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Changing of Soil Properties under Drought and Saline Water Intrusion Conditions in Different Land-Use Patterns – A Case Study in the Ben Tre Province, Vietnam

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ABSTRACT

The study aimed to assess the change of soil properties of land use patterns affecting drought and saline intrusion in the Ben Tre province during 2019–2020. Soil samples were taken, and the data on land use patterns of Rice, bare soil, Shrimp, and Coconut in three horizons were at 0–20 cm, 20–60 cm, and 60–100 cm. The analysis of soil pH, EC, organic matter, and bulk density was conducted to assess the changes in soil properties. The results showed that soil pH, EC, and salinity had to be slightly increased in 2020, but soil organic matter and bulk density were not changed. Therefore, the Ben Tre province's drought and saline intrusion conditions had a negligible impact in general evaluation. However, it is necessary to perform more other studies to clarify the effects of drought and salinity.

Keywords: climate changes, coastal, impact, vulnerable.

INTRODUCTION

Climate change is considered one of the most concerning topics and essential in impacting sustainable development globally. As a consequence of climate impact change, global natural disasters occur more frequently and with more substantial and severe effects.

Vietnam is one of five countries considered the most vulnerable to climate change (Chaudhry and Ruysschaert, 2007). Due to a long coast and low coastal lands subject to saltwater intrusion, they impacted agricultural production (Zalidis et al., 2002). The farmers in this region lack the facilities and means of self-protection against risks, especially natural disasters related to climate change (Vo Thi Anh Tuyet and Tran Tien Khai, 2022). Because of climate change, more floods or drought, and saline intrusion due to rising sea levels, tens of millions of people may lose their houses (Olsson et al., 2014).

The Vietnamese Mekong Delta (VMD) is the main agricultural production area and the most critical region for rice production in Vietnam, which contributes up to 90% of Vietnam's rice export volume and supplies more than 54% of the national rice production, contributing to 32.3% GDP of VMD in 2016 (Sebesvari et al., 2012). However, this place is the most affected by climate change. Therefore, it is threatening the agricultural production of the Delta and increasingly challenging flood risk and saline intrusion management (Hoang et al., 2018). Mekong Delta covers approximately 1.7 million ha, but about 45% of the delta area was impacted by saline intrusion (Tuan et al., 2014) during the dry season. When flow rates in the Mekong River are at their lowest, especially in April, saline water intrudes into the Delta, causing saline conditions in vast areas of cultivated land (MRC, 2005). In the future, the dry season is expected to be longer and thus negatively affect the water discharge in the river. Given the expansion of the tidal-driven inundation in the coastal plains of the VMD (Tri et al., 2015), it is projected to become more severe, leading to adverse effects on the socio-economic and environmental settings of the coastal areas (White, 1996).

Ben Tre is a province on the east coast of the Mekong Delta with three districts located in the coastal area facing the saline intrusion situation, the agriculture land becoming more severe in the dry season. The dryness and saline water intrusion will change the soil quality (Tully et al., 2019). and affected the land-use efficiency (Khoa, 2013). Currently, drought and saline intrusion are considered to have significantly impacted and hindered agricultural production in the Ben Tre province, affecting the growth and productivity of crops (Nhan and Thuy, 2011). Agriculture in Ben Tre accounts for 76% of the natural land area. However, saline intrusion and drought have occurred in the Ben Tre province over the years, especially from 2015 to 2019 (Mai Xuan et al., 2019). Therefore, it is an important issue and one of the challenges for agricultural management, especially in changing the socio-economic and environmental conditions (Thao and Trung, 2018).

MATERIALS AND METHODS

Experiment details and treatments

The experiments were carried out in three coastal districts of Binh Dai, Ba Tri, and Thanh Phu of Ben Tre province. Soil survey and soil sampling on the four land-use patterns: Rice, Bare Soil, Shrimp, and Coconut from March to April 2019 and 2020. The soil samples were analyzed in the Laboratory of Environment and natural resources College, Can Tho University.

Soil sampling

The soil samples were collected at 4 sites and repeated 3 times on each land use pattern. The soil samples were collected in 3 horizons of 0–20 cm, 20–60 cm, and 60–100 cm. Soil sampling was carried out on four land-use patterns and repeated twice in March 2019 and March 2020. There is a total of 248 soil samples collected for the study.

Soil analysis

The soil samples were analyzed for 4 indicators: EC, pH, soil bulk density, and organic matter.

The soil samples were processed and extracted with an extract ratio of 1:5, then the HACH pH meter 40d PHC 201 SN 183402617826 was used to determine the pH value and EC values.

The soil salinity (NaCl) is determined by the formula:

$$\text{‰ salt in solution (g/L)} = 0.64 \times \text{EC (mS/cm)} \quad (1)$$

Soil bulk density – the pycnometer method was used to analyze the soil bulk density and determined by the formula:

$$\rho^{p} = \frac{Msp}{Vw} \quad \frac{Ms - Me}{(Ms - Me) - (Msw - Mw)} \quad (2)$$

where: ρ^p – soil density (g/cm^3);
M_{sp} – mass of dry soil particles (g);
V_w – the volume of water in the pycnometer is repaced by soil samples (cm^3);
M_e – pycnometer tank volume (clean and dry) with lid (g);
M_s – mass of dry soil + pycnometer tank volume with lid (g);
M_{sw} – pycnometer tank volume tilled with demineralized water + soil (g);
M_w – pycnometer tank volume tilled with demineralized water (g).

Statistical analysis

SPSS 20 statistical software is used to analyze data. DUNCAN test was applied to compare the difference in soil properties among horizons, and the T-test was used to compare the difference in soil properties between the years 2019 and 2020.

RESULTS

Soil pH

The analysis results showed that the pH values have not fluctuated. They varied from 4.97 to 6.65 in 2019 and from 4.78 to 5.98 in 2020 (Table 1). However, most pH values in both two years were not significantly different among horizons for four land-use patterns, accepted in the horizon at 60–100 cm of Rice LUP in 2020 (Table 1 & Figure 1). While comparing LUPs, it was found that pH had almost no difference among LUPs, accepted in horizons at 0–20 cm and 20–60 in 2019 (Table 1). The pH values between 2019 and 2020 were not different; the accepted differences in Shrimp LUPs were statistically significant for both horizons (Table 1 and Figure 3).

Table 1. Comparison of the pH value among horizons and between years of LUPs

Years	Horizons (cm)	Rice	Bare soil	Shrimp	Coconut
2019	0–20	5.88±0.5aAB	5.53±0.39aAB	6.46±0.97aA*	5.3±0.87aB
	20–60	4.97±0.44aC	5.78±0.18aAB	6.65±1.25aA*	5.36±0.58aABC
	60–100	4.98±0.88aA	6.21±0.64aA	5.87±1.42aA*	5.57±0.64aA
2020	0–20	5.96±0.94aA	5.82±0.49aA	5.40±0.30aA	5.64±0.66aA
	20–60	5.68±0.25abA	5.49±0.28aA	5.79±0.26aA	5.72±0.50aA
	60–100	4.78±0.53bB	5.28±0.76aAB	5.46±0.53aAB	5.98±0.68aA

The numbers in columns with different common letters are statistically significant differences at p <0.05% among horizons, and the numbers in a row with different printed letters are statistically significant differences at p <0.05% among LUPs.

The numbers with star (*) are statistically significant difference between 2019 and 2020 in the same horizon by T-test at p <0.05%.

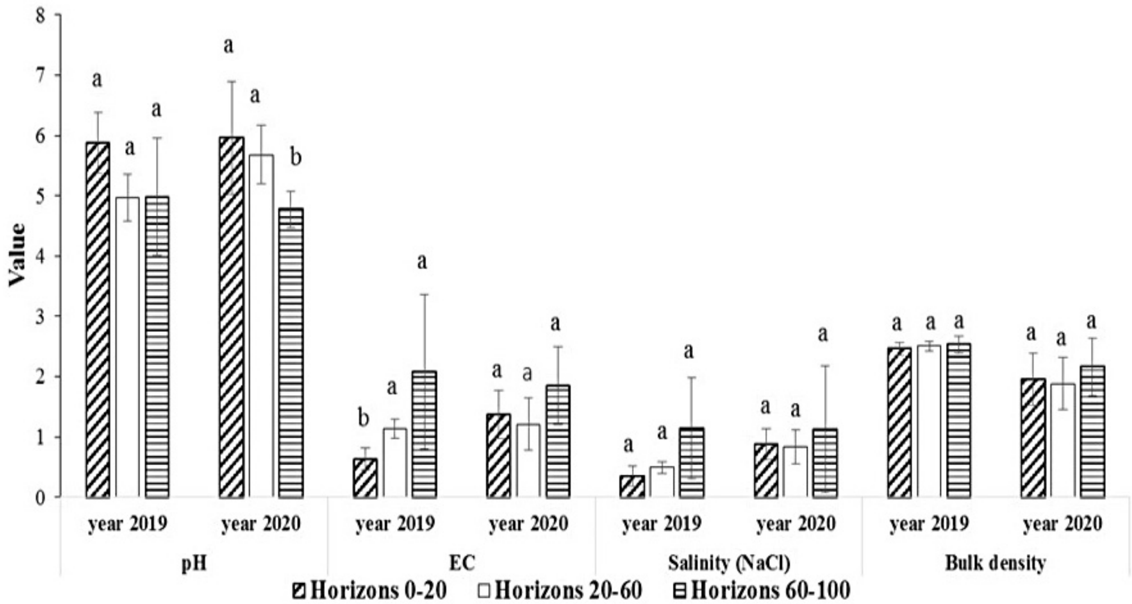

Figure 1. The pH, EC, salinity and bulk density of Rice pattern. The columns value with different letters are statistically significant differences among horizons at p <0.05%, and the columns with an asterisk (*) are statistically significant differences between 2019 and 2020 in the same horizon by T-test at p <0.05%

Soil EC/salinity

The EC value of LUPs in 2019 varied from 0.55 to 2.42 mS/cm and had no difference among horizons, accepted at 0–20 cm of Rice LUP. The horizon had a lower significant difference than two other deeper horizons (Table 2 and Figure 1).

Only EC of bare soil was a lower significant difference than that LUPs of Shrimp for both horizons and Coconut at 0–20 cm and rice at 60–100 cm (Table 2). In 2020, EC varied from 0.49 to 4.19 mS/cm. Only the EC of Coconut LUP at 60–100 cm was a higher significant difference from two other upper horizons (Table 2 and Figure 4). While comparing LUPs, the difference only found in Shrimp LUP was more considerable than other LUPs for both horizons (Table 2). The EC value of LUTs in 2020 increased more than that in 2019, and statistically significant differences, especially the EC value of 4 LUTs, were enormously increased at 60–100 cm (Figure 1, 2, 3 and 4).

The analysis of soil samples conducted in 2019 showed that the soil salinity of LUPs was lower than 2‰. Assessment of salinity among horizons showed no significant difference, except for the Rice LUP at 60–100 cm, which was higher than 0–20 cm and 20–60 cm (Table 3 and Figure 1). However, the soil salinity among LUPs differed from that for most of the horizons. In horizons at 0–20 cm, the LUP of Rice and bare soil was lower than the LUP of Shrimp and Coconut.

Table 2. Comparison of the EC value among horizons and between years of LUPs

Years	Horizons (cm)	Rice	Bare soil	Shrimp	Coconut
2019	0–20	0.63±0.19bB	0.56±0.16aB	2.35±1.28aA	2.0±0.98aA
	20–60	1.13±0.69aAB	0.55±0.27aB	2.42±1.29aA	1.6±1.21aAB
	60–100	2.08±1.14aA	0.59±0.27aB	2.27±1.00aA	1.74±1.1aAB
2020	0–20	1.37±0.40aB	1.1±0.43aB*	3.68±1.64aA*	0.89±0.24bB*
	20–60	1.21±0.29aB*	1.32±0.55aB*	2.94±2.04aA	1.20±0.67bB*
	60–100	1.85±0.53aB*	2.1±0.89aB*	4.19±2.5aA*	3.16±1.35aA*

The numbers in columns with different common letters are statistically significant differences at p <0.05% among horizons, and the numbers in a row with different printed letters are statistically significant differences at p <0.05% among LUPs.

The numbers with star (*) are statistically significant difference between 2019 and 2020 in the same horizon by T-test at p <0.05%.

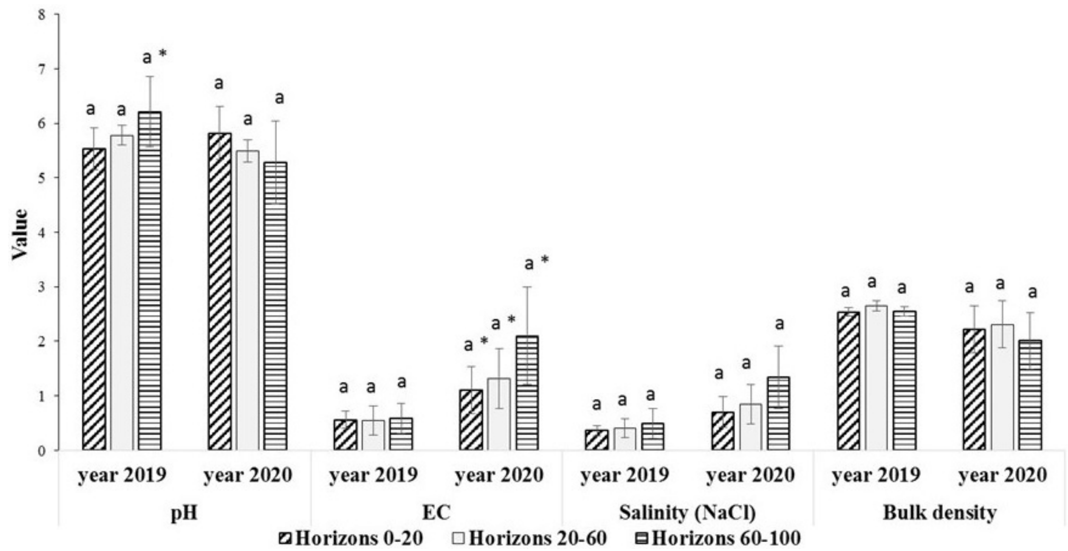

Figure 2. The pH, EC, salinity, and bulk density of bare soil pattern. The columns with different common letters are statistically significant differences among horizons at p <0.05%, and the columns with an asterisk (*) are statistically significant differences between 2019 and 2020 in the same horizon by T-test at p <0.05%.

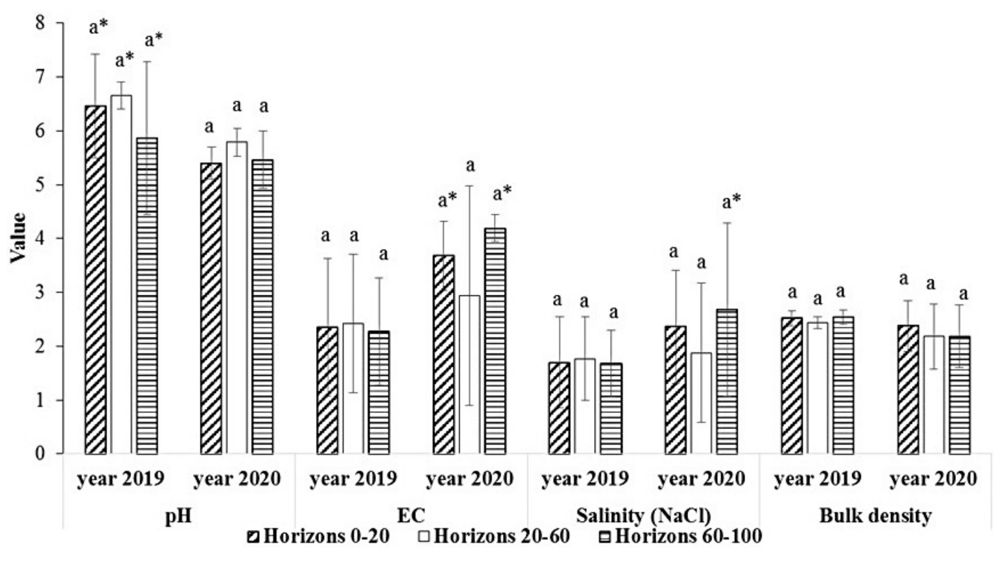

Figure 3. The pH, EC, salinity and bulk density of Shrimp pattern. The columns with different common letters are statistically significant differences among horizons at p <0.05%, and the columns with an asterisk (*) are statistically significant differences between 2019 and 2020 in the same horizon by T-test at p <0.05%

On the horizon at 20–60 cm, the soil salinity of Shrimp LUP was highest and considerably higher than the LUP of rice and bare soil (Table 3). In 2020, the soil salinity was also stable, and no difference among horizons, only the Coconut LUP at 60–100 cm was different from 0–20 cm

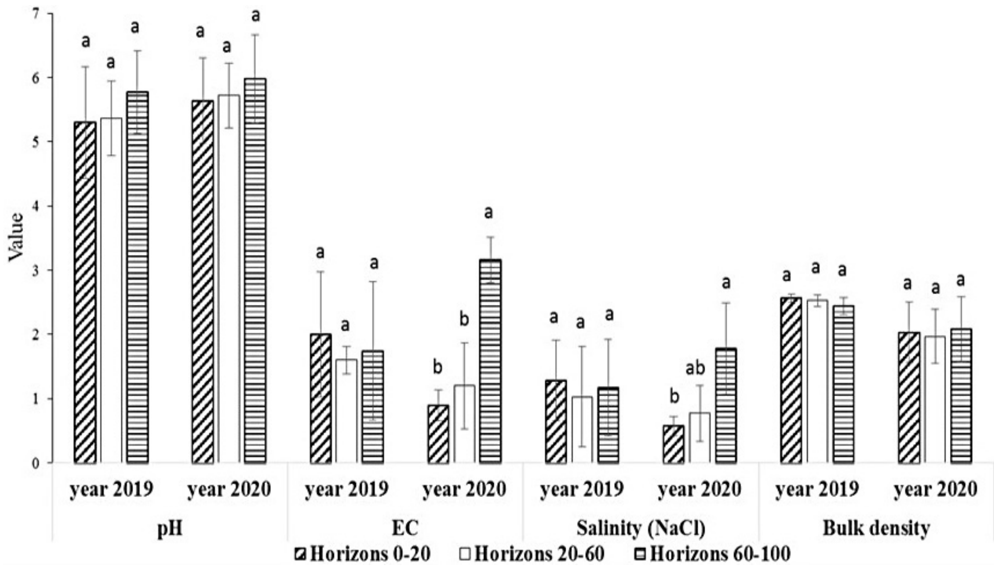

Figure 4. The pH EC salinity and bulk density of Coconut pattern. The columns with different common letters are statistically significant differences among horizons at p <0.05%, and the columns with an asterisk (*) are statistically significant differences between 2019 and 2020 in the same horizon by T-test at p <0.05%

Table 3. Comparison of soil salinity (NaCl) among horizons and between years of LUPs

Years	Horizons (cm)	Rice	Bare soil	Shrimp	Coconut
2019	0–20	0.35±0.17bB	0.36±0.10aB	1.7±0.84aA	1.28±0.63aA
	20–60	0.49±0.12bB	0.41±0.17aB	1.77±0.78aA	1.02±0.78aAB
	60–100	1.15±0.60aAB	0.49±0.27aB	1.67±0.62aA	1.17±0.75aAB
2020	0–20	0.88±0.26aB	0.70±0.28aB	2.36±1.05aA	0.57±0.15bB
	20–60	0.83±0.21aB	0.84±0.36aB	1.88±1.30aA	0.77±0.43abB
	60–100	1.12±0.34aB	1.34±0.57aAB	2.68±1.60aA*	1.78±0.71aAB

The numbers in columns with different common letters are statistically significant differences at p <0.05% among horizons, and the numbers in a row with different printed letters are statistically significant differences at p <0.05% among LUPs.

The numbers with star (*) are statistically significant difference between 2019 and 2020 in the same horizon by T-test at p <0.05%.

Table 4. The soil bulk density (g/cm^3) of land use patterns

Years	Horizons (cm)	Rice	Bare soil	Shrimp	Coconut
2019	0–20	2.46±0.10aA	2.54±0.08aA	2.52±0.14aA	2.57±0.06aA
	20–60	2.51±0.10aAB	2.65±0.09aA	2.44±0.11aB	2.53±0.09aAB
	60–100	2.53±0.07aA	2.55±0.09aA	2.54±0.13aA	2.42±0.13aA
2020	0–20	1.96±0.43aA	2.22±0.43aA	2.38±0.47aA	2.03±0.47aA
	20–60	1.88±0.50aA	2.31±0.43aA	2.18±0.60aA	1.97±0.42aA
	60–100	2.16±0.34aA	2.01±0.52aA	2.18±0.58aA	2.08±0.51aA

The numbers in columns with different common letters are statistically significant differences at p <0.05% among horizons, and the numbers in a row with different printed letters are statistically significant differences at p <0.05% among LUPs.

The numbers with star (*) are statistically significant difference between 2019 and 2020 in the same horizon by T-test at p <0.05%.

and 20–60 cm (Figure 3). To compare LUPs, the Shrimp LUP was the highest level, with a significant difference from 0–20 cm and 60–100 cm of Rice LUP (Table 3). The soil salinity of LUPs and horizons were increased in 2020. However, the significant difference was only found in the horizon at 60–100 cm of the Shrimp LUT (Table 3 and Figure 3).

Soil bulk density

Soil bulk density in both two years did not vary much. It ranged from 2.46 to 2.65 g/cm^3 in 2019 and 1.88 to 2.38 g/cm^3 in 2020. There was no difference between horizons and among LUPs in both two years (Table 4). Soil bulk density in 2020 was slightly decreased compared to 2019, and a significant difference between the years 2019 and 2020 was not found (Table 4 and Figures 1, 2, 3, and 4).

DISCUSSIONS

The soil pH was moderately acid for both LUPs and two years, around 5.3 to 6.65 in 2019 and 5.28 to 5.89 in 2020. Despite the soil meeting saltwater during the flooded time, the drought condition also impacted soil oxidization leading to the moderate acidity of the soil. On the other hand, the impact of drought and saline intrusion conditions during 2019 – 2020 seems to decrease (Mai Xuan et al., 2019; Mai Xuan and Le Tan Loi, 2021).

Soil EC was not different among horizons and LUPs (Table 2 and Figures 1, 2, 3, and 4). However, soil EC was higher than in 2020, showing that drought conditions and saline intrusion affected the soil EC. However, soil EC did not exceed > 2.6, which was not a concern for all LUPs, especially rice LUP (Lam Van Tan et al., 2014).

The impact of drought and saline intrusion on soil salinity was not clarified. The salinity level was only slightly increased in 2020, particularly in the deeper horizons. Extended drought conditions lead to more salinity accumulation in soil (Vo Thi Guong et al., 2014).

Drought conditions and saline intrusion were not affected soil bulk density. Therefore, soil bulk densities were not different. However, soil density depends on the mineral composition and soil structure (FAO, 1976).

CONCLUSIONS

The pH values had no difference among horizons and land-use patterns, and between the years 2019 and 2020, there was almost no difference. However, most of the EC values of LUPs in 2019 and 2020 had significant differences among horizons. The soil EC in 2020 increased more than in 2019. Soil salinity of LUPs had a low concentration. Despite the soil salinity of LUPs and among horizons, most of them were not different. The impact of drought conditions and saline intrusion on the soil pH, EC, and salinity in 2019–2020 was not clarified, with no effect on soil OM and soil bulk density.

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