The properties of soil as impacted by sea level rise in the dry season: A case study of Nonthaburi Province, Thailand

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Abstract. This study contributed to the understanding of the effect of sea level rise on soil properties in the agricultural area during the dry season and the providing of more detailed information needed to improve agricultural practices in the area. Five study sites, which located in Nonthaburi province, were selected according to the disparate distance from Chao Phraya River, comprising tropical fruit orchard (location 1 to 4) and paddy field (location 5). Soil morphology was recorded by the genetic horizon and soil samples were collected at depth of 0-15, 15-30, 30-60, 60-90 and 90-120 cm in March 2018 to analyze soil properties involving to salt affected soils, including Electrical Conductivity ($EC_e$), Sodium Adsorption Ratio (SAR), and soil moisture. Moreover, the correlation between their soil properties was also examined by using SPSS Statistics version 22.0 at p-value < 0.05. The result divulged that all soils are deep, poorly drained, and low development. Soil textures are clayey. $EC_e$ and SAR of these soils ranged from 0.27-4.38 dS m$^{-1}$ and 8.54-37.23, accordingly. The trend of soil moisture from 0-90 cm usually increased as the following depth except location 5. The relationship between $EC_e$ and SAR of these soils at 0-15, 15-30, 30-60, 60-90 and 90-120 cm revealed highly significant correlation, namely, the correlation coefficient ($r$) was 0.93, 0.94, 0.72, 0.77 and 0.86, respectively. These results suggest that sea level rise in the dry season influences on some properties of soil.

1. Introduction
There is a clear demonstration to indicate that climate change has occurred on a broad range of different timescales from decades to many millions of years [1]. An average temperature of Earth has been rising since the Industrial Revolution. From 1880 to 2015, average global surface temperatures increased by 0.9°C [2]. Moreover, the future change projections of global average surface warming were carried out by the Intergovernmental Panel on Climate Change (IPCC) pronouncing that globally averaged surface temperatures would be between 2.5-4.7°C higher by 2100 contrasted with pre-industrial levels [3]. The large-scale hazard of climate change is one of the principal matters confronting the world due to there is strongly affecting for present lives, for future generations, and for ecosystems on which humanity resides [1, 2].

As the result of climate change, sea levels rise (SLR) is directly consistent with the world warms, both because stepping temperatures up induce melting glaciers and ice caps as well as the polar ice sheets and because of the thermal expansion of the oceans [2, 3]. Rates of SLR have accelerated since approximately 1870 [2]. During the 20th century, SLR occurred at an average rate of 1.7 mm per year, and has since hastened to 3.2 mm per year [4, 5]. In addition, the global change in sea level at the end
of the 21st century was projected by IPCC that will therefore most likely be range from 0.63 to 0.98 m [3, 4].

According to the situation of SLR, when seawater has transited into the soil and freshwater systems, especially during high tide of sea level, the crucially various problems have been occurred, for instance, domestic consumption, water supply, aquaculture, and agriculture. In Thailand, the Chao Phraya River has been also affected by SLR from Gulf of Thailand. Consequently, the electrical conductivity value (EC_w) of this river is occasionally increased, particularly in the dry season due to inadequate of freshwater to force seawater influencing the agricultural areas either located adjacent the river or used water from the river straightway. Nonthaburi province is one of the areas faced by the above-mentioned problem. Therefore, the aim of this study was to grasp of the effect of sea level rise on soil properties in the agricultural area during the dry season and supply of more detailed information demanded to improve agricultural practices in the area.

2. Materials and Methods

2.1. Site description

The study sites are located between coordinates (UTM) 1530567 N and 47 0659292 E where designation is Nonthaburi province (Figure 1). There is one of the central provinces of Thailand, which located directly northwest of Bangkok on the Chao Phraya River, covers an area of approximately 622.3 km². Geologically, it is characterized by the Lower Central Plain, whose estuarine sediments were deposited in a complex alluvial and deltaic environment during the Holocene Epoch [6]. Elevation of all study sites is 2 m above sea level. Its climate is classified as tropical savanna, which has an average annual temperature of 27 to 30°C. The rainy season extends between May and October with an average annual rainfall of 903 mm for the Central region [7].

2.2. Soil sampling

Soil samples were taken from five selected locations base on the different distance from Chao Phraya River during the dry season of March 2018. The land uses are mainly tropical fruit orchard such as durian, and mango (location 1 to 4), only one study area is a paddy field (location 5). Soil profiles were described by genetic horizon according to standard field methods [8] at depth of 120 cm and classified as the following Soil Taxonomy [9]. Soil samples were collected by hand auger at depth of 0-15, 15-30, 30-60, 60-90 and 90-120 cm in order to analyze the soil properties related to salt affected soils, comprising Electrical Conductivity (EC_e), Sodium Adsorption Ratio (SAR), and soil moisture.

2.3. Soil preparation and analysis

Soil samples were air-dried at room temperature, gently crushed to pass through a 2 mm sieve. The samples were analyzed for soil chemical and physical properties. Electrical conductivity (EC_e) in saturation paste extracts was measured following the method described by the United States Department of Agriculture (USDA) [10]. The sodium adsorption ratio (SAR) was measured from the saturation extract cations Na^+, Ca^{++} and Mg^{++} by using atomic absorption spectrophotometry [11] and calculated according to the USDA [10] as follows:

\[ \text{SAR} = \frac{[\text{Na}^+]}{\sqrt{[\text{Ca}^{++}] + [\text{Mg}^{++}] / 2}} \]  

where Na^+, Ca^{++} and Mg^{++} are expressed in meq/L. Soil moisture (\(\theta_m\)) was measured by using the gravimetric method, which expressed by percent on weight basis as the ratio of the mass of water present (\(m_w\)) to the dry weight of the soil samples (\(m_s\)) [12] as the following equation:

\[ \theta_m = \frac{m_w}{m_s} \]
2.4. Statistical analysis
The SPSS Statistics version 22.0 was utilized to analyze the correlation between their soil properties, and identified correlation significant at p-value < 0.05. This correlation analysis was performed according to Pearson’s correlation procedure.

Figure 1. Sampling locations for agricultural area in Nonthaburi Province, Thailand.

3. Results and Discussion
3.1. Morphological properties of soils
The typical appearance of soils profiles is shown in Figure 2. All the soil profiles are deep with no rocks discovered within 120 cm depth because of the presence of deep alluvium at each site. Generally, Soil textures are clayey leading to poorly drained demonstrating a 2.5Y to 10YR hue with low chroma colour (≤ 2) in either some or all soil horizons of each study site resulting from the annual reduction/oxidation cycles imposed over many years [13]. These soils are low development due to its horizontal arrangements have been changed by weathering, but not distinctly exhibited to accumulate in subsoil layer. The moisture condition of all soils is aquic moisture regime. According to the soil taxonomy, these soils could be classified as an Aquepts [9].

3.2. Chemical and physical properties of soils
The trend of ECₖ values with depth of all soils from each location is presented in Figure 3a. The ECₖ values of these soils ranged from 0.27-4.38 dS m⁻¹ displaying a substantially considerable variation between locations. However, only location 5 had high ECₖ values of more than 4 dS m⁻¹, which facing at 0-15 and 15-30 cm depth with 4.38 and 4.09 of values, respectively indicating that these soils were affected by salt according to the classification of Brady and Weil [14]. The high ECₖ value in surface soil is caused by the upward movement of saline groundwater under high evaporation [15]. In addition, the ECₖ of location 1 was higher than 2 dS m⁻¹ in some horizons, which was adequate to affect plant growth [14, 15].

Generally, SAR values of these soils varied between locations and also varied within its soil profiles (Figure 3b). The variety of SAR values in these soils was 8.54-37.23. Moreover, this study exposed that all locations possessed SAR values more than 13 in some layers of the soil profiles, clearly stating that these soils were impacted by sodium ion (Na⁺) [14]. This result could be interpreted
that the SAR values of these soils were very high due to either slowly mobile of Na\(^+\) in natural system or the adsorption of Na\(^+\) by clay minerals, especially in clayey texture soils \([16, 17]\).

Soil moisture of each study site is exhibited in Figure 3c. Soil moisture of these soils ranged from 18.88 to 60.87 percent. The tendency of soil moisture from 0 to 90 cm usually increased as the following depth except location 5 where the farmer used to grow the rice under an alternate wetting and drying irrigation. Hence, soil moisture in this area depends upon irrigation management of the farmer.

![Profile development and morphology of soil at each study site with color, and texture indicated (SiC = silty clay, C = clay).](image)

**Figure 2.** Profile development and morphology of soil at each study site with color, and texture indicated (SiC = silty clay, C = clay).

![Depth functions of EC\(_e\), SAR, and soil moisture for the soils in this study.](image)

**Figure 3.** Depth functions of EC\(_e\), SAR, and soil moisture for the soils in this study.
3.3. **The correlation between their soil properties**

Correlation of their soil properties is shown in Table 1. The relationship between EC<sub>e</sub> and SAR of these soils at depth of 0-15, 15-30, 30-60, 60-90 and 90-120 cm revealed highly significant correlation (the correlation value ≥ 0.70), namely, the correlation coefficient (r) was 0.93, 0.94, 0.72, 0.77 and 0.86, respectively.

**Table 1.** Pearson's correlation coefficients of EC<sub>e</sub> and SAR values at the different soil depth.

| Soil depth | EC<sub>e</sub> | SAR |
|------------|--------------|-----|
| 0-15 cm    | -            | 0.93* |
| 15-30 cm   | -            | 0.94* |
| 30-60 cm   | EC<sub>e</sub> - | 0.72* |
| 60-90 cm   | EC<sub>e</sub> - | 0.77* |
| 90-120 cm  | EC<sub>e</sub> - | 0.86* |

* Correlation significant at p-value < 0.05.

4. **Conclusion**

This study investigated the influence of sea level rise on the properties of soil in Nonthaburi province in the dry season base on the different distance from the Chao Phraya River. It could be summarized that sea level rise has affected the concentration of ions in these soils, especially sodium ion explaining by high SAR value. Normally, the direction of EC<sub>e</sub> and SAR values in the subsoil (30-90 cm) was increasing according to the close distance of Chao Phraya River. However, location 5 is located farthest from the Chao Phraya River, but EC<sub>e</sub> and SAR values were actually higher than other locations. This situation may be occurred by the irrigation management of the farmer, which directly using the water from the Chao Phraya River through the branch canal trail. Consequently, sea level rise in combination with irrigation management play the imperative role on the EC<sub>e</sub> and SAR values of these soils. Furthermore, to provide a more complete understanding of the sea level rise on agricultural soil properties for the agricultural management in Thailand, more detailed studies on its influence should be persuaded and investigated further.

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