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# STUDYING SOME PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN CUA TIEU RIVER, TIEN GIANG PROVINCE

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**ABSTRACT**

*This paper reports the results of research on some physical and chemical characteristics of soil in relation to the vegetation of Cua Tieu riverbank in Tien Giang province. There are 6 popular vegetation types: 1) Sonneratia casaeolaris* L.*, 2) Sonneratia casaeolaris* L. *- Nypa fruticans* Wurmb *- Avicennia officinalis* L. *- Kandelia candel* L. Druce, *3) Sonneratia casaeolaris* L. *- Phragmites karka* (Retz.) Trin. ex Steud, *4) Phoenix siamensis Miq., 5) Sonneratia casaeolaris* L. *- Nypa fruticans* Wurmb, *6) Nypa fruticans Wurmb. In the mudflats, soils are not mature, and pioneer vegetation species is usually Sonneratia casaeolaris* L.. *On land accreted for years the soil maturity increases, vegetation species such as Avicennia officinalis* L., *Kandelia candel* L. Druce, *Nypa frutiicans* Wurmb *are present.*

***Keywords:*** physical and chemical characteristics of soil; vegetation along river; alluvial ground; accretion land.

**TÓM TẮT**

***Nghiên cứu đặc điểm lí, hóa học của đất dưới thảm thực vật ven sông Cửa Tiểu tỉnh Tiền Giang***

*Bài báo nêu kết quả nghiên cứu một số đặc điểm lí, hóa học của đất trong mối quan hệ với thảm thực vật ven sông Cửa Tiểu - tỉnh Tiền Giang. Có 6 kiểu thảm thực vật phổ biến: 1) Bần chua (Sonneratia casaeolaris* L.*), 2) Bần chua-Dừa lá - Mấm - Trang (Sonneratia casaeolaris* L. *- Nypa fruticans* Wurmb *- Avicennia officinalis* L. *- Kandelia candel* L. Druce)*, 3) Bần chua - Sậy (Sonneratia casaeolaris* L. *- Phragmites karka* (Retz.) Trin. ex Steud)*, 4) Chà là biển (Phoenix siamensis Miq.), 5) Bần chua - Dừa lá (Sonneratia casaeolaris* L. *- Nypa fruticans* Wurmb)*, 6) Dừa lá (Nypa fruticans* Wurmb)*. Ở các bãi bồi, đất chưa thành thục, loài tiên phong của thảm thực vật thường là Bần chua. Trên đất bồi tụ lâu năm độ thành thục đất tăng, xuất hiện các loài như Mấm, Trang, Dừa lá.*

***Từ khóa:*** đặc điểm lí, hóa học của đất; thảm thực vật ven sông; bãi bồi; đất bồi tụ lâu năm.

## 1. Introduction

According to the report "Master Plan for Socio-Economic Development of Tien Giang Province to 2020" [1], the Tien River stretches through the territory of Tien Giang Province about 120 km long. The two tributaries of Tien River, which are related to Tien Giang province, are the Cua Tieu River, the Cua Dai River and the canal system in the

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province, which is strongly influenced by the uneven tide of the East Sea. The Tien River and its catchment are the main source of irrigation and water supply for Tien Giang province, which is a favorable environment for aquaculture and fisheries development. The Tien River has formed a natural vegetation that functions as a protective and permanent mudflat area, which helps to protect the catchment area, effectively store rainwater from the shore, prevent erosion, replenishment of groundwater, regulation of surface water. In Tien Giang province, in the last 10 years, hydrological and weather conditions have been rather complicated. The situation of natural disasters, floods and cyclones has been continuously occurring, the shortage of fresh water and saline intrusion is quite serious. in the dry season in Go Cong salt-affected area and Dong Thap Muoi alum area in Tan Phuoc district.

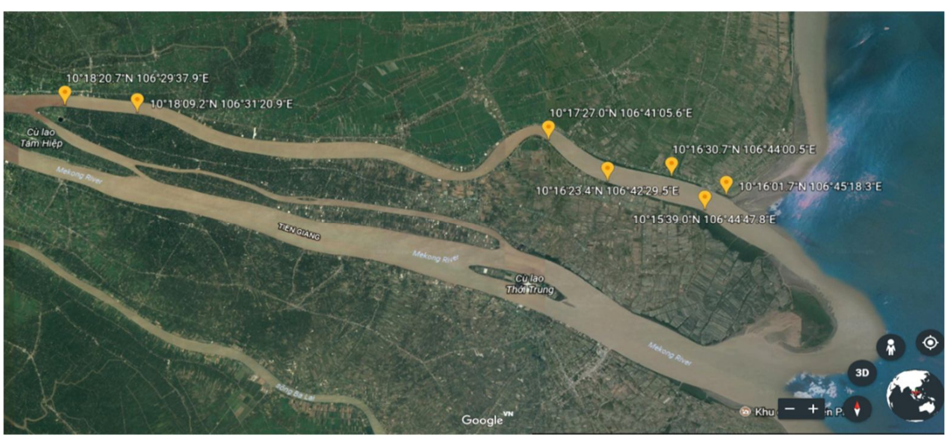
In order to contribute to the supply of data on a number of soil environmental factors under the vegetation along the Tien River, the topic "Studying some physical and chemical properties of soils in Cua Tieu river, Tien Giang province" was made. Research results from the project aim to contribute to the scientific basis in the planning, conservation, utilization and sustainable development of natural resources.

## 2. Research methodology

### *2.1. Object, scope, and time*

- Object and scope: Some physical and chemical properties of soil on the carpet of Cua Tieu river, Tien Giang province.
- Time: August 2016 - October 2017.
- Place:

+ The survey area, data collection vegetation and soil samples, identified 7 survey sites on the Cua Tieu river coastal area of Tien Giang province as shown in *Figure 1*.




***Chú thích***: : survey sites

***Figure 1.*** *Site map of 7 survey sites on Cua Tieu river - Tien Giang province*

+ Coordinate of sampling points:

Point 1: 10 ° 15'30.62 "N - 106 ° 44'57.38" E; by the estuary of Tan Phu Dong district

Point 2: 10 ° 15'58.74 "N - 106 ° 45'21.78" E; river bank at Tan Thanh

Point 3: 10 ° 16'30.13 "N - 106 ° 44'0.61" E; mudflats near the Border Station

Point 4: 10 ° 16'23.44 "N - 106 ° 42'29.52" E; *S. casaeolaris* L. - *N. fruticans* Wurmb (strong landslide)

Point 5: 10 ° 17'26.98N - 106 ° 41'5.61E; *S. casaeolaris* L. - *Phr. karka* (Retz.) Trin. ex Steud (without landslide)

Point 6: 10 ° 17'18.17 "N - 106 ° 41'13.86" E; *S. casaeolaris* L., *A. officinalis* L, *N. fruticans* Wurmb

Point 7: 10 ° 18'20.74 "N - 106 ° 29'37.93" E; *N. fruticans* Wurmb (landslide outside)

+ Location of soil analysis: Laboratory of Plant, Department of Biology - HCMC University of Pedagogy.

### 2.2. Method, technique used

- Conduct three field surveys: in April 2016, October 2016 and June 2017.
- At each site, describe the status of plant species (Pham Hoang Ho, 1999-2003 [2]).
- Criteria for analyzing soil samples:

+ In the dry season (April 2016): $pH_{H2O}$, $pH_{KCl}$; total salt dissolved; conductivity (EC); mechanical components; density; total organic carbon content (OC); $SO_4^{2-}$ content.

+ In the wet season (October 2016): $pH_{H2O}$, $pH_{KCl}$; maturity; total soluble salt, EC.

- Soil analysis method: Soil analysis is done in accordance with guidelines of Institute for Soils and Fertilizers (1998) [3].

Criteria for maturity of land were made on the "fresh soil" sample, other indicators were analyzed on air dried soil samples.

+ Maturity (n): weigh the soil mass before and after drying (to constant mass), calculate the percentage of water content in soil with % solids of soil.

+ Density (d): Determine the volume of water (without $CO_2$) or volume of inert liquid corresponding to the volume of soil taken for analysis.

+ Mechanical composition: pipette method.

+ pH: pH measurement by glass electrodes in soil and distilled water ($pH_{H2O}$) or 1M KCl ($pH_{KCl}$); soil : water = 1: 2.5 (w/v).

+ EC: conductivity measurement in soil and distilled water suspension after shaking 2 hours; soil : water = 1: 5 (w/v).

+ Total dissolved salt: mass method.

+ Organic carbon content (OC): Wakley Black method.

+ $SO_4^{2-}$ conten: sulphate extraction with $CH_3COOH$ buffering solution pH 4.5, soil : solution = 1: 5 (w/v).

### *2.3. Data processing*

Data processing using Excel software, Analysis of Variance (ANOVA) and Least Significant Differential Test (LSD) at probability P $\leq$0.05 by MSTATC software.

## 3. Results

### *3.1. Morphological profile of the soils under Cua Tieu river vegetation*

There is no clear distinction between layers between different survey sites and at the same site. Because this is alluvial ground, the nature is new alluvial soil, structure is quite homogeneous. The results of 15 soil profiles showed that the soil layers were quite similar in color; however, there are some differences:

- In the deep layers, the soil color is darker. The land is submerged more frequently, darker than the less submerged land. Land near the river bank is submerged more frequently, most of the land is reduced. Land far from the river is heavily influenced by tides, with alternating periods of dry and flooding, so oxidation and de-interlacing processes. Under the *Nypa frutiicans* Wurmb vegetation the land is less water flooded, so the colors are brighter, the structure tighter than the soil under the other vegetations.

- The upper soil layer has higher humidity due to frequent flooding. The sites closer to estuary have more wetlands, higher soil humidity compared to the sites far from estuary.

According to Do Dinh Sam (2006), the land near estuary has the youngest age, so in the soil profile there is no formation of layers. The differences in color, grain composition, content of alkaline cations exchanged from topsoil to deep layers depend mainly on sedimentation processes, sedimentation of sediment in the coastal zone. This means that geological processes are more influential than land-formation processes [4].

### *3.2. Physical and chemical properties of the soils under Cua Tieu river vegetation*

***Table 1.*** *Physical and chemical properties of the soils under Cua Tieu river vegetation - Tien Giang province*

| Vegetation | Soil layers (cm) | Mechanical composition | Maturity (n) | Density | EC (mS/cm) | | Total dissolved salt (‰) | | Acidity | | | | $SO_4^{2-}$ soluble (%) | OC (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | $pH_{H2O}$ | | $pH_{KCl}$ | | | |
| | | | | | Dry season | Rainy season | Dry season | Rainy season | Dry season | Rainy season | Dry season | Rainy season | | |
| *S. casaeolaris* L. | 0-30 | Clay loam | Soft Clay clay | 2.91 | 4.59 | 1.45 | 14.69 | 4.65 | 6.7 | 7.1 | 6.4 | 6.8 | 0.235 | 1.16 |
| | 30-60 | loam | Clay | 3.13 | 4.36 | 2.27 | 13.95 | 7.27 | 7.1 | 7.2 | 6.7 | 6.8 | - | 1.14 |
| *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce | 0-30 | Clay loam | Clay | 2.98 | 4.31 | 1.46 | 13.80 | 4.67 | 6.9 | 6.9 | 6.5 | 6.6 | 0.206 | 0.95 |
| | 30-60 | Clay loam | Clay | 3.08 | 4.10 | 2.39 | 13.12 | 7.63 | 6.9 | 6.7 | 6.5 | 6.4 | - | 1.21 |
| *Phoenix siamensis Miq.* | 0-30 | Loamy clay | Sét cứng | 3.03 | 5.32 | 0.43 | 17.01 | 1.39 | 5.8 | 6.8 | 5.3 | 6.1 | 0.058 | 1.49 |
| | 30-60 | Loamy clay | Hard clay | 3.23 | 4.52 | 0.63 | 14.45 | 2.02 | 5.1 | 6.7 | 4.5 | 6.3 | - | 1.32 |
| *S. casaeolaris* L. - *Phr. karka* (Retz.) Trin. ex Steud | 0-30 | Clay loam | Clay | 3.09 | 4.01 | 0.49 | 12.82 | 1.58 | 7.4 | 6.8 | 7.0 | 6.1 | 0.208 | 1.08 |
| | 30-60 | Clay loam | Clay | 3.19 | 4.41 | 1.74 | 14.10 | 5.57 | 6.8 | 6.9 | 6.4 | 6.3 | - | 1.40 |
| *S. casaeolaris* L. - *N. fruticans* Wurmb | 0-30 | Clay loam | Soft clay | 2.23 | 1.16 | 0.42 | 3.70 | 1.36 | 6.4 | 6.6 | 5.7 | 6.1 | 0.100 | 1.11 |
| | 30-60 | Clay loam | Clay | 2.68 | 0.99 | 0.91 | 3.16 | 2.91 | 6.3 | 6.1 | 5.6 | 5.6 | - | 1.05 |
| *N. fruticans* Wurmb | 0-30 | Loamy clay | Clay | 3.00 | 2.21 | 0.52 | 7.07 | 1.67 | 6.5 | 6.7 | 5.8 | 6.2 | 0.127 | 0.96 |
| | 30-60 | Clay loam | Clay | 3.03 | 2.05 | 0.50 | 6.56 | 1.61 | 5.9 | 6.6 | 5.4 | 6.4 | - | 0.98 |

*3.2.1. Soil mechanic composition*

The analysis results of soil samples presented in Table 1 shows that there is no difference in classification of soil mechanic components between two soil layers at each site. Particularly for *N. fruticans* Wurmb, the second layer is clay, while the first layer is loam clay.

The soil in the study area of Cua Tieu river in the study area was of heavy mechanical composition - high content of loam and clay - clay loam and loam clay types. The soils under vegetation such as *S. casaeolaris* L., *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce, *S. casaeolaris* L. - *Phr. Retina*. Trin. ex Steud and *S. casaeolaris* L. - *N. fruticans* Wurmb are clay loam. The soil mechanical composition of the clay loam is quite suitable for mangroves as *S. casaeolaris* L. grows. For *Phoenix siamensis* Miq. and *N. frutiicans* Wurmb vegetation, the ratio of sand in the soil is very low, the soil is of clay type. Under each vegetation, the difference in soil mechanical composition between the 0-30 cm layer and the 30-60 cm layer is almost negligible.

According to Do Dinh Sam (2005, 2006), with high content of loam and clay, soil has good nutrient and water storage capacity. Therefore, the soil mechanical composition under the vegetation in the study area as mentioned above may be one of the natural conditions for mangrove forests grow medium to good [4], [5].

*3.2.2. Soil maturity*

Applying the soil maturity levels according to Do Dinh Sam et al. (2005, 2006) [4], [5], the soils under the vegetation at the survey sites has the value n (soil maturity) in the range of 0.53-1.19, the soil is sorted hard clay, clay and soft clay.

In the soil first layer, the soil under *Phoenix siamensis* Miq. is most mature, value n: 0.58 is hard clay. The least mature soil is under *S. casaeolaris* L. (n: 1.15) and under *S. casaeolaris* L. - *N. fruticans* Wurmb (n: 1.19), soft clay. Under the other vegetations in the form of clay, relatively mature. The results on the second layer are similar to those in the first layer, *Phoenix siamensis* Miq. vegetation has the most mature soil, value n: 0.53, hard clay; difference is statistically significant compared to soil under 5 remaining vegetations. In other words, except the *Phoenix siamensis* Miq. grows on hard clay with high maturity, the remaining vegetations on slightly less maturity clay.

Comparison of the two soil layers under each type of vegetations showed that the soil under vegetations such as *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L, *Phoenix siamensis* Miq., *S. casaeolaris* L. - *Phr. karka* (Retz.) Trin. ex Steud and *N. fruticans* Wurmb have same maturity between two layers. In the soils under *S. casaeolaris* L. and under the *S. casaeolaris* L. - N. fruticans Wurmb, the soil maturity increased with depth, so that the soil was soft clay on the first layer, down to the second layer as clay. In general, the soils under survey vegetations - soft clay and clay - are favorable for mangroves to develop [6].

For the soil under *S. casaeolaris* L. vegetation, the site near the water edge, has high depositional sediment and is under the influence of tides. The soil here is quite young so the profile is rather homogeneous, not divided into distinct layers. Regular wetlands should be light brown to dark gray. The upper layer is moist and the bottom layer is quite flexible, with sand particles. The soil under *S. casaeolaris* L. is not mature, the upper layer is soft clay and the lower layer is clay. The soil under *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce has relatively good maturity, in the form of clay. The mechanical composition of clay loam is quite suitable for mangrove such as *S. casaeolaris* L., *N. fruticans* Wurmb, *A. officinalis* L. and *K. candel* L. Druce.

*Phoenix siamensis* Miq. is a tree in the mudflats that only submerged at high tide, growing in small groups. According to Hoang Van Thoi [8], *Phoenix siamensis* Miq. Distributed in the form of land near maturity to maturity and distributed at salinity of 30-35 ‰. At the survey site with *Phoenix siamensis* Miq. vegetation, the soil was light brown to dark gray, with a lighter color than the soil under *S. casaeolaris* L. and *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce due to this position is less submerged. The soil is quite smooth, the division into layers is not clear. The soil is quite mature, hard clay. The background soil under *Phoenix siamensis* Miq. being higher, hard and mature is suitable for the development of *Phoenix siamensis* Miq..

In short, the further intoland the terrain is gradually raised and the soil structure becomes tight and stable, the soil has thick silt layer. The dominant group of plants is *S. casaeolaris* L. but also there are other species such as *N. fruticans* Wurmb, *A. officinalis* L. and *K. candel* L. Druce. However, these species have to stand to relatively high salt concentrations in brackish water estuaries as well as salt fluctuations between different seasons.

*3.2.3. Soil density*

In the same vegetation, the density of soil in the 30-60 cm layer was higher than that of the 0-30 cm layer, except under *N. fruticans* Wurmb vegetation. According to the Vietnam Association of Soil Science (2000) [9], the density of lower soil layers are usually higher compare to surface soil layers due to the sedimentation deposition of heavy materials to the lower soil layers and the organic matter content in the lower soil layers is often lower compare to surface soil layers.

Considering among the survey vegetations, the soils under *Phoenix siamensis* Miq. (1st layer: d = 3.03, 2nd layer: d = 3.23) and the soil under *S. casaeolaris* L. - *Phr. karka* (Retz.) Trin. Ex Steud (1st layer: d = 3.09, 1st layer: d = 3.19) have the highest density, the soil under *S. casaeolaris* L. - *N. fruticans* Wurmb has the lowest density (1st layer: n = 2.23, 2nd floor : 2.68); these results are statistically significant. The difference in soil density among the soils under vegetations such as *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce, *N. fruticans* Wurmb and *N. fruticans* Wurmb were not statistically significant.

In general, the soil idensity in the study areas is quite high. The solid content of soil depends on the mineral and chemical composition, the density of the humus soil and density of layer below humus soil layer are lower the upper soil layer. The density of some Vietnamese soil types ranges from 2.3-2.9, most of soils has a density of 2.5-2.7 [3]. According to the Vietnam Association of Soil Science [9], the density of main soils in Vietnam varies from 2.49-2.88, of which Fluvisols has a density of 2.62-2.68.

*3.2.4. Electric conductivity and total dissolved salts in the soil*

In the study sites, the highest soil EC was 5.32 mS/cm under the *Phoenix siamensis* Miq. and the lowest is 0.42 mS/cm under the *S. casaeolaris* L. - *N. fruticans* Wurmb in the dry season (Table 1).

- In the dry season: In the first layer (0-30 cm), the highest EC value was recorded in the soil under *Phoenix siamensis* Miq. (EC: 5.32 mS/cm) significantly higher than all other sites, and lowest in *S. casseus* L. - *N. fruticans* Wurmb (EC: 1.16 mS/cm). In the second layer (30-60 cm), the highest EC value remains in *Phoenix siamensis* Miq. (EC: 4.52 mS/cm), statistically significant difference compared to *S. casaeolaris* L. - *N. fruticans* Wurmb and *N. fruticans* Wurmb; however, not different from *S. casaeolaris* L., *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce and *S. casaeolaris* L. - *Phr. karka* (Retz.) Trin. ex Steud.
- In the rainy season, the first soil layer under *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce has the highest EC (1.46 mS/cm), was not significantly different from *S. casaeolaris* L. but significantly different from that of the other five remaining vegetation types. The soil of *S. casaeolaris* L. - *N. fruticans* Wurmb has the lowest EC (0.42 mS/cm). Similarly, in the second soil layer, the highest EC value is observed in *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce (2.39 mS/cm), not different from *S. casaeolaris* L. but significantly different from soil under 5 remaining vegetation. The soil under *N. fruticans* Wurmb has the lowest EC value (0.5 mS/cm).

Based on the soil salinity classification according to the EC value documented by the Institute for Soils and Fertilizers, [3] and some of the literature disseminated abroad [10], [11] the salinity of the soil under survey sites was divided into levels from non-salinity to high-salinity. In which, the vegetations are infected with heavy salinity in the dry season include: *S. casaeolaris* L.; *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce; *N. fruticans* Wurmb and *S. casaeolaris* L. - Phr. *karka* (Retz.) Trin. ex Steud. In particular, the *S. casaeolaris* L. - *Phr. karka* (Retz.) Trin. ex Steud is far from estuary than *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce, *S. casaeolaris* L. and *Ph. siamensis* Miq. so the soil salinity is lower. Medium salinity soil under *N. fruticans* Wurmb, mildly salinized soil under *S. casaeolaris* L. - *N. fruticans* Wurmb.

At a site under each vegetation types, the salinity in the two soil layers (0-30 cm, 30-60 cm) is almost the same. The salinity of the two layers in the rainy season is reduced compared with dry season, the second layer is more salty than the first layer; except the soil under *Ph. siamensis* Miq. and *N. fruticans* Wurmb are not salty. On the surface layer, there are two medium-saline soils (under S. casaeolaris L. and *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce), two non-saline soils (under *Ph. siamensis* Miq., *S. casaeolaris* L. - *Ph. karka* (Retz.) Trin. ex Steud, *S. casaeolaris* L. - *N. fruticans* Wurmb and *N. fruticans* Wurmb). In the lower layers (30-60 cm), the soils under *S. casaeolaris* L. and *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce is of high salinity. The medium-saline soil is under *S. casaeolaris* L. - *Phr. karka* (Retz.) Trin. ex Steud. The soil under *S. casaeolaris* L. - *N. fruticans* Wurmb is slightly salty. Non-saline soil under *Ph. siamensis* Miq. and *N. fruticans* Wurmb.

The results of the analysis of the total dissolved salt content of the soil in the study area ranged from 6,56-17,01‰ in the dry season; 1,36-7,63% during the rainy season. In the dry season, the soils under *S. casaeolaris* L., *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce, *Ph. siamensis* Miq. and *S. casaeolaris* L. - Phr. *karka* (Retz.) Trin. ex Steud are very salty; the soil under *N. fruticans* Wurmb is medium salty; the one is *S. casaeolaris* L. - *N. fruticans* Wurmb little salty. During the rainy season, the soils under *S. casaeolaris* L. and *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce are low salinity to medium salinity, under others vegetation types the soils are light saline or non-saline (except 2$^{nd}$ soil layer under *S. casaeolaris* L. - *Phr. karka* (Retz.) Trin. ex Steud is medium saline). The land under *S. casaeolaris* L. - *N. fruticans* Wurmb is quite inland so that soils are less saline than other sites. The vegetation cover is *S. casaeolaris* L. and *N. fruticans* Wurmb, which shows that these two species are widely distributed and tolerant to wide salinity fluctuations.

According to Hoang Van Thoi, *S. casaeolaris* L. is distributed in saline soils with a salinity of 25-35 ‰ [8], indicating that S. casaeolaris L. is suitable for broad salt amplitude variation.

*N. fruticans* Wurmb live in low salinity water streams and on a depth of no more than 200 m, where less hard clay is more suitable for them than for hard ground sites. Phan Nguyen Hong (1990) suggested that the *N. fruticans* Wurmb species is a narrow species of salt, and is therefore considered to be a typical brackish water species. *N. fruticans* Wurmb is located at the soil salinity of 24.3 - 36.5 ‰; however, it is suitable at salinity of 28.5 - 33.5 ‰ [7]. *N. fruticans* Wurmb vegetation was at the deepest inland position in the survey sites; as a result, the soil at this site is less saline than other sites.

K. candel L. Druce grows on sandy soils along the river with varying salinity; usually mixed with mangrove [12]. According to Hoang Van Thoi, K. candel L. Druce is present at salinity soil of 25-40 ‰ and grows on mature and semi-mature soils. The distribution of *A. officinalis* L. species was broad in saline magnitude 19.8-45 ‰, however, suitable for salinity of 27.2 ‰. A. officinalis L. is a species of high salinity tolerance (25-35 ‰), widely distributed in all tidal areas [8]. Considering the variation and seasonal variation, the result of soil total amount of dissolved salts under the servey vegetations has the same pattern as the result of soil EC as noted above. There is a linear correlation between the total dissolved salts in the soil and the conductivity of the extracted water with distilled water [3].

Joschi and Ghose (2003) investigated the relationship between forest structure and species distribution across the pH range and salinity of the soil in the Sundarbans mangroves, India. The study showed that the salinity of the soil decreased (13.0-31.3 ppt) with the increasing distance from the tidal coastline, but that trend did not appear for soil pH (7.0-7,9). The authors suggest that the frequency of flooding affects the salinity of the soil [13]. In addition, the increase in sea level affects the current salinity intrusion and mangrove forests are most affected. Tidal dynamics affect the distribution of salinity and groundwater flow [14]. The major difference between mangroves is due to soil pH, salinity, cation exchange capacity, nutrients, carbon and organic matter of the mangroves. Recent findings show that different soil properties affect vegetation, species composition and mangrove structure [15].

*3.2.5. Soil acidity*

The soil pH values at the survey sites change in soil layer and by season; the highest pH value was 7.4 and the lowest was 5.1; $pH_{KCl}$ is lower than $pH_{H2O}$, fluctuating between 4.5-7.0.

- In the dry season, the 0-30 cm soil layer has the lowest pH value under *Ph. siamensis* Miq. (pH: 5.8), significantly different from soil in the other 5 vegetation types. The highest $pH_{H2O}$ value is in the *S. casaeolaris* L. - *Phr. karka* (Retz.) Trin. ex Steud (pH: 7.4). In the 30-60 cm soil layer, the lowest $pH_{H2O}$ is observed in the *Ph. siamensis* Miq. (pH: 5.1), significantly different from the soil in the remaining 5 vegetation types. The soil under *S. casaeolaris* L. has the highest pH value (pH 7.1). At each survey site, soil pH of upper layer tends to be higher than that of the lower layer.
- In the rainy season, on the 0-30 cm layer the lowest soil pH is 6.6 (*S. casaeolaris* L. - *N. fruticans* Wurmb) and the highest is 7.1 (*S. casaeolaris* L.). On the 30-60 cm layer, the lowest soil pH is 6.1 (*S. casaeolaris* L. - *N. fruticans* Wurmb) and the highest was 7.2 (*S. casaeolaris* L.). In the rainy season, the difference in soil pH between study sites is not significant; the pH values between the two soil layers are almost the same.
- The soil acidity in the study sites ranges from acid, slightly acid to neutral, almost of plants are able grown well under this pH condition. Depending on the type of vegetation, seasons and soil depths, the soil pH value varies and the difference is statistically significant. In particular, there is a change in the pH value of land by season (dry season, rainy season). According to Le Tan Loi (2011), during the dry season, the soil receives more oxygen, which increases the oxidation leading to lower pH. In the wet season, the pH is diluted by precipitation and surface runoff leading to higher pH. Higher inland areas are drier and more acidic than riverine land (Tam and Wong, 1997 - cited by Le Tan Loi, 2011 [6]). Other studies have suggested that most wetlands have a neutral pH (6.5-7.5) (Gambrell, 1994, Mitsch and Gosselink, 2000 - cited by Le Tan Loi, 2011) [6].

*3.2.6. Soil soluble $SO_4^{2-}$ content*

The $SO_4^{2-}$ percentage highest (0.235%) is in the soil under S. casaeolaris L. vegetation, the lowest is in Phoenix siamensis Miq. (0.058%).

Soil $SO_4^{2-}$ content under S. casaeolaris L. compared with soils under *Phoenix siamensis* Miq., *S. casaeolaris* L. - *N. fruticans* Wurmb and *N. fruticans* Wurmb is statistically different; but not statistically different from the soils under *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce and *S. casaeolaris* L. - *Phr. karka* (Retz.) Trin. ex Steud.

According to Do Dinh Sam (2006) [4], soils in mangrove have $SO_4^{2-}$ contents as follows:

- At estuary areas: $SO_4^{2-}$ (%): 0.05-0.33
- In mudflats: $SO_4^{2-}$ (%): 0.66-2.12

*3.2.7. Soil organic carbon contents*

The organic carbon content (OC) in soil varies in range 0.95-1.49%, belonging to from poor to medium levels [9]. The soil at the vegetation cover *S. casaeolaris* L. and *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce - the pioneer plants, appearing in the mudflats with frequent saline intrusion - contains organic carbon content in the range of 0.95-1.21%. According to Do Dinh Sam (2005, 2006) most suitable for growing forest is the soil containing organic carbon content of 2-8% [4], [5].

Considering the organic carbon content of the two soil layers (0-30 cm, 30-60 cm) below each vegetation, there is a marked difference and no rule. Among the different vegetation types, the organic carbon content of the soil differs mainly in the 0-30 cm soil layer, while that does not differ in the 30-60 cm soil layer.

## 4. Conclude

- Soil under vegetation cover in the study area (1) *S. casaeolaris* L., 2) *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce, 3) *S. casaeolaris* L. - *Phr. karka* (Retz.) Trin. ex Steud, 4) *Ph. siamensis* Miq., 5) *S. casaeolaris* L. - *N. fruticans* Wurmb, 6) *N. fruticans* Wurmb) have a rather high density, heavy mechanical composition - high content of loam and clay, belong to clay loam soils and loam clay soils. Those soils are mostly clay and soft clay soils that suitable for the development of mangrove forests.

- Soil salinity varies greatly between rainy and sunny seasons, the distance from the estuaries and coastal edge, the height of the area and the depth of the soil. During the dry season, most of the survey sites were seriously affected by salinity. In the rainy season, except for the soils under *S. casaeolaris* L. and *S. casaeolaris* L. - *N. fruticans* Wurmb - *A. officinalis* L. - *K. candel* L. Druce. Salinity are still saline and medium salinity; at the remaining vegetations (*S. casaeolaris* L. - *Phragmites karka* (Retz.) Trin. ex Steud, *Phoenix siamensis Miq*., S. *casaeolaris* L. - *N. fruticans* Wurmb, *N. fruticans* Wurmb) the soil salinity reduces to medium and non salinity.

- The acidity of the soil at the surveyed sites is low and near to neutral, during the dry season, the soil pH decreases compared to the rainy season. Soil soluble sulphate content in soil is at low level, soil is not contaminated with alum.

- The content of soil organic carbon is poor to medium, without significant difference in content of soil organic carbon between the different 6 survey vegetation types.
- It is necessary to assess the ecological adaptability of plants to the climate, hydrology and soil conditions of the study area in order to predict and evaluate the impacts of climate change on the change of the habitat, soil chemistry and vegetation.

❖ ***Conflict of Interest:*** *Authors have no conflict of interest to declare.*

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