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PRELIMINARY STUDY ON INFLUENCE OF FIRE TO PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOIL AT TRAM CHIM NATIONAL PARK, DONG THAP PROVINCE

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Abstract

This study aims to evaluate the effect of fire on soil properties at Zone A5, Tram Chim National Park, Tam Nong district, Dong Thap province. Findings indicated that soil type was acid sulfate, soil structures were clay, clay-silt and silt-clay. pH was low while moisture was high. Electrical conductivity and bulk density were in the tolerance range for the Eleocharis community. The soil was rich in nitrogen, phosphorus, and organic matters while it was medium in total potassium. After firing, clay tended to decrease while sand and silt to slightly increase. Moisture, pH, electrical conductivity, total phosphorus and potassium increased whereas organic matters and nitrogen content tended to decrease. Bulk densities were almost unchanged over time. This study preliminary provides valuable information on the changes of soil properties under firing.

Keywords: Tram Chim National Park; Soil properties; Acid sulfate soil; Organic matters.

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1. Introduction

Fire is considered a major disturbance and can affect soil quality (Ekinci and Kaydir, 2005; Tuc, 2011). It can lead to changes in porosity, texture, color, moisture, permeability (Alcaniz et al., 2018) and organic matters (Kavdir et al., 2005) of soils. In addition, the amount of ash remaining after burning may affect the chemical properties of the soil because it is rich in some cations and anions (Raison, 1979; Pyne, 2001). Previous studies conducted in the laboratory simulated the effects of soil through heating or burning methods to evaluate changes in soil properties (Doerr et al., 2004; Stoof et al., 2010). However, there were also some studies reported that the burning of soil in a laboratory did not clearly and accurately explain the direct impact of fire on soil quality (Glass et al., 2008; Stoof et al., 2010). Therefore, planned fires could be a good choice to manage and protect soil quality, each fire could have different purposes such as stimulating the regeneration of a plant species or maintaining biodiversity (Alcaniz et al., 2018). A number of studies have been conducted on soil quality assessment after forest fires in western Canada, Canakkale (Turkey), Colombian, Boulder Creek Critical Zone Observatory (Heard et al, 2006; Ekinci, 2006; Weiting et al., 2017). In Vietnam, studies also were implemented to evaluate soil quality influenced by fire in Son La, Tien Giang and Kien Giang (Lien and Tuyen, 2016; Vu et al, 2014; Bao and Duan, 2011). However, there are currently very few studies on the effects of burning of vegetation on soil quality changes (Moody et al., 2016), especially in some places that play an important role in protecting nature and biodiversity such as National Park, Nature Reserve, Species-Habitat conservation, etc.

Tram Chim National Park is located in Dong Thap Muoi area of Tam Nong district, Dong Thap province. Tram Chim National Park has an area of 7,313 ha which is divided into many zones. Of which, Zone A1 covers the area of 4,942.8 ha, Zone A2 covers the area of 1,122.7 ha. The zone A3, A4, and A5, and Zone C with smaller areas of 44.5, 731.9, 440, 5 ha, respectively (Sum, 2016). This is a seasonally inundated wetland, which is classified as a special-use forest system of Vietnam characterized by acid sulfate soil (Thang and Duc, 2016). Acid sulfate soils in the Mekong Delta wetlands were characterized by high total sulfur (SO_4^{2}), iron (Fe^{3+}), salt (NaCl), low calcium carbonate ($CaCO_3$), low phosphorus and highly acidic. However, these wetlands function as the places for recharging groundwater, controlling floods, preserving nutrients and filtering toxic substances (Ni, 2013). There have been a number of studies on assessing water and soil quality as well as biodiversity dynamics at Tram Chim National Park. There is little study has been focused on the impact of vegetation burning on dynamics of physical and chemical properties of soil. This study was carried out to assess soil quality and changes in soil properties before and after burning of dry vegetation at zone A5, Tram Chim National Park, Dong Thap province. The findings from this study provide better understanding of the variation of soil properties under fires.

2. Materials and methods

2.1. Sampling sites

The study was conducted in March 2019 at Zone A5 (Figure 1), Tram Chim National Park, Tam Nong District, Dong Thap Province. Zone A5 was selected for the study since it is the current feeding area of the cranes, a thick layer of vegetation, relatively isolated with the melaleuca forest. The site was adjacent to the water source, firing equipment and human resources which were well-prepared for fire control.

The soil samples were collected at three times, including before the burning (Period 1), 7 days (Period 2) and 37 days after burning (Period 3).

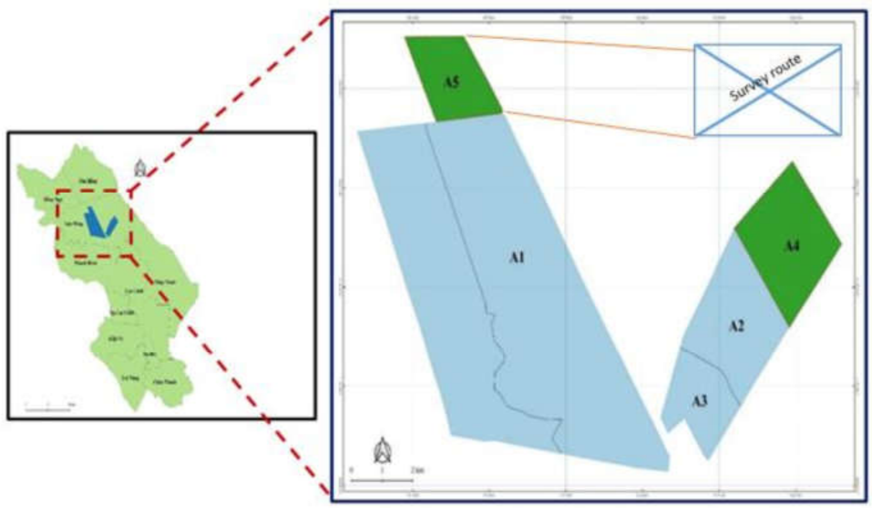

Figure 1: Location of study area Zone A5, Tram Chim National Park

2.2. Soil sampling and analysis

2.2.1. Soil sampling

Twelve soil samples were collected per one period at 6 sites, of which 5 locations (denoted from D1 to D5) were collected in the burned area with zone A5 (D1 - D5) and one control location which was collected outside the burned area (denoted D6) (Figure 2).

The first burning did not completely burn the vegetation in the area of 10 h, for example location 1 and 4 were completely burned, location 2 was not completely burned while the location 3, 5 and 6 were not exposed to the firing. There was a small rain on the day before the burning, fresh biomass and burning time in the morning (10:00 am) which could be the reason for incomplete burning in the first burning of the experimental area. The second burning resulted in destroying the vegetation completely.

Figure 2: Sampling locations of soil in Zone A5

For analysis of soil physical parameters such as moisture and bulk density, soil samples were collected using a metal auger with the volume of 98,125 cm^3. Using force from hands to push the auger into the soil until the auger was filled with soil at approximate soil depth of 0 - 20 cm. Then the auger containing soil was closely covered and transported to the laboratory for analysis. For soil texture analysis, soil samples were collected as described in the following paragraph, however, the dried soil samples after pulverized were sieved through 2 mm size mesh instead of 0.05 mm.

For analysis of soil chemical parameters, soil samples were collected at the depth of 0 - 20 cm at four positions within the standard plot of 1 m^2 for every soil sample in increasing the representative of the soil quality at each sampling point. One kg of soil was collected at each position then put into four separate nylon bags which was sealed and returned to the laboratory for processing. Soil samples were dried at room temperature, then pulverized, sieved through 0.05 mm mesh size. The sieved soil samples at every sampling site were pooled (50 gram of each sample at the same collecting site) and then sent to the laboratory for analysis of pH, electrical conductivity (EC, mS/cm), organic matter (OM, %), total nitrogen (N, %), total phosphorus (% P_2O_5), total potassium (% K_2O).

2.2.2. Soil analysis

Soil texture was analyzed using Robinson method while moisture and bulk density were determined based on weighting samples before and after the samples were dried at 105^{o}C (until mass constant). pH and EC were extracted with distilled water, ratio 1: 1.25 (soil/water), then determined by pH and EC meters, respectively. Organic matter was analyzed by Walkley-Black dichromate (Walkley-Black dichromate wet oxidation method), total nitrogen analyzed by Kjeldahl method, and total phosphorus was analyzed by colorimetric method after digesting the samples with a mixture of H_2SO_4 and $HClO_4$. Potassium was determined using an atomic absorption spectrometer (AAS, Agilent, AA240).

Table 1. Soil analysis methods

No.	Parameter	Unit	Methods
1	Soil texture	%	Robinson method
2	Bulk density	g/cm^3	Weighting method after dried at 105^{o}C
3	Moisture	%	Weighting method after dried at 105^{o}C
4	pH	-	pH meter
5	EC	mS/cm	EC meter
6	Organic matter	%	Walkley-Black
7	Total nitrogen	%N	Kjendhal method

8	Total phosphorus	$\%P_2O_5$	Colorimetric development
9	Total potassium	$\%K_2O_5$	AAS

3. Results and discussion

3.1. Variation of physical properties of soil at Zone A5 under impact of vegetation burning

Soil texture is closely related to sizes of soil particles. The size of the soil particles is always fixed, so it is considered a basic characteristic of the soil (Hung et al., 2017). The results of physical characteristics of soil at the Zone A5, Tram Chim National Park were presented in Table 2. Table 2 indicated that soil at the zone A5 was high in clay ranging from 39.84 to 63.33%, followed by silt (30.22 - 51.56%) and finally, sand (3.29 - 1172%). The percent of clay is high because the soil at zone A5 is acid sulfate soil (Khoa and Be Ti, 2013; Hung et al, 2017). According to the classification of USDA/soil taxonomy, the composition of soil structures in the A5 area is of clay, silt-clay (loam) and clay-silt (medium clay).

Table 2. Soil texture at Zone A5 before and after vegetation burning

	D1			D2			D3		
	Before burning	**1st burning**	**2nd burning**	**Before burning**	**1st burning**	**2nd burning**	**Before burning**	**1st burning**	**2nd burning**
Sand (%)	3.29	4.25	3.38	9.25	5.41	17.11	8.6	5.78	13.96
Silt (%)	35	34.11	28.85	30.22	45.40	39.73	51.56	38.93	44.92
Clay (%)	61.71	61.64	67.77	60.53	49.19	43.16	39.84	55.29	41.12
Classification (USDA)	Clay	Clay	Clay	Clay	Clay-silt	Clay	Silt-clay (Loam)	Clay	Clay-silt
	D4			**D5**			**D6**		
	Before burning	**1st burning**	**2nd burning**	**Before burning**	**1st burning**	**2nd burning**	**Before burning**	**1st burning**	**2nd burning**
Sand (%)	11.72	11.13	5.36	5.49	6.58	2.76	6.06	6.68	3.77
Silt (%)	43.84	51.11	53.55	31.18	38.50	40.35	48.07	37.51	44.52
Clay (%)	44.44	37.76	41.09	63.33	54.92	56.89	45.87	55.81	51.71
Classification (USDA)	Clay-silt (mediun clay)	Silt-Clay	Clay-silt	Clay	Clay	Clay-silt	Clay-silt	Clay	Clay-silt

As can be seen that the soil texture in this study after burning percent of clay particles significantly decreased compared to those before burning. The percent of clay in soil ranged from 37.76 to 61.64% after 7 days of burning and from 41.09 to 67.77% after 37 days of burning, tending to be lower than that at the control site D6 (55.81 and 51.71%, respectively). This finding was contradictory with the previous research reported that the clay content in the soil was not affected by fire unless the temperature during burning is very high (> 400ºC) (Ulery and Graham, 1993). This study found that the percent of sand and silt after burning were higher than those before the burning, especially at D4.

Physical properties of the soil were presented in Figure 3. Because the soil has a major component of clay particles with good moisture retention capacity, the soil moisture in the study area was relatively high, ranging from 45 - 58%. The site D3 was the lowest moisture content. The bulk density of soil at D1 - D5 ranged from 0.5 to 0.8g/cm^3) which was not different from that at D6 (0.7g/cm^3). This result was also consistent with the study of Dang (1999) reported that soil density in Vietnam ranging from 0.7 - 1.7%. However, if the soil density is> 1.2 g/cm^3, the cultivation is very difficult, crop productivity is often low due to too much clay, less organic matter, preventing the growth of the roots. In general, the bulk density of soil in the study area is still suitable for vegetative growth.

Results showed that soil pH in Zone A5 is low and thus the soil is classified as acidic soil (USDA, 1978). This result is consistent with previous research by Sum et al. (2016) and Hung et al. (2017). According to Hoa (2017), EC is defined as the electrical conductivity of solutions in soil, an indicator used to measure the presence of dissolved ions in soil solution. EC values in soil in the study area ranged from 1.23 to 3.25 mS/cm, which is considered to have no effect on the development of Eleocharis communities in the study area (Sum et al., 2016).

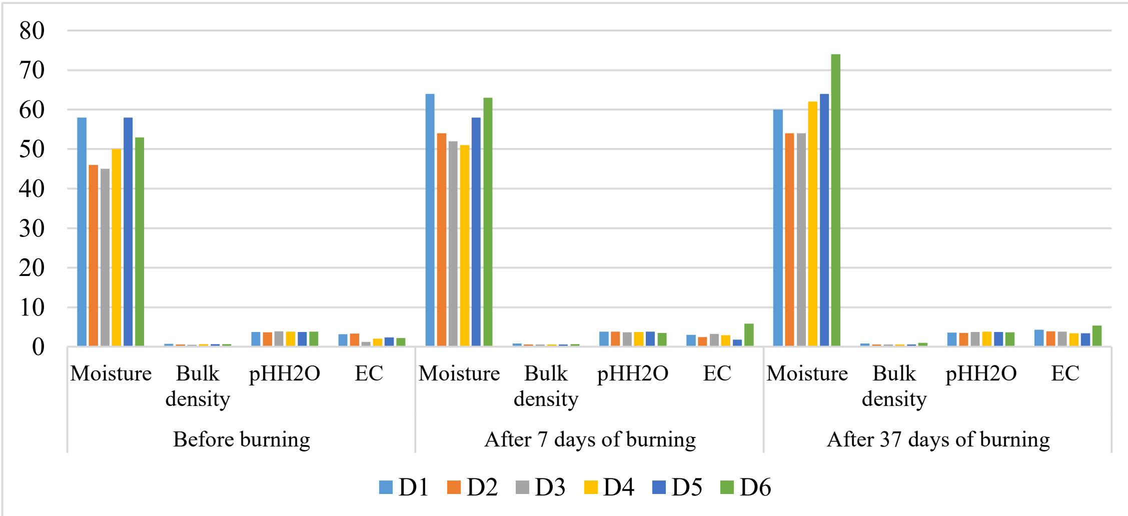

Figure 3: Physical properties of soil at Zone A5 before and after vegetation burning

Moisture contents of soil after burning tended to be higher than those before burning. Within the sampling location, moisture contents at burned sites (D1 - D5) tended to be lower than that at control site (D6) (Figure 3). Moisture content after 7-day burning ranged from 51 to 64%, increased to about 2 - 17.4% compared to before burning. Moisture content after 37 days of burning were from 54 to 64%, increasing by 0 - 21.6% compared to before burning. The reason could be related to the thickness of the vegetation layer and the water holding properties of the clay particles in the area (Lien and Tuyen, 2017). In addition, the amount of ash after burning has water-retaining properties and could make sand grains act as clayey sand (Moore, 1996). The bulk densities of soil were 0.6 - 0.9 g/cm^3 and 0.6 - 1 g/cm^3 after 7 days and 37 days of burning, respectively which were not different with those before the burning (0.5 - 0.8g/cm^3).

pH values of the soil after burning were not significantly changed ranging from 3.54 to 3.87. However, pH after 7 days of burning increased by 0.8 - 4.38% and after 37 days increased by 1.08 - 3.38%. pH before or after burning is still in highly acidic condition (USDA, 1978). The change in EC values was very significant before and after burning. Values of EC ranged from 1.8 to 3.3 mS/cm (7 days) and 3.44 to 4.35 mS/cm (37 days), an increase by 15-90% in Zone A5 after burning compared to that in before burning of vegetation. This could be because the soil after burning contain more cations (i.e. Fe^{3+}, Cu^{2+}, Ca^{2+}, Mg^{2+}, Na+ and K^+) (Khan and Qasim, 2008). Similarly, EC at site D6 (the control site) was also increased significantly after 7 days of burning. Previous study also found that with the release of ash on the ground leads to increased moisture, pH and EC in soil (Kalra et al., 2000). In short, burning of vegetation in Zone A5 did not produce significant changes to the physical properties of the soil.

3.2. Variation of chemical properties of soil at Zone A5 under impact of vegetation burning

Chemical properties of soil in Zone A5 were presented in Figure 4. Soil organic matter in Zone A5 was high, ranging from 12.1 to 18.5% (Metson, 1961). Total nitrogen at study sites was in the range of 0.459 - 0.648% which was significantly higher than that regulated in TCVN 7373: 2004 - acid sulfate soil. The nitrogen is evaluated as rich nitrogen level according to Kuyma (1976) but medium in nitrogen (at site D1 and D2) according to Metson (1961). The total nitrogen concentration found in the current study was in line with that found in the previous study of Sum et al. (2016). Total phosphorus in the A5 zone ranged from 0.118 to 0.157%. The total phosphorus in the A5 zone (D1 - D4) was higher than that at the control point D6 (0.129%). According to Can (1978), total phosphorus in all study sites was evaluated at a rich level with total phosphorus values always greater than 0.11%. The main reason for high levels of total phosphorus is because rich organic matters in Tram Chim National Park (Sum et al., 2016). Similar to total phosphorus, to tal potassium in soil at sampling sites D1 - D5 (0.99 - 1.44%) also tends to be higher than that at control site D6 (1.28%) except position D3. According to Hoa (2017), total potassium concentration in the Mekong Delta in acid sulfate soil ranges from 0.98 - 1.63%. Total potassium concentration found at Zone A5 was in line with the previous research and classified as medium according to the rating scale of Kuyma (1976).

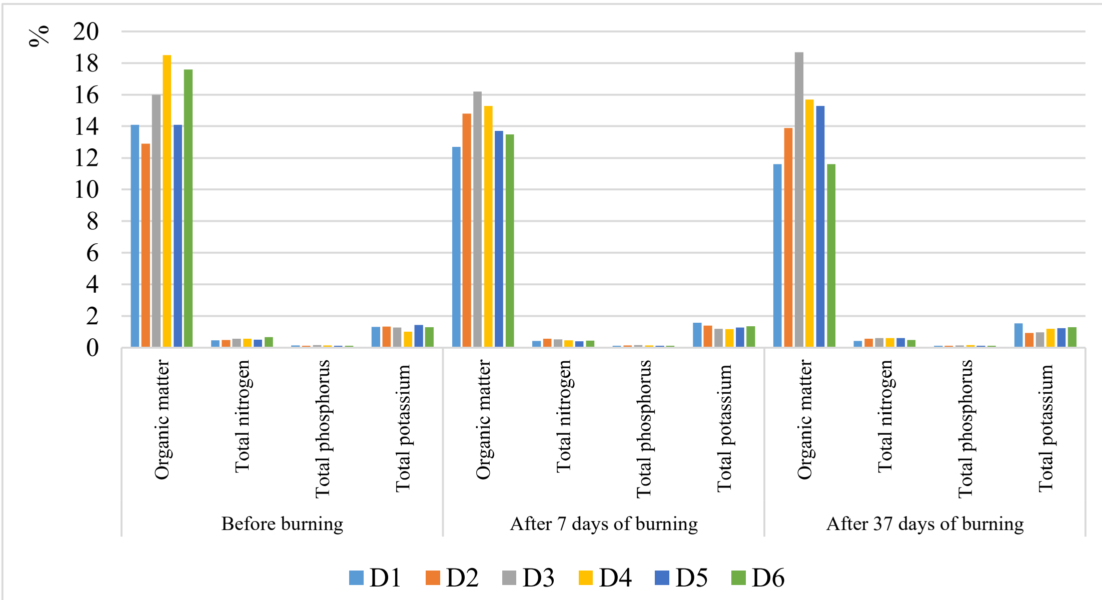

Figure 4: Variation of chemical properties of soil before and after vegetation burning

The change in soil chemical properties was presented in Figure 4. The impact of burning of vegetation on organic matters was negligible. The content of OM after 7 days of burning and 37 days ranged from 12.7 to 16.2% and 11.6 - 18.7%, respectively. The main cause of organic matter loss could be due to volatilization and conversion of organic matters into ash (Boerner, 1982; Raison et al., 1985). However, the organic matters tended to increase at the location D2 and D3 at the first burning could be related to the incomplete combusting. Total nitrogen content in the burning area after 7 days decreased by 5.4% - 20.8%, but after the second burning, total nitrogen increased significantly from 14.5 to 52.6%. Previous study found that total nitrogen decreased after burning due to volatilization (Choromanska and DeLuca, 2001; Caldwell et al., 2002, Neary et al., 1999).

Total phosphorus content in soil was higher than that of control soil D6 after 37 days (0.114%). Moreover, most of the total phosphorus content of the soil after burnings was higher than that of unburnt soil. The increase in total phosphorus content was previously found higher in the soil after burning (DeBano, 1990). The increase in total phosphorus concentration in the soil after burning in this study was also reported in the previous studies (Marion et al., 1991; Kutiel & Shaviv, 1993). Burning could reduce organic matters but increases the total content of substances such as Ca, K, Mg, and P in surface soil layer (DeBano, 1990). Total potassium content after 7 days burning tended to be higher than that of no burning. However, potassium concentration was reduced after 37 days of burning. The reason may be the impact of the wind in ash after burning (DeBano and Conrad, 1978).

In addition, C/N ratio is often used to assess the degree of decomposition of organic matter and the quality of soil organic matter. Table 8 showed the C/N ratio of the soil samples before and after burning. The results indicated that the average C/N ratio in Zone A5 before burning was 29.13 and the ratio of C/N after 7 days of burning was 30.32 and after 37 days of burning was

26.78. At the control site D6, the C/N ratios at before, 7 days after burning, and 37 days after burning were 27.16; 29.67 and 24.17, respectively. However, the ratio of C/N after the first burning tended to be higher than before the burnings. This could be because the soil is already rich in organic matters and the layer of vegetation is not thick. It could be possible that weather conditions (i.e. wind, rain) also effect the chemical compositions of soil after burnings.

Table 8. C/N ratios before and after burning at Zone A5

	Before the burning		**7 days after burning**		**37 days after burning**	
	Within Zone A5	**Control**	**Within Zone A5**	**Control**	**Within Zone A5**	**Control**
OM	15.12	17.60	14.54	13.50	15.04	11.60
TN	0.52	0.65	0.48	0.46	0.56	0.48
C/N	29.13	27.16	30.32	29.67	26.78	24.17

4. Conclusion

The assessment of physical and chemical properties of soil at Zone A5, Tram Chim National Park showed that the area is acid sulfate soil. Soil structures in the area were clay, clay-silt and silt-clay. pH was low and moisture was high. Bulk density and EC were in suitable ranges for vegetation, especially Eleocharis community. The soil was rich in nitrogen, phosphorus, and organic matters. However, total potassium was only in the medium range. After vegetation burnings, the physical and chemical properties of soil in the study area were not much different. Clay particles tended to decrease while sand and silt tended to increase after burnings. Moisture, pH, EC, total phosphorus and potassium tended to increase whereas organic matters and nitrogen content tended to decrease after burnings. Bulk densities were almost unchanged over time. The findings provide useful information of dynamics of physical and chemical properties of soil under impact of fire.

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