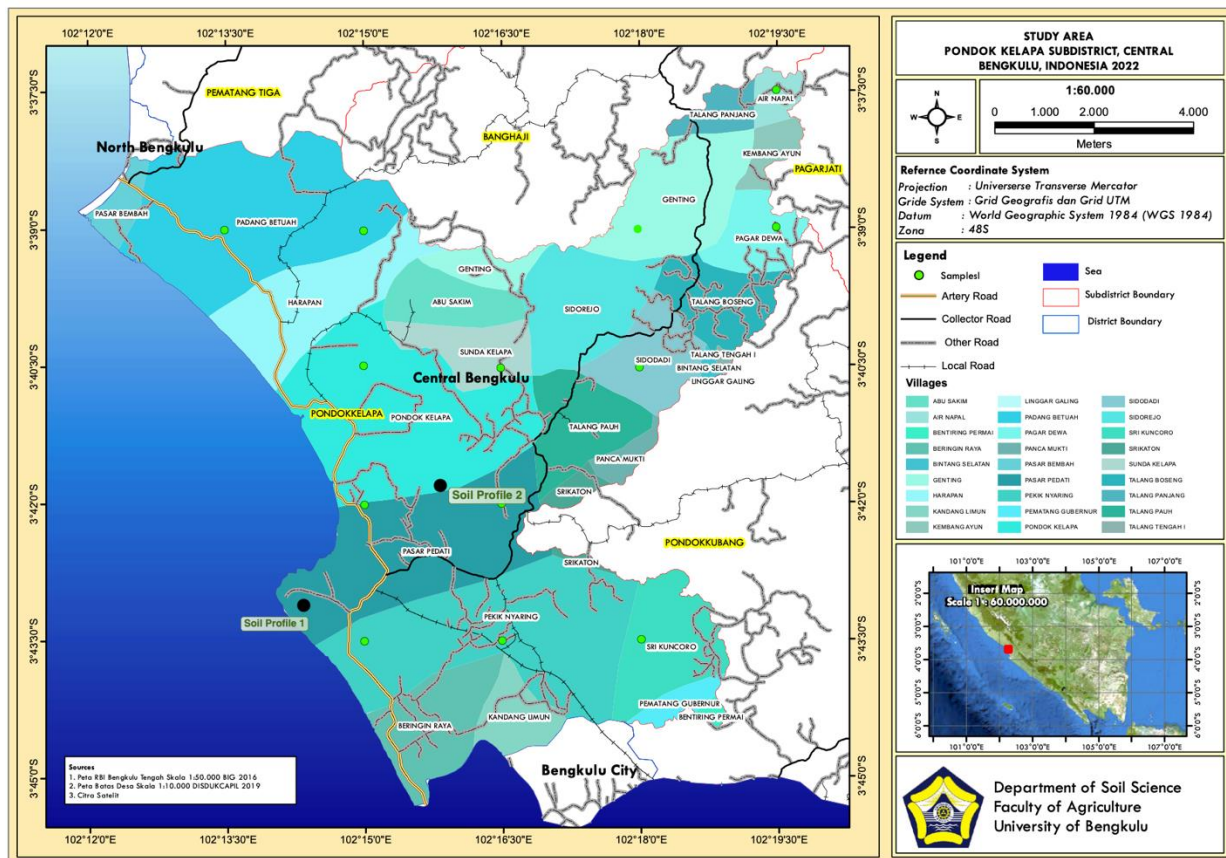


Figure 1. Study area and location of the soil profile

The description of the soils was conducted on 7 July 2022 by constructing the profile for each soil. It started by examining the boundary of each horizon and identifying the soil color using Munsell Color Chart. The different horizon was determined according to the soil color and/or the level of the massiveness of the soil layer. Soil sample of each horizon was collected for measurement of their physical and chemical characteristics. The sample collection was initiated from the bottom horizon and subsequently to the top horizon to avoid the contamination of soil samples from the upper horizon. An undisturbed soil sample was also collected from the top horizon to measure soil field capacity and bulk density. The soil profile of Entisols is limited to the depth of 105 cm due to the groundwater table, consisting of three horizons with a depth of 0-17 cm, 17-43 cm, and 43-

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105 cm. On the other hand, the profile of Inceptisols was as deep as 150 cm, containing five horizons with a depth of 0-20 cm, 20-44cm, 44-62 cm, 62-94 cm, and 94-150 cm.

Soil Analysis

Soil sample from each horizon was air-dried for 2 days, gently ground using a grinder, sieved with a 0.5 mm screen, and analyzed for physical and chemical properties of the soils. Undisturbed soil samples directly measure their field capacity moisture content using a pressure plate at 1/3 atmosphere or pF of 2.54 while bulk density using the method developed by Grossman and Reinsch (2002). Total soil organic carbon (TSOC) was measured using Walky and Black Method, total soil nitrogen (TSN) by Kejl Dahl Method, available phosphorous (P) by Bray I Method, Exchangeable potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) by buffer 1 N NH₄OAcetate extraction and detection using Atomic Absorption Spectroscopy (AAS), available Fe, Mn, Cu, and Zn by extraction with DTPA and detection using AAS, exchangeable aluminum (Al) by extraction using 1N KCl and titration, Cation Exchange Capacity (CEC) using extraction by 1N Ammonium acetate, pH at 1:1 ratio of soil and distilled water using pH meter, and electrical conductivity (EC) at 1:5 ratio of soil and distilled water using conductometer (Eviati and Sulaiman, 2009). Base saturation was computed by the exchangeable bases and CEC ratio, while exchangeable sodium percentage was calculated by dividing the exchangeable Na by CEC. Data of both soils were described and compared among soils and depths.

Results and Discussion

Characteristics of Coastal Entisols

The soil was located approximately 20 m to the shoreline with a slope of 5%. At soil sampling, the land was barrow and broadleaf weeds and nutsedge (*Cyperus rotundus*) were the predominant plants. A soil profile was constructed at the center of the land and described its properties. Field description supported by laboratory analysis confirmed that the soil was classified as Entisols. Table 1 indicates that the soil has a high content of sand, decreasing with depth but clay increases at the lower horizon. The content of sand decreased by 37.5%, while clay increased by 33.9% when compared between the first and third horizons. Higher content of sand at the upper horizon might be associated with the wind sedimentation of sand from the seashore. The color of the soil is brighter with depths, indicated by higher chrome. This result suggests that the lower horizon has less TSOC, as presented in Figure 2a. A previous study confirmed that soil color is closely related to organic carbon content (Vodyanitskii and Savichev, 2017). They also suggested that soil color was represented by some of the colors of mineral matrix and organic matter.

Table 1. Physical characteristics of Entisols from the coastal area

Depth (cm)	Color	Sand (%)	Silt (%)	Clay (%)	Texture	BD (g/cm ³)	FC (%)
0-17	2.5 YR 3/2	41.47	20.12	38.41	Sandy clay loam	1.14	24.66
17-43	2.5 YR 4/6	41.49	14.00	44.51	Sandy clay		
43-105	2.5 YR 4/6	30.16	18.26	51.58	Clay		

In general, TSOC, TSN, available P, and exchangeable K decreased with depth while exchangeable Ca is comparable and exchangeable Mg increased with depth (Figure 2). Total soil organic carbon and TSN were reduced by 309% and 107%, respectively, at a depth of 43-105 cm compared to the upper layer (Figure 2a, b). Higher TSOC, TSN, and available P might have been related to the accumulation of organic matter from crop leftover and weed biomass. The concentration of organic carbon in forest soils is higher in the upper layer than in the lower layer, suggesting the accumulation of organic matter in the upper part of the soil profile (Fang et al., 2015). Upon decomposition, organic matter will eventually contribute to the increased content of TSN and available P (Muktamar et al., 2020; Muktamar et al., 2022).

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On the other hand, at the same depths, exchangeable Mg increases by 79% (Figure 2f). At the upper layer, exchangeable Ca was higher than exchangeable K and Mg, while exchangeable Mg was the highest at the lowest layer. This result might be due to seawater's salt intrusion, as indicated by the increase of exchangeable Na at the same depth (Figure 3a). This trend is different from forest soil, where exchangeable Mg decreases with depth, as reported by Blonska and Lasota (2017).

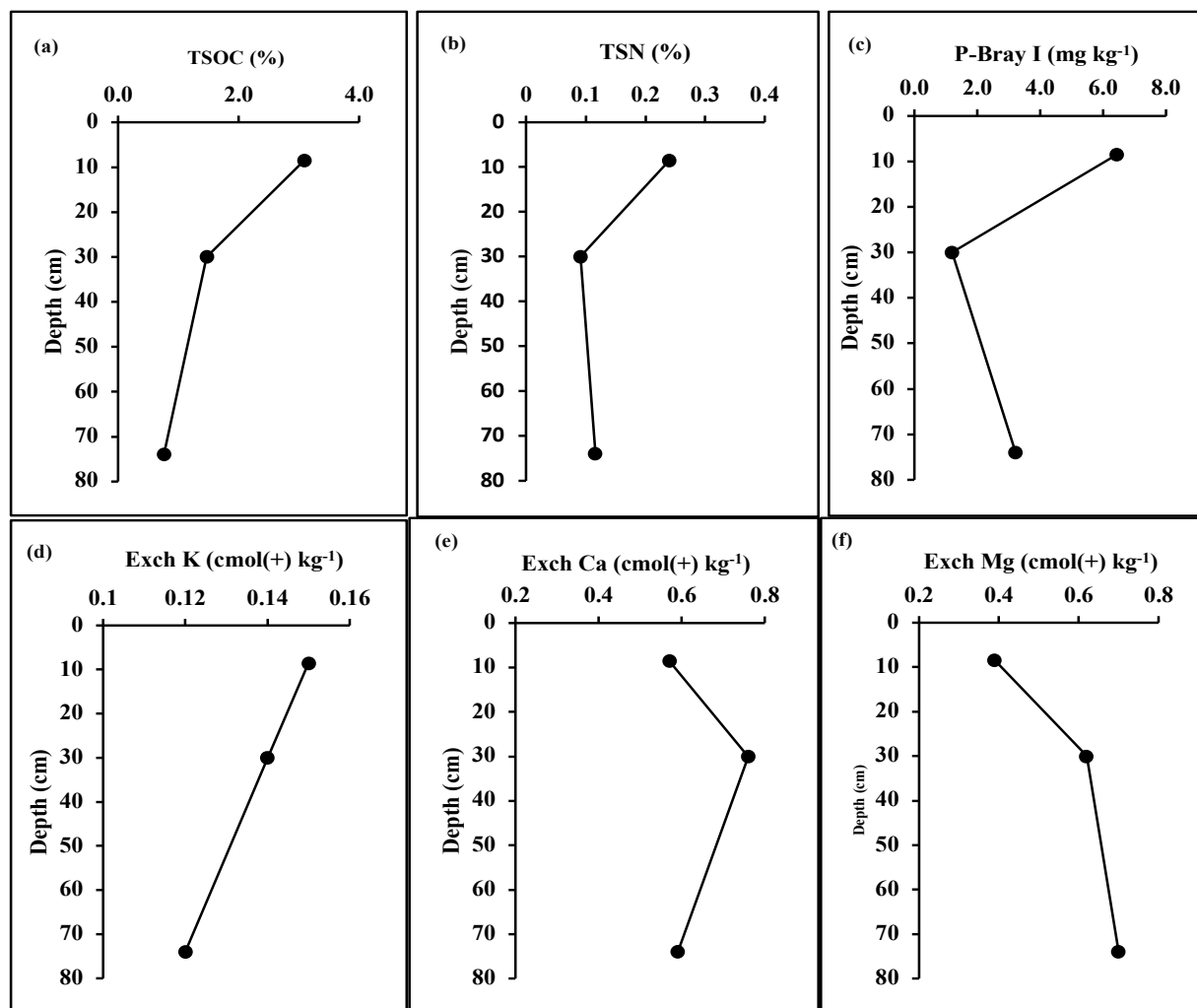


Figure 2. The contents of TSOC, TSN, P-Bray I, exchangeable K, Ca, and Mg at each depth of Entisols.

Exchangeable Na and Al of Entisols increased as soil depths deeper, while available Fe, Zn, Mn, and Cu tended to decrease with depths (Figure 3). The increase in exchangeable Na at lower depths indicates a salt intrusion of salt water from the sea shore and a slight rise of ESP (Figure 4a). As the main compound in seawater, sodium chloride might be responsible for the higher exchangeable sodium at a lower depth. A previous study in Damghan Basin, Iran, carried out by Ebrahimi et al. (2016), suggested that saltwater intrusion was the significant factor contributing to high salinity and degradation of the groundwater quality. The Na concentration in the groundwater reached up to 19.1 me l⁻¹. This result differs from that found by He et al. (2004), where exchangeable Na is higher at the upper layer than in the lower one.

Figure 3c also shows that exchangeable Al is higher at a lower depth. The trend is typical in the soil profile around the area, even though the land position is farther away from the seashore. Higher content of TSOC at the upper layer of the soil leads to the bounding of Al with the humic/fulvic resulting from the decomposition of organic matter to form the organo-Al complex (Yvanes-Giuliani et al., 2014). Available Fe,

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Zn, Mn, and Cu are essentially low and decrease with depth (Figure 4b, d, e, f); therefore, they do not suppress the concentration of their toxicities in plants.

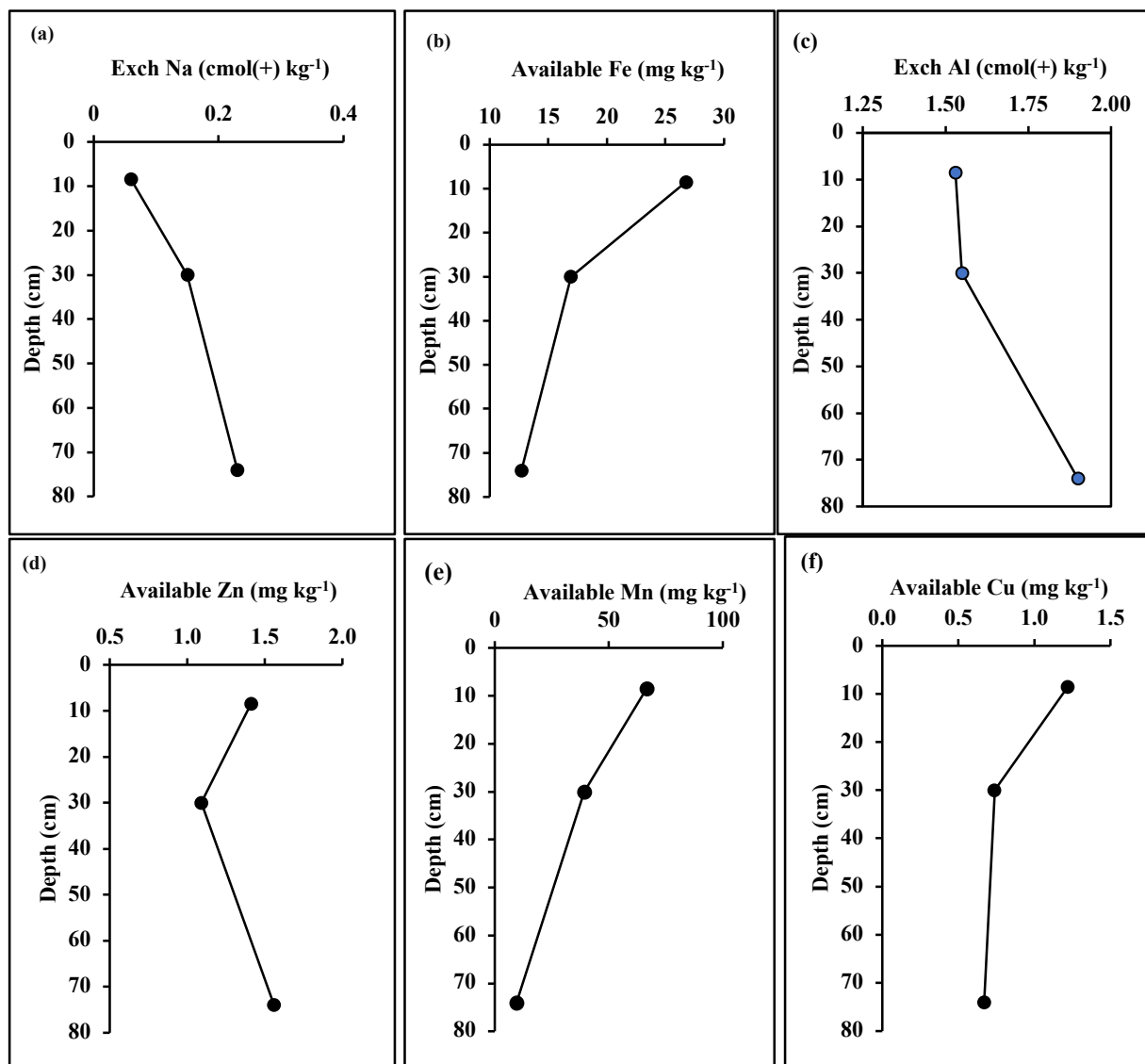


Figure 3. Exchangeable Na, Al, available Fe, Zn, Mn, and Cu as a function of soil depth of Entisols

The study resulted in the CEC of the soil being acquired higher with depth. Electrical conductivity, ESP, and BS tended to lower while pH was comparable with depths (Figure 4). The increase in CEC with depth is associated with the clay content of the soil (Table 1), where its content of the most bottom depth was the greatest as compared to the previous depths. This result indicates that the clay content significantly contributes negative charges to the soil. The soil pH is essentially low, ranging from 4.66-4.82, comparable among the depths. This trend is quite different from that of exchangeable Al, where its concentration at the bottom is almost 27% higher than the top layer.

The EC and ESP of the soil were uncharacteristic of the soil in the coastal area, where EC of the soil was less than 4 dS m^{-1} and ESP was much lower than 15%; consequently, the soil was not considered saline soil. This result might have been related to the altitude of the land (10 m above sea level); therefore, the soil is independent on the tiding of sea waves. The increase in exchangeable sodium with depths (Figure 3a) does not significantly contribute to the ESP and EC, as indicated in Figure 4d, e. Soil from the coastal area in different

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areas in India has much greater EC (Arulmathi and Parkodi, 2020), and soil from coastal Shanghai, China, exhibits much greater ESP (He et al., 2004).

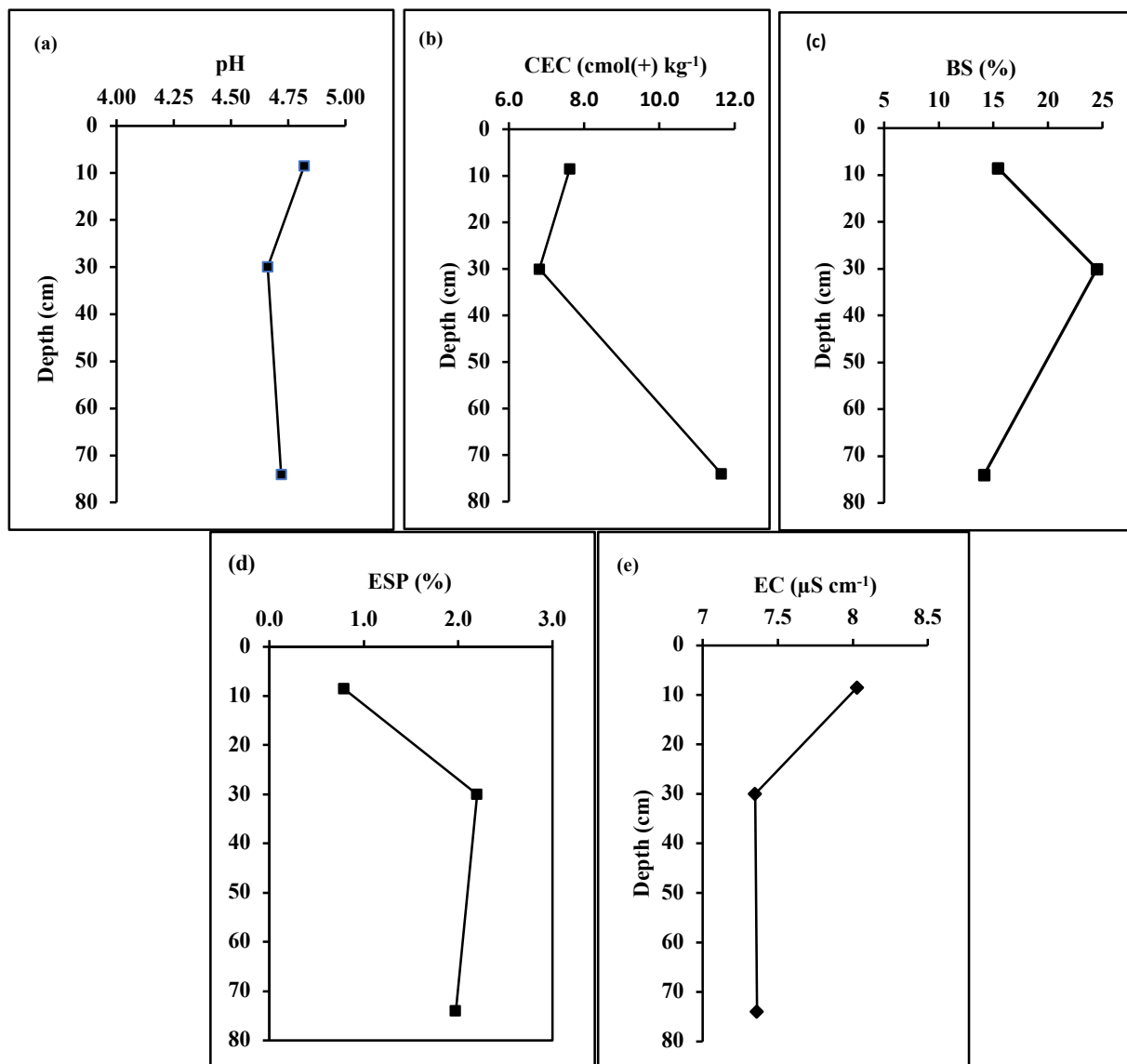


Figure 4. Cation exchange capacity, pH, BS, ESP, and BS of Entisols at different depths

Characteristics of Inceptisols

During the study, the soil site was barrow after being continuously cultivated by horticultural crops. The land was dominated by broadleaf weed and a few nutsedges. Field investigation using soil profile indicated that the soil was classified as Inceptisols. The physical characteristics of Inceptisols are presented in Table 2. As in the case of Entisols, the color of the soil is brighter as the soil layer becomes deeper, as indicated by the chrome. Meanwhile, clay content in each depth is more than 60%, classified as clay texture. The content of clay is higher than Entisols.

The BD of the soil is lower than Entisols which might be attributed to higher TSOC at the upper layer of Inceptisols (Figure 5a). Higher organic matter consequently will improve particle aggregation so that the BD decreases. Study on Coimbatore soil, Athira et al. (2019) suggested that soil organic matter had a good relationship with bulk density where increasing organic matter lowered bulk density.

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Field capacity moisture content in the upper soil profile of Inceptisols is 50.5% higher than Entisols (Tables 1 and 2). The higher FC of this soil is related to the higher clay content and TSOC. According to Gong et al. (2003), soil water content is positively correlated with clay content. Another study confirmed that higher clay and soil organic carbon content increases soil water content (Olness and Archer, 2005).

In general, the contents of TSOC, TSN, available P, and exchangeable K, Ca and Mg sharply decreased at the first second to fourth depths from the soil surface of Inceptisols and continuously lowered at the following depth. Higher contents of these nutrients at the upper layer might have been associated with the continuous addition of organic matter from crop leftovers, weed biomass, or fertilization. Decomposition of organic matter will eventually release humus, available N, P, and K. Previous research resulted that organic matter decomposition brought about higher microbial activity, organic-C, the concentration of total and available N as well as total and available P (Duong et al., 2013; Mukhtamar et al., 2020; Mukhtamar et al., 2022). A study by Syrlybekkyzy et al. (2014) confirmed that, in general, humus, nitrogen, organic-C, Ca, and Mg decreased at the lower layer of the soil profile. The different trend of exchangeable Ca and Mg in Inceptisols from those in Entisols indicates that both cations in Entisols are affected by the intrusion of salt from seawater due to its closeness to the seashore. The distance of the Entisols is approximately 10 m from the seashore while the Inceptisols is about 1 km; therefore, the effect is negligible.

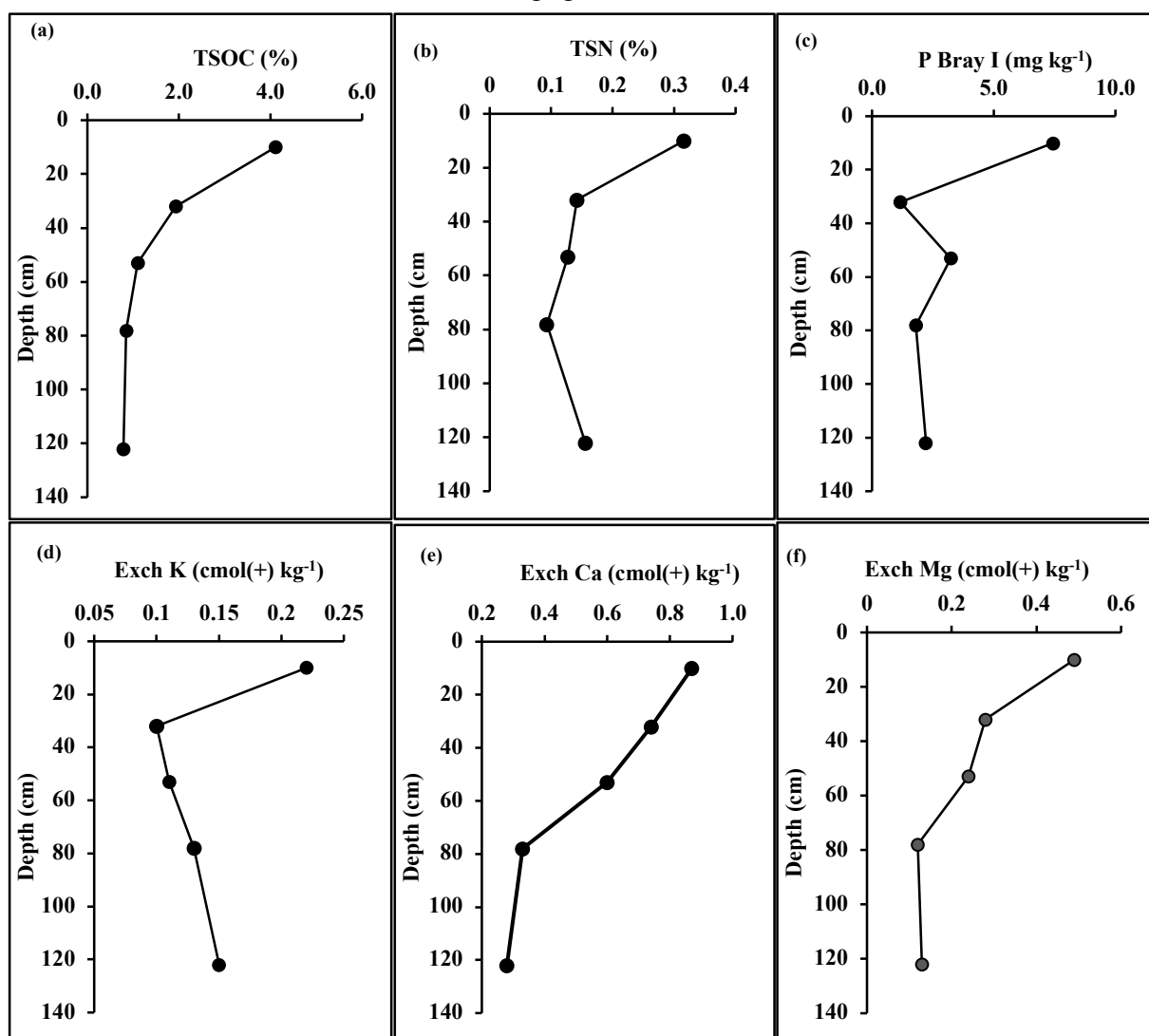


Figure 5. The content of TSOC, TSN, available P, exchangeable K, Ca, and Mg through the depths of Inceptisols.

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Similar to those in Entisols, exchangeable Na and Al were lower at the upper layer of the profile, while available Fe, Mn, Zn, and Cu were higher at the upper one. (Figure 6). A similar trend in the soils indicates that both soils are derived from the parent materials. However, the effect of the seawater is more significant to Entisols than Inceptisols, as noted in the exchangeable Na, Ca, and Mg. The saltwater intrusion will eventually increase the concentration of those cations, especially at the bottom layers of Entisols' profile. The trend of available Fe, Mn, Cu, and Zn in Inceptisols is similar to those in Entisols.

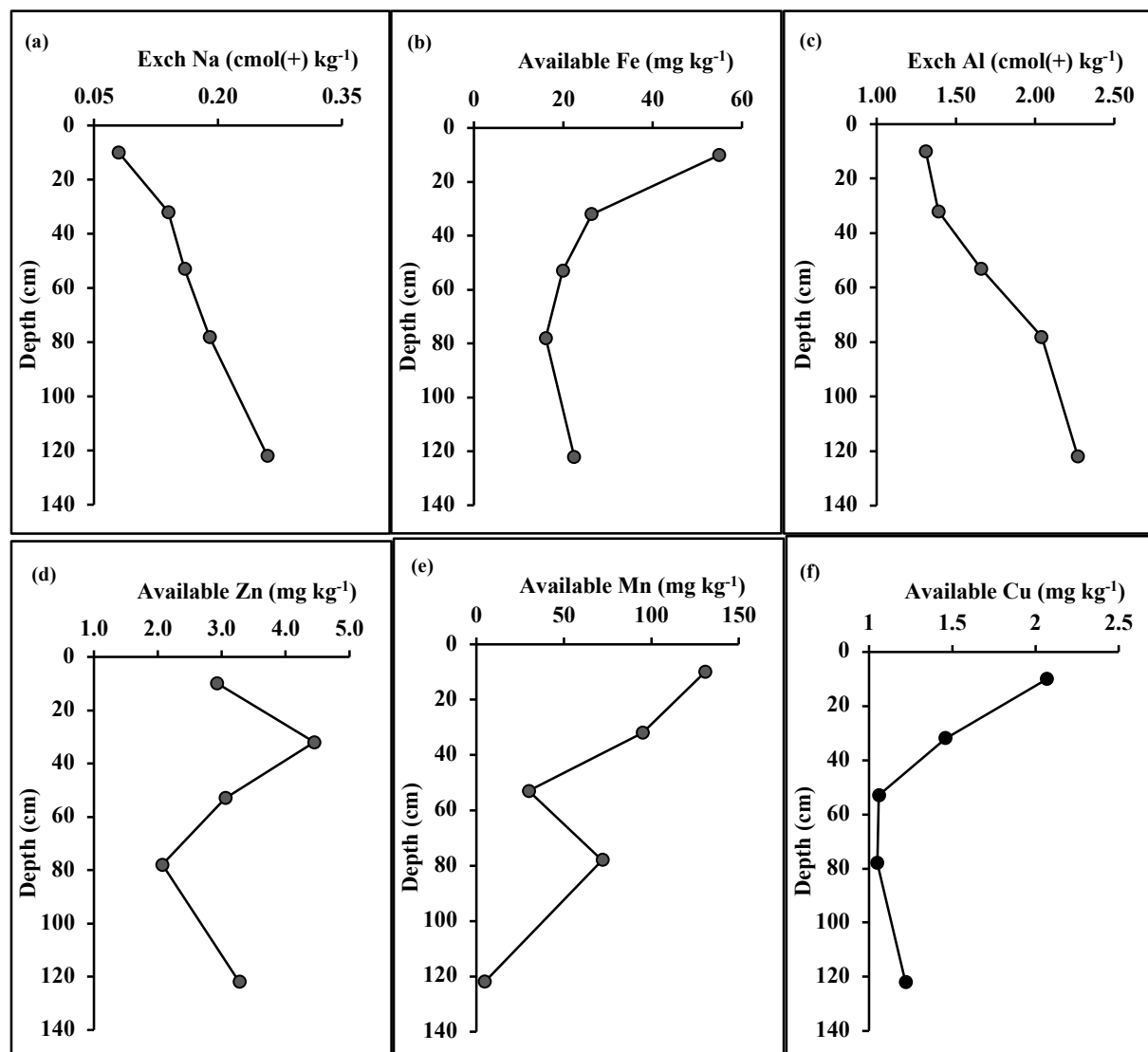


Figure 6. Exchangeable Na, Al, available Fe, Zn, Mn, and Cu as a function of soil depth of Inceptisols

Figure 7a shows that soil pH increases slightly with depths, mainly from the profile's first to the second layer. Lower pH at the upper layer might be attributed to the continuous fertilization of the land, such as synthetic nitrogen fertilizer. Work by Wulandari et al. (2018) concluded that the application of urea on Ultisols lowered the soil pH. Meanwhile, the CEC at the bottom layer increases significantly compared to the previous layers (Figure 7b). This result is associated with the clay content at the bottom layer, which is almost 29% higher (Table 2).

The exchangeable sodium percentage increased with depth, being the greatest at the deepest layer (Figure 7d). The ESP at 94-150 cm depth was approximately double higher than that of the first depth. This trend is related to exchangeable Na, where at the same depth, this cation increased more than two times (Figure 6a). The

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increase in exchangeable Na, Ca, and Mg did not significantly influence the EC of the soil, as shown in Figure 7e.

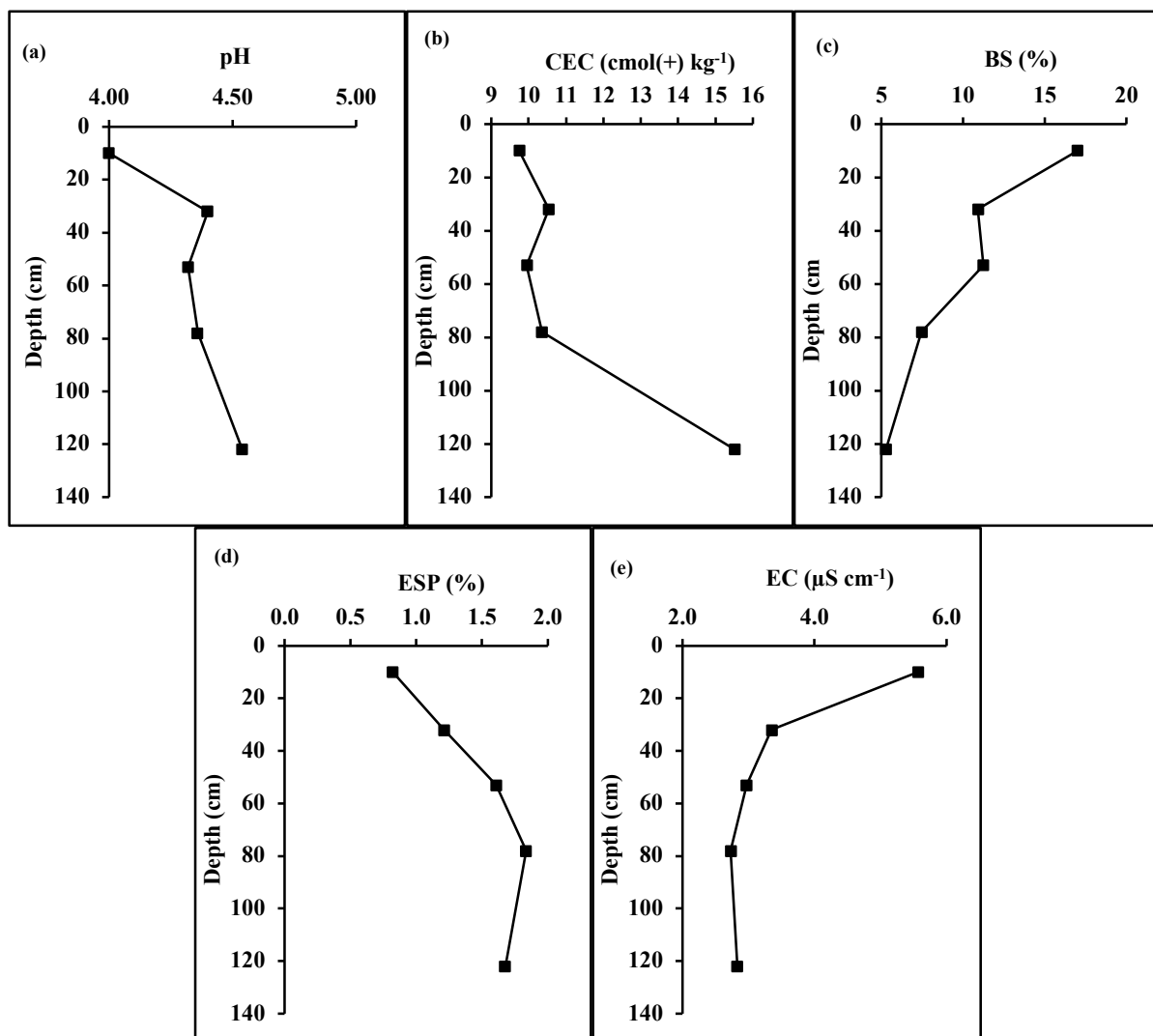


Figure 7. Cation exchange capacity, pH, BS, ESP, and EC at each layer of Inceptisols

Conclusions

The soil in the coastal area of rural Bengkulu was slightly affected by the coastal environment. The influence of the seawater was primarily due to the intrusion of seawater at the bottom layer of Entisols rather than tiding, as indicated by the greater exchangeable Na, Ca, and Mg, as well as ESP. However, the EC of the soil was constantly low throughout the depth of the soil profile and did not closely relate to exchangeable Na, Ca, and Mg. The effect of seawater was more significant on Entisols than Inceptisols since the former soil was closer to the seashore. The EC and ESP of both soils were less than 4 dS m² and 15%, respectively; consequently, both soils are potential for agricultural land expansion.

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