Organic Carbon in Wetland Soil: Seasonal Flooded Forest, Northeastern Thailand

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ABSTRACT

Seasonal flooded forest is one of the most important wetlands in northeastern Thailand, not only for its abundant biodiversity, but also as a source of carbon sequestration. Organic carbon plays an specially important role in the soil carbon cycle. To reinforce comprehension on soil organic carbon, five profiles in a northeast plateau were observed and determined. The most common trees were *Albizzia Odoratissima*, *Combretum quadrangulare Kurz*, and *Streblus asper Lour*. The contents of Soil Organic Carbon (SOC) varied from 3.52 g/kg to 5.90 g/kg in top soil and varied from 4.01 g/kg to 4.60 g/kg in sub soil. There was a close relationship between SOC content and basic soil properties, especially the bulk density of both top soil layer and sub soil layer. The distribution of SOC content was harmonized with distribution of plants. In comparative analysis, the flooded forest that composted with a high percentage of vegetation coverage (Khud Tew, Khud Chi Tao) had a significantly higher SOC content. The SOC storage varied from 2.65 kg/m^2 to 4.18 kg/m^2. Khud Chi Tao contained the maximum amount of SOC storage, whereas Kwo Chi Yai had the minimum. Limitation of flooded forest survival concerned over landscape change, particularly plant disappearance and waterlogged shortage. Therefore, vegetation and hydrology management have to be implemented practically to retain the existing organic carbon in wetlands and allow the soil to sequester additional carbon.

1. INTRODUCTION

One of the most important wetland ecosystem services is carbon sequestration. it is worth emphasizing that, in wetland landscapes, all components are continually interacting with ecosystems (Chaikumbung et al., 2019). Wetlands have mostly been recognized as the transitional zones that fall between terrestrial and aquatic ecosystems and are highly productive. They are characterized by waterlogged conditions with a low decomposition rate of organic material and impact the wetland creation on carbon stocks. Wetlands are also known to be an important component of the global carbon cycle (Moomaw et al., 2018). Although wetlands occupy only 6% of the earth's surface but is one of the most important parts of terrestrial ecosystems and the largest carbon pool (Stolarski et al., 2018). However, the complexity of the wetland carbon cycle causes difficulty in estimating the wetland carbon pool. Soil organic carbon (SOC) is one of the keystone elements in controlling soil properties. It enables soils to be resilient against extended droughts and extreme rainfall events, especially in wetlands. Generally, wetlands contain a disproportionate amount of the earth's total soil carbon which holding between 20 and 30% (Ren et al., 2020). The global soil organic carbon stock in wetlands is uncertain, ranging from 202 to 535 Pg C (Mitra et al., 2005). The SOC content in wetland soils is also affected by natural conditions and human activities (Ma et al., 2015), which play a key role in the global Carbon cycle and how much organic carbon remains in wetlands. SOC is a reservoir in the terrestrial ecosystem and it maintains soil properties such as organic matter, and it is critical in tackling climate change because of its carbon storage capacity (Lal et al., 2018). Soil properties play a key role in soil

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carbon accumulation and transformation (Sims et al., 2012). During the management of wetlands, we should pay attention to the original SOC content before wetland cultivation, as well as the balance of SOC inputs and outputs during the wetland cultivation process. In addition, other soil properties, such as pH, total nitrogen, and bulk density, should be considered due to their close correlation with SOC (Xu et al., 2019). The 12th session of Conference of Parties (COP 12) aspires to increase global soil organic matter stocks as a compensation for the global emissions of greenhouse gases by SOC anthropogenic sources (Minasny et al., 2017), highlighting the extreme role that wetlands play in the carbon cycle. Therefore, carbon sequestration is an important environmental service that wetland ecosystems can provide (Marin-Muniz et al., 2014). However, information about the vertical distribution and storage of SOC in wetlands is scant.

The Chi River is located in the Chi River Basin, Northeastern of Thailand. The Chi River Basin is one of the two major sub-basins forming the lower part of the Mekong River and its estimated catchment area is 4,947,600 ha (Arunyanart et al., 2017). One of the wetland types within the Chi River is the seasonal flooded forests which are mostly influenced by water and climate conditions. Nowadays, the loss of seasonal flooded forests in the Chi River territory is considered to be the highest among the lower Mekong area over the past 60 years (Homdee et al., 2016). The seasonal flooded forests serve as a natural wetland capital or stock, yielding a sustainable flow of useful goods and services. However, increasingly intensive human activities and the vulnerability of climate change have caused severe degradation of natural wetlands, which directly threatens wetland health and causes the decline of its ecological functions. Hence, the natural wetland conditions and human activities also affect SOC content in soils and its major role in forming and stabilizing soil structure, enhancing soil physical properties, and nutrient recycling. Because of the extreme role that wetlands play in the carbon cycle, it is feasible to consider changes in wetlands, along with the SOC process, may transform them to be a carbon sink. To envision this, an explicit description of the SOC distribution and storage is needed. The overall objectives of this study were (i) to examine the relationship between some soil properties and SOC content; and (ii) to estimate the SOC storage of the wetland.

2. METHODOLOGY

2.1 The study site

The Chi Basin is located in the central part of Northeastern Thailand between the range 15.3 ºN to 17.3 ºN and 101.3 ºE to 104.3 ºE (Figure 1). The overall topography has an average elevation of 120 to 170 m.a.s.l., and its total catchment area covers approximately 49,476 km^2. Rice is the major crop in the rain-fed agricultural area, which accounts for 60% of the land use in the basin. There are mountains and high plateau ranges on the border from the North to the West making the lower part look like a flat bowl in which deciduous and evergreen forests are the main forest types covering 20% of the entire area (Homdee et al., 2016). Chi River has wetlands composed of flooded forests as follows: Khud Tew, Nong Ngow, Kang Kha, Khud Chi Tao and Kwo Chi Yai. These five seasonal flooded forests and wetlands, which cover along the river basin, are public benefit areas. These five wetlands provide important ecological services and benefits to the local communities causing continuous use and disturbance of the area. The local climate is influenced by tropical monsoons and this area usually undergoes a long period of warmth due to its inland nature and tropical latitude zone. From March-May is the summer season, the hottest period of the year, with maximum temperatures usually reaching 40ºC or higher. The following rainy season significantly reduces the temperatures from mid-May to lower than 40ºC. Then, the outbreaks of cold weather from China occasionally reduce the temperatures to fairly low values in the winter.

In the Northeast Plateau of the Chi River Basin, the average annual precipitation is approximately 1,150 mm/year and the range in precipitation varies between 900 mm and 1,700 mm. The terrain slopes downward slightly from West to East and this area has distinct geological features, characterized by sandy sedimentary rocks from mainly the Triassic period and younger with a limited area of quaternary alluvium (Department of Mineral Resources, 2013). The quaternary alluvium can be found particularly along the river valleys.

2.2 Sampling and laboratory method

The field survey was conducted from January to March in 2017. The sampling points of soils were distributed according to seasonal flooded forests and each site was assigned a set of 10 plots to collect

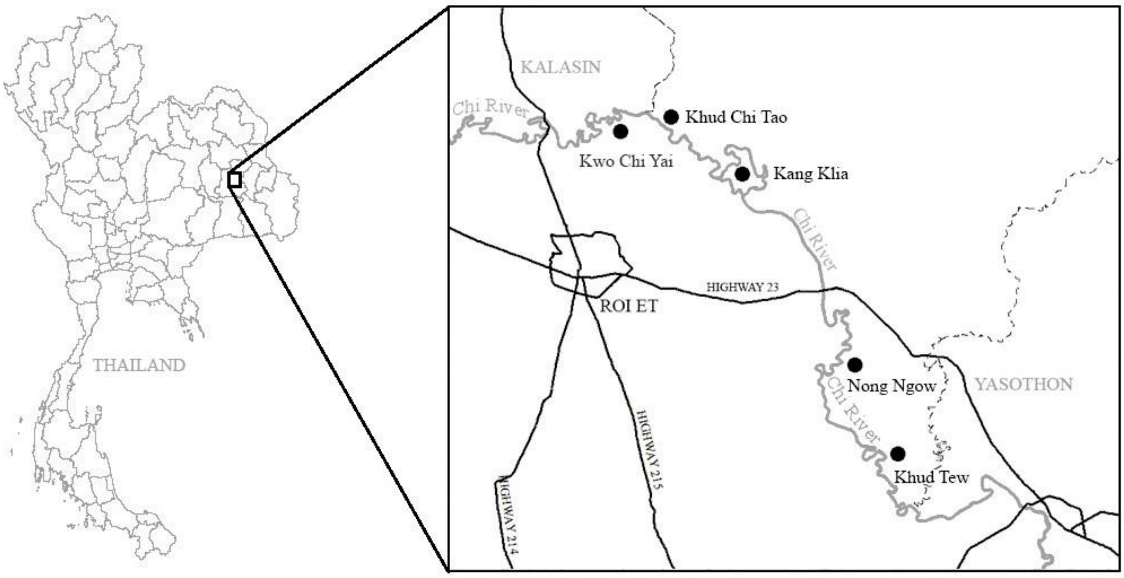

Figure 1. Location of Chi River Basin and distribution of the sampling points. Seasonal flooded forests P1 (Khud Tew); P2 (Nong Ngow); P3 (Kang Klia); P4 (Khud Chi Tao); P5 (Kwo Chi Yai).

soil samples. Samples from each plot were collected in triplicate from both the surface and subsurface soil. The soil samples were collected after the removal of plant debris and detritus. Sampling was performed using a 10 cm diameter drill in each layer at two depth ranges, 0 cm to 30 cm and 30 cm to 60 cm, to get a total of 300 soil samples that were kept in plastic bags. Using a cut ring method, two bulk density samples were collected in a stainless steel cylinder of 100 cm^3 in volume. At the laboratory, the composite soil samples were oven dried until constant weight and then weighed g for soil bulk density determination (Rayment and Higginson, 1992). The soil samples were described as air dried, then the temperature shall not be more than 30°C). The dried samples were sieved by 100 meshes. The SOC was determined by dry combustion method (Wang et al., 2016). Ammonium saturation method was used to determine cation exchange capacity (CEC) (Chesworth, 2008). Soil reaction (pH) was measured in a solution with 1 to 5 ratios between soil and water (He et al., 2012). Soil texture was determined by pipet method. Kjeldahl method determined total nitrogen (Bremner and Mulvaney, 1982). Organic matter was determined by Walkley- Black method. For general wetland surveys, we used line transect and vegetation inventory and specie identification (Table 1).

Table 1. Wetland and environment

Profile	Wetland	Coordinate	Flood duration (months/year)	Vegetation		Soil sample
				Species	Coverage	
P1	Khud Tew	103.97E 15.86N	<2	*Albizia Odoratissima, Combretum quadrangulare Kurz, Streblus asper Lour*	66%	30
P2	Nong Ngow	103.93E 15.96N	<2	*Albizia Odoratissima, Streblus asper Lour*	55%	30
P3	Kang Klia	103.82E 16.16N	<2	*Albizia Odoratissima, Combretum quadrangulare Kurz*	53%	30
P4	Khud Chi Tao	103.74E 16.22N	<2	*Albizia Odoratissima, Combretum quadrangulare Kurz, Streblus asper Lour*	78%	30
P5	Kwo Chi Yai	103.96E 16.21N	2-3	*Albizia Odoratissima, Combretum quadrangulare Kurz*	41%	30

Soil bulk density was determined by undisturbed soil sampling with stainless steel cylinder. Then the bulk density of dry matter (BD, g/cm^3) was calculated from (1).

$$BD = m(1-C_w)/V \quad (1)$$

Where; m is total weight of wet soil (g); C_w is water content (%); V is volume of cylinder (cm^3).

The soil organic carbon density of a single section is calculated by the layer thickness and weight. The difference of SOC in difference depths can help to reduce the estimation error (Zhang et al., 2018). The density of SOC (D_{soc}, kg/m^3) was calculated from (2).

$$D_{soc} = BD \times SOC \quad (2)$$

Where; BD indicates soil bulk density (g/cm^3); and SOC indicates the organic Carbon content of dry soil (g/kg).

In the other profile, the organic carbon storage was calculated from (3) (Bridhikitti, 2017).

$$TC = \sum D_{soci} \times H_i \quad (3)$$

Where; TC is the SOC storage per unit area (kg/m^2); H is the thickness of profile (m); " i" is number of layers.

2.3 Statistical analysis

The data analysis was calculated by statistical software (SPSS). Soil properties were measured in terms of average and deviation. The relationship between SOC components and partial soil properties were conducted with Pearson's correlation coefficient by proposing the related variables in the linear regression model. The differences of mean values in the soil data sets were determined between various wetlands and at different depths. The t-test method was used to determine statistical differences at a 95% level of confidence ($p<0.05$).

3. RESULTS AND DISCUSSION

3.1 Result

3.1.1 Soil physical and chemical properties

Table 2 shows the physical and chemical properties of all the soil samples. The pH values indicated that all layers were slightly acid (less than 6.5). Cation exchange capacity values were medium to moderately high (more than 10 meq 100/g). The rich exchange properties of these soils are in the clear results indicate.

The whole bulk density was 1.12 g/cm^3 to 1.51 g/cm^3. However, the areas with flood duration of 2-3 months/year showed lower bulk densities than the areas with flood duration less than 2 months/year.

The organic matter of all layers also showed a variability of contents from low to moderately high (less than 3.5%). However, the average organic matter content of soil samples with high vegetation cover (P1, P2, P3, and P4) was a little higher.

In general, the percentage nitrogen in these soils showed low values (less than 0.2%). Except that soil samples of P3, P4, P5 had high nitrogen values in the top soil, depending strongly on both organic matter and soil depth. When the organic matter values were high, the percentage nitrogen tended to be higher and certainly was more abundant in top soil layers than sub soil layers.

Table 2. Soil properties

Wetland	Depth	BD	CEC	pH	OM	N	SOC
		g/cm^3	meq 100/g		%	%	g/kg
Khud Tew (P1)	Top soil	1.23±0.02	20.52±1.84	4.64±0.29	3.34±1.55	1.83±0.19	5.81±3.30
	Sub soil	1.48±0.05	14.32±3.73	4.65±0.30	0.72±0.21	0.14±0.06	4.60±1.90
Nong Ngow (P2)	Top soil	1.21±0.02	19.28±2.81	5.04±0.38	2.00±0.58	1.96±0.08	5.33±3.02
	Sub soil	1.41±0.05	20.21±3.01	5.52±0.41	0.74±0.31	0.16±0.06	4.21±2.51
Kang Klia (P3)	Top soil	1.28±0.01	20.33±1.80	4.72±0.24	2.02±0.51	6.22±2.39	5.02±1.94
	Sub soil	1.51±0.01	15.01±4.23	5.09±0.25	0.65±0.36	0.13±0.04	4.04±1.51
Khud Chi Tao (P4)	Top soil	1.32±0.04	19.04±2.48	4.56±0.32	2.49±0.72	6.83±2.64	5.90±2.73
	Sub soil	1.50±0.06	13.49±3.42	4.94±0.46	0.74±0.27	0.13±0.06	4.01±1.92
Kwo Chi Yai (P5)	Top soil	1.12±0.01	15.14±4.05	4.88±0.23	1.12±0.13	3.77±1.21	3.52±0.91
	Sub soil	1.20±0.03	15.72±4.77	5.07±0.27	0.96±0.23	0.13±0.03	4.11±1.10

Remark: Top soil is 0 cm to 30 cm; Sub soil is 30 cm to 60 cm; ± is standard deviation

3.1.2 Distribution of the SOC content

In Figure 2, the vertical distributions of SOC are shown. Profiles P1, P2, P3 and P4 had high SOC content in the top soil layer and decreased sharply in sub soil layers. Profile P5 presented the inverse SOC content distribution pattern, showing higher SOC content in the sub soil layer. Plants in P5 had probably undergone drought circumstances or human exploitation creating abandoned plant matter on the ground. Thus, tree leave debris was found deeper than the surface layer. Variation in SOC content between top and sub soil was small, only 0.6 g/kg, while the variation between profiles was more than 1 g/kg. It has been reported that the hydrologic condition is the main factor that causes the SOC content to be uniform with depth (Zhang et al., 2016).

3.1.3 Organic carbon density and organic carbon storage

For all of soil profiles, the SOC density of top soil layer varies from 3.92 kg/m^3 to 7.79 kg/m^3, with a mean of 6.3 kg/m^3. Meanwhile, sub soil layers vary from 4.92 kg/m^3 to 6.81 kg/m^3, with a mean of 5.9 kg/m^3, reflecting a decreasing soil bulk density of P4 followed by P1, P2, P3, and P5, sequentially. Similarly, the SOC content was highest in P4 followed by P1, P2, P3, and P5.

The vertical distribution of SOC density showed two patterns along with increase of soil depth. Profiles P1, P2, P3, and P4 had higher SOC density in the top soil layer and lower SOC density in the sub soil layer. The exception to this pattern was seen in profile P5, which presented the inverse SOC density distribution pattern. The SOC density in profile P5 increased in the sub soil layer. The estimation of SOC storages showed variation in values from 2.65 kg/m^2 to 4.18 kg/m^2, with a mean of 3.68 kg/m^2. The highest was P4 followed by P1, P2, P3, and P5, sequentially.

3.1.4 Bulk density and organic carbon relationship

The correlation analysis found that SOC content in wetland is closely related to bulk density ($r=0.36$, $p<0.05$). Interestingly, as the SOC content decreased, the bulk density increased. The reasonable cause may be that plant matter, particularly the stem and leaves of plants, accumulate to become a litter layer, porous-textured high organic matter with an abundance of organic carbon inside. According to the results, SOC density showed a distribution pattern similar with the SOC content. SOC content and soil bulk density determine the SOC density. The linear correlation value between SOC density and SOC content was estimated to be highly significant ($r=0.85$, $p<0.05$) (Figure 3).

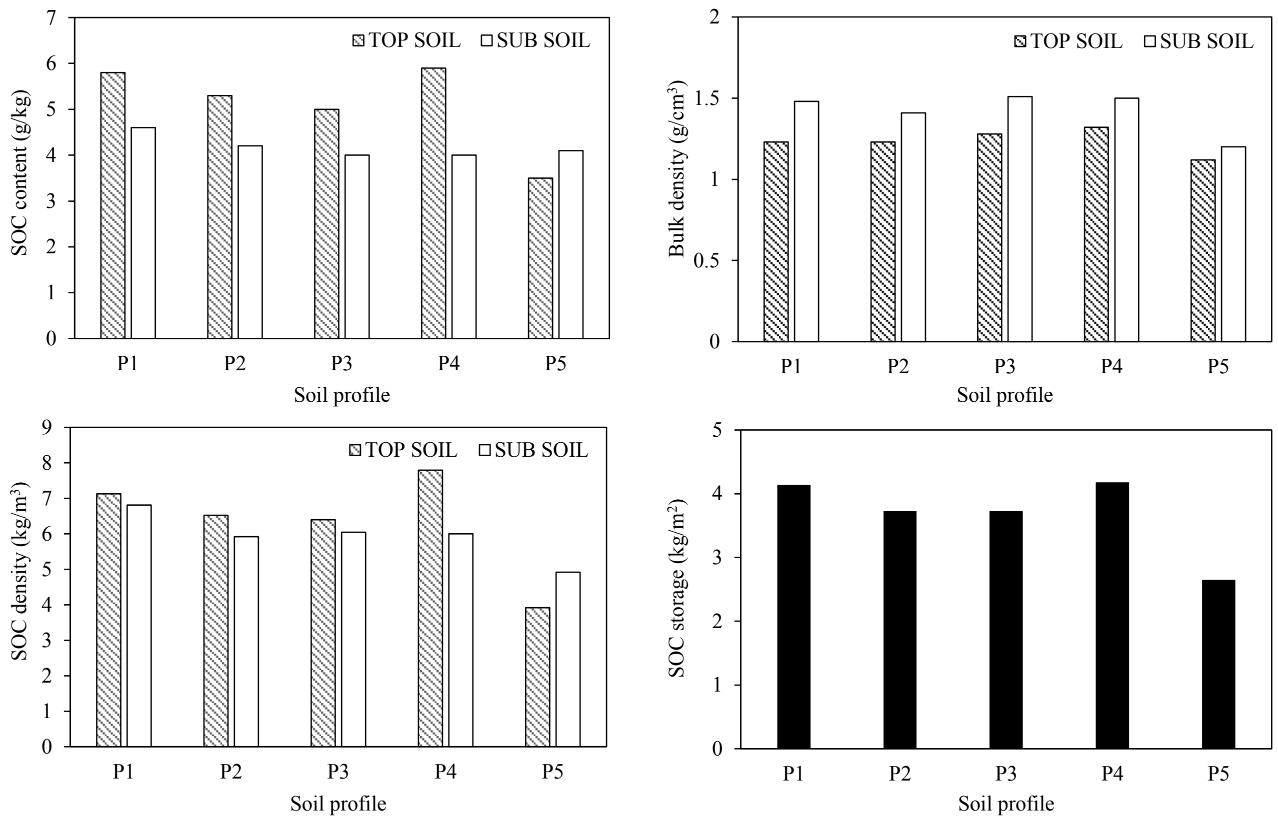

Figure 2. Distribution of SOC content, bulk density, SOC density, and SOC storage

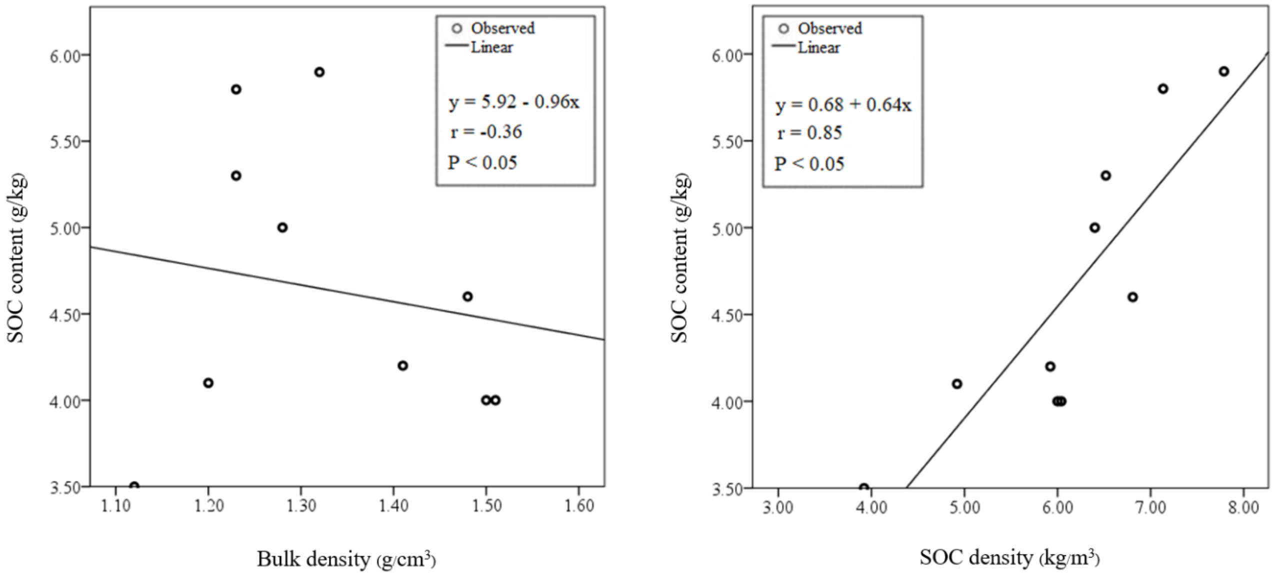

Figure 3. Scatter plot correlation in SOC content, Bulk density, and SOC density

3.1.5 Soil organic carbon content and density in vertical distribution

The vertical distribution of SOC content and SOC density normally decreased top-down to the lower depth. The wetlands (P1, P2, P3, and P4) showed high SOC content in top soil, more than 5 g/kg and then decreased significantly in sub soil, less than 5 g/kg. The results show the maximum SOC density occurred in the top soil in profile P4 (7.79 kg/m^3) and the minimum in profile P5 (3.92 kg/m^3). Conversely, the profile P5 showed higher values in sub soil. It is possible that there were previous events causing a lot of carbon input to the sub soil depth, such as logging and droughts. The vertical distribution database is found in Table 3.

Table 3. Vertical distribution of SOC content and SOC density

Profile	SOC content (g/kg)		SOC density (kg/m^3)	
	Top soil	Sub soil	Top soil	Sub soil
P1	5.81^{Aa}	4.60^{Ba}	7.13 ^{Ca}	6.80 ^{Db}
P2	5.33^{Ab}	4.21 ^{Ba}	6.51 ^{Cb}	5.92 ^{Da}
P3	5.02^{Ab}	4.04 ^{Ba}	6.40 ^{Cb}	6.04 ^{Da}
P4	5.90^{Aa}	4.01 ^{Ba}	7.78 ^{Ca}	6.00 ^{Da}
P5	3.52^{Ac}	4.11 ^{Aa}	3.92 ^{Cc}	4.82 ^{Dc}

Remark: Mean value followed by a different upper case letter indicates significant differences between the soil depths at p<0.05, mean value followed by a different lower case letter indicates significant differences between soil profiles at p<0.05.

3.2 Discussion

3.2.1 Characteristic of soil organic carbon content in wetland

A consequence of interactions among many factors affect the vertical distribution of SOC. Land use and vegetation are main factors that input organic matter directly to the soil by plant litter (roots, stems, leaves). In this study, SOC content decreased with the change in depth. SOC in the top soil was significantly higher than sub soil (Xu et al., 2016). One wetland area (P5) of this study presented SOC content that differs from the others in that the top soil SOC was 3.5 g/kg and increased to 4.1 g/kg in sub soil. This might be the effect of plants that were buried due to some previous drought, and exploitation by man, indirectly in combination with this area having the lowest percentage of vegetation of only 41%. Moreover, we suggest that the organic matter (OM) value was somewhat high (0.96%) in this sub soil. Organic matter contributes most of the organic carbon (Rennert et al., 2018). This finding is in agreement with Mayer et al. (2019), who also found high amounts of SOC in sub soil caused by alluvial sediments rich in OM that were successively buried during previous flooding events. In addition, the study of Wang et al. (2016) that found the deeper soil contained higher SOC content than the top layer at a sampling site in a coastal wetland. This might be influenced by some previous events such as storm, drought, and human disturbances leading to the accumulation of plant material in the subsoil and a more thorough decomposition, which is affected by depth and age. Moreover, since this area has the lower amount of vegetative coverage, the downward migration of organic matter to the deep soil by water leaching combined with rainfall might be a factor of higher SOC in the deeper soil. In addition, the lower SOC in top soil might be caused by human activities leading to the loss of SOC in the top soil (Okebalama et al., 2017). Moreover, wet conditions are obviously related to biochemical processes in soil. Long duration flooding causes an anaerobic environment that restricts the degradation of organic matter (Lim et al., 2020). This balance may be altered by both natural and anthropic factors. Esteves et al. (2001) suggested that permanent waterlogging induces anaerobic conditions in which the SOC decomposes slowly while the optimal range soil proportions for the physiological performance of the plants were adequate by of air and water (Morales-Olmedo et al., 2015). Ferronato et al. (2019) found that the effect of soil waterlogging on chemical and biological reactions in wetlands depended on the rate of water flow and erosional processes.

The vegetation mainly affected the horizontal distribution of SOC content. In particular, the vegetation coverage contributed plant debris to SOC content. Our study revealed the SOC content of five wetlands ranged from 3.5 g/kg to 5.8 g/kg with an average of 5.1 g/kg in top soil. Comparatively, it was higher than paddy fields which have 2.40 g/kg (Yod-i et al., 2014). Obviously, the profile P4 had the highest SOC content followed by P1, P2, P3, and P5, sequentially which correlated with the descending order of vegetation coverage. The results also show SOC content among sites was significantly different. This is in accordance with the studies of Demenoisa et al. (2017) and Wang et al. (2016) who suggested that the highest vegetation covered areas with stable plant communities had enriched SOC content and the vegetation coverage was highly aligned with the horizontal distribution of SOC content.

This research showed the conversion of wetland into abandoned plant not only caused a breakdown of the SOC content that changed the soil structure, but also the decline of SOC. Kunlanit et al. (2019) found that the SOC contents in top soil were higher than sub soil in a forest area. This research indicated that the SOC content and distribution depended on various factors, including not only soil properties, but also the surrounding environment. Questions still remain about the influence of vegetation, particularly because of the short-time of this investigation. The change of seasonal vegetation may provide a dynamic of SOC contents caused by the variation of plant residue. Therefore, the continuous monitor in all seasons should be considered for more understanding of this accumulation process and its relationship with SOC content.

3.2.2 Organic carbon density and storage in wetland

The important measurements to estimate the SOC density is the soil bulk density and SOC content. Apparently, the SOC density showed the trends of being lower in the sub soil with little variability between locations, while top soil had a higher SOC density and more variability. Amber and Ken (2011) and Zhang et al. (2019) suggested that SOC density is not only an important role in organic carbon storage estimating but the characteristics of organic carbon storage in different ecosystem are also reflected since horizontal consideration, the difference of canopy cover had significant. Our results indicate that SOC density in profile P4 was 1.98 times of SOC density in profile P5. Obviously, a large amount of vegetation coverage was found at the area with the predominant SOC density. Wu et al. (2015) suggested that reclamation has a great influence on bringing down SOC density which might be due to reclamation not only reducing plant residue, but also changing physical factors of soil and water, such as heat condition, accumulation, and microorganism disappearance. Therefore, Sulman et al. (2009) stated that the decomposer activity and vegetation input were interrupted, as well as the SOC density was obviously conducive to decline and parallel decay of different individual compounds (Schowalter, 2017). Xu et al. (2016) mentioned that SOC content decreases with increasing depth in a corn field. Similarly, the other profiles with large vegetation coverage lead to more storage canopy of SOC as well. From this point of view, in the wetland, the primary factor that limits the storage of SOC was the condition of the vegetation. This conforms to the study of Wang et al. (2016) that suggested the significance of vegetation coverage on

SOC content, and also indicated that plant factors, as well as sedimentation rate, water content and coarse grain size of soil were considered as the key factors that have an effect on the sequestration of organic carbon. Meanwhile, Kayranli et al. (2010) stated that the relative degree of carbon input and output is the factor that controls SOC. This research found the mean of SOC storage was 3.68 kg/m^2, whereas Wu et al. (2015) observed the SOC in a wetland plateau of China was 14.6 kg/m^2, Zhang et al. (2018) observed the SOC in a wetland in Northeast China was 27.4 kg/m^2. This research found the mean of SOC storage was 3.68 kg/m^2, whereas Zhang et al. (2019) observed a site at Guizhou Province of China stored approximately 1.58 Pg of SOC and suggested that the average SOC density in the top 1.00 m of soil associated with different land uses decreased. Xu et al. (2016) indicated the existence of global patterns in carbon related to time, temperature and latitudinal gradients following afforestation. YaoMin et al. (2012) found the SOC content in wetlands is an important part of the terrestrial soil organic carbon pools, but there was a lack of data.

In comparison, this research finding was much lower than other reports with respect to SOC storage. Thus, the explanation for this finding may be that the flood duration was too short, making low sedimentation rate, limiting vegetation decomposed as well as the soil parent material was sandstone that producing somewhat coarse grain size of soil particle and soil drainage well until organic matter avoids embedding in situ. The best practice should be implemented to pause the organic carbon decline, such as zoning for plant protected areas, emphasizing understanding and wise use of wetlands by the local communities, as well as supporting permanent waterlogging by checked dam.

4. CONCLUSION

In this study, the distribution and preservation of soil organic carbon in flooded forest wetlands was examined. The results showed that SOC content of top soil was higher than sub soil. The horizontal distribution of SOC content in top soil varied much more than in sub soil. Either soil bulk density or SOC density have related with SOC content, the soil bulk density closely related SOC content in term of negative relationship ($r=-0.36$, $p<0.05$), and this suggested that The SOC density had a strong positive relationship with SOC content ($r=0.85$, $p<0.05$). Comparison of areas with different vegetation coverage and also waterlogged less than three months a year showed the SOC content had a tendency of decreasing from high to low as the percentage of vegetation coverage decreased. Apparently, Khud Chi Tao, which had the highest vegetation coverage (78%), had the maximum amount of soil storage, containing 5.90 g/kg, whereas Kwo Chi Yai, which had the lowest vegetation coverage (41%), had the minimum amount of soil storage, only 3.52 g/kg. Due to the limitation of plant coverage area took care of SOC storage depressing, as showed 4.18 kg/m^2 in highest percentage of vegetation coverage and 2.65 kg/m^2 in lowest percentage of vegetation coverage. These wetlands indicated that the soil storage had an average value of 3.68 kg/m^2. Thus, the wetland management should consider maintaining plants and moisture in the soils to permanently conserve organic carbon. Actually, this approach is rarely practical because the wetland area suffers from frequent droughts, and the local people still disturb the natural resources regularly. Therefore, in terms of sustainable management, there should be specific measures set up for land utilization, following wetland management measures at the national level and in accordance with local needs. Thus, the wetland measures taken will lead to action and the relevant sectors will be able to formulate strategies and allocate budgets to restore and reclaim flooded forest wetlands to maintain ecological value. Meanwhile, steps should also be taken to raise awareness in the local communities of the importance of flooded forest wetlands to mitigate climate change.

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