Post Peat Fire Soil Natural Recovery Based on Physical Properties in South Kalimantan, Indonesia

ABSTRACT

Indonesia always experiences forest and peatland fires during the extreme dry season. Forest and land fires greatly affect productivity and the environment. The fire was very detrimental to the ecological, economic and social aspects, in addition to the spread of smoke in various countries. This study examines the recovery rate of peat soil after the 2015 fire in the Balangan River - Batangalai River Peat Hydrological Unit (KHG), South Kalimantan. Test results on post-fire land in 2015 after five years (T+5) with a pH value of 2.93; water content is 270.94% and bulk density is 0.225 g cm^{-3}. At (T+7) the test results showed that the pH value was 3.20, the water content was 288.22% and the bulk density was 0.165 g cm^{-3}. Changes in the value of physical properties for five years and seven years after the fire for the pH value increased by 8.60%; the water content value also increased by 5.99% and the bulk density value decreased by 5.99%. Test results on natural (unburn) land in 2015 after five years (T+5) with a pH value of 3.32; water content is 342.60% and bulk density is 0.098 g cm^{-3}. At (T+7) the test results showed that the pH value was 3.43, the water content was 349.94% and the bulk density was 0.082 g cm^{-3}. Changes in the value of physical properties for five years and seven years after the fire for the pH value increased by 3.13%; the value of water content also increased by 2.10% and the value of bulk density decreased by 19.51%. This research is able to indicate that the post fire peat soil naturally become getting close to the unburn condition even though it still in a degraded condition.

Keywords: peatland, post fire, pH, water content, bulk density

1. INTRODUCTION

Peatland soils, store 25% of the world's terrestrial carbon with approximately ~560 Gt of carbon even though covering the Earth's land surface less than 3%, are significant reservoirs of carbon [1], [2], [3]. Peatland area in Indonesia cover around 14.91 million ha that roomy in Sumatra 6.44 million ha (43 %), in Kalimantan 4.78 million ha (32 %), and in Papua islands 3.69 million ha (25 %) [4]. Kalimantan Selatan Province, part of Kalimantan Island (also known as Borneo Island), has four Peat Hydrological Units (KHG). Those KHG are the Barito River-Alalak River KHG (covering an area of 47,935 ha) has a peatland area of 20,301 ha, Sungai Utar-Sungai Serapat KHG (covering an area of 107,737 ha) has peat land of 27,176 ha, the Balangan River-Batangalai KHG (covers an area of 30,859 ha) has peatland of 11,008 ha and the Barito River- Tapin River KHG has an area of 112,227 ha with peatland covering an area of 45,998 ha [5], [6], [7]. Study by [8] was using visual image interpretation in mapping the status of peatland degradation and development in Sumatra and Kalimantan from 94 high resolution (10–20 m) satellite images. Physical properties degradation by deforestation, fires, erosion, and soil contamination in the forest soils reduce its capacity to function fully and can be either temporary or permanent [9], [10], [11]. During peat fires, fire ignited on its surface goes through in small cavities and extend into the peat soil and once able to maintain a high fire temperature for at least 1 – 2 h, otherwise its spots gradually disappear. Afterwards, a smoldering front starts to burn into the surface peat to a depth of 0 – 20 cm and can be deeper (20 – 50 cm) [12], [13], [14].

Study by [15] observed the effect of a peat fire in 2019 in South Sumatra display that the ash content increased 57% and also improved the soil pH [16]. Moreover, other study showed that peat fires decrease water retention capacity by 1 - 12 % [17]. Peatland fires that particularly affecting soil characteristics occur yearly in the South Kalimantan Province Indonesia. The study by [18] indicated that the physical characteristics of the soil on burned land in October 2018 had higher pH level than in January 2019. Meanwhile, [19] found that one year after peatland fires, changes some physical characteristics such as peat humification level, bulk density, peat thickness, organic matter content, hydraulic conductivity, and soil water content. [20] also found peat soil properties were affected by forest and land fire both peatland in Jambi and Central Kalimantan and have insignificant differences of bulk density, porosity and pH.

On the post-fire peatland pH measurement, [21], [22] show two kinds of conditions of pH, it can be increasing and/or decreasing. Post-fire peatland pH measurements by [15], [16], [18], [23] [24], [25] showed that the pH condition was increasing. Meanwhile, post-fire measurements by [26], [27], [28] show the pH was decreasing. Specifically, One year of post-fire pH measurement by [29] shows its value was decreased slightly (7.1 ± 0.2) and reached 6.3 ± 0.2 at the end of the experiment.

Soil water content (SWC) plays an important part in seed germination, plant growth, and plant nutrition as it affects water infiltration, redistribution, percolation, evaporation, and plant transpiration [30]. Water content as usually used in soils work is either a dimensionless ratio of two masses or two volumes or is given as a mass per unit volume or in percentage [29]. Moreover, water content condition in the peatland significantly influences peatland inflammation due to its value is a sensitive parameter [31].

Since 2014 to the present, Indonesia faces forest and land-fires and became the biggest problem. Various methods to prevent forest and land fires from occurring have been implemented. Study by [26] used hydrogel for extinguishing forest and land fires and showing the tendency of declining the average water content of peat due to the drying process based on different intervals ranged from 61.25% to the highest with a water content of 109.57%. According to [16], peat will be vulnerable to burning at a water content of less than 125%.

Soil bulk density as one of the basic soil property can be influenced by some soil physical and chemical properties such as the amount of organic matter in soils, their texture, constituent minerals and porosity. The information of soil bulk density is crucial for soil management and in soil compaction as well as in the planning of modern farming techniques [32]. Several factors such as compaction, consolidation and amount of soil organic carbon present determined of the soil bulk density [32], [34]. Carbon pools estimation is frequently using soil organic carbon, soil organic matter and the correlation between bulk densities [35]. Those previous research show that soil bulk density is one of the soil quality parameter.

As the study on the natural recovery time of peatlands after fires are still very limited. This research will provide information on the recovery rate of post-fire peatlands in the Balangan River-Batangalai River, South Kalimantan. The peat soil samples tested came from peatlands after the 2015 fires and those that had not experienced fires in the timeline of five years and seven years afterwards. The peatland recovery rate is based on soil physics testing characteristics including pH, water content and bulk density.

2. MATERIAL AND METHODS

This research was conducted in the Balangan River-Batangalai River, South Kalimantan, Indonesia (as seen in Figure 1). This research experimented mainly on the three physical properties of the peat soil that are pH, water content and bulk density. Location of the samples indexed as BB and there are 7 location with two categories which are post-fires conditions and non-burning condition. Main material in soil research at location BB-01; BB-02; BB-03, BB-04; BB-05 and BB-06 for post-fire conditions and BB-07; BB-08 and BB-09 for non-burning conditions. At each location, soil samples were taken at depths of 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm and 40-50 cm. Soil sampling was carried out in sunny weather conditions.

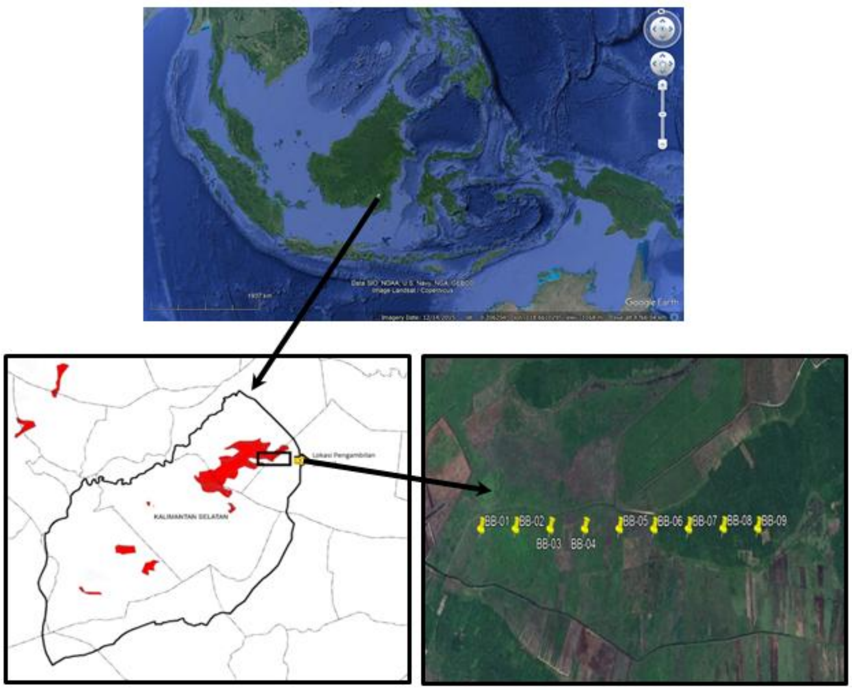

Fig. 1. Map of soil sample measurement location in South Kalimantan, Indonesia (above) and the research location of the Balangan River-Batangalai River (below) [36], [37].

The procedure for testing the pH value of soil samples starting from calibrating the pH meter next is sample preparation by inserting a 20 g soil sample into a 50 ml chemical tube by adding 20 ml reagent water and stirring for five minutes. Next step is the solution was left for about one hour, and then the pH was measured on the soil sample. Lastly, the procedure for testing soil pH was carried out according to American Society for Testing and Materials on miscellaneous materials (ASTM D) 4972-19 [38], [39].

Water content testing conducted by weighing the sample weight before and after drying. The water content formula as follows:

$$Water\ Content = \frac{weight\ of\ wet\ soil}{weight\ of\ dry\ soil} - 1 \quad (1)$$

Equation (1) is useful when standard cans are used and the tare weight is balanced in the weighing process so that the sample weight is obtained directly and multiplied by 100 brings the percentage of water in the sample based on dry mass [40].

Soil samples for bulk density testing are undisturbed soil samples and are in intact condition as good as in the field. To obtain intact soil samples and soil samples are placed in fixed tubes (rings). Total bulk density (Mg m^{-3}) was calculated by dividing the oven-dry mass by the sample volume [41] based on the formula as follows:

$$Bulk\ Density = \frac{M_s}{V_t} \quad (2)$$

This method is based on the procedure outlined in International Organization for Standardization (ISO) and requires a solid ring or volumetric cylinder to take a pressed core sample. The total volume of the soil is estimated as the internal volume of the cylinder [42]. All calculation and graphs of the obtained data were proceeded by spreadsheet software.

3. RESULTS AND DISCUSSION

Peat soil test of pH can be clearly seen in Fig. 2 (a) – Fig. 2 (c) from both the post-fire and the unburned condition. Meanwhile, Fig. 3 (a) – Fig. 3 (c) illustrates water content value of both the post-fire and the unburned condition. Finally, bulk density value presented in Fig. 4 (a) – Fig. 5 (c) both the post-fire and the unburned condition.

Fig. 2 (a) shows that the pH value at the burned locations five years after burned (2015) in 2020 (T+5) (BB-01; BB-02; BB-03; BB-04; BB-05 and BB-06) shows an average value is 2.93, which is smaller (more acidic) compared to locations that were unburned (BB-07; BB-08 and BB-09) with an average value of 3.32. During the interval, Fig. 2 (b) shows that the pH values at the burned locations in 2022 (T+7) (BB-01; BB-02; BB-03; BB-04; BB-05 and BB-06) show an average value of 3.20 which is more small (more acidic) with unburned locations (BB-07; BB-08 and BB-09) with an average value of 3.43. So the test results show that the pH value at the location after the fire is lower than the location that is unburned as in the study of [26], [27], [28], [29]. The results of an increase in the pH value at the location after the fire within a period of five to seven years were due to the remaining burning ash in which allegedly increased soil pH had disappeared.

Fig. 2 (c) shows changes in the increase in pH values in soil samples from five years after fires (T+5) and seven years after the fires (T+7). The data explains that the pH value at several locations has increased from T+5 to T+7. Changes in the increase of the pH value on the land after the BB-01 fire; BB-02; BB-03, BB-04; BB-05 and BB-06 are 8.60% and on land that did not experience fires BB-07; BB-08 and BB-09 are 3.13%.

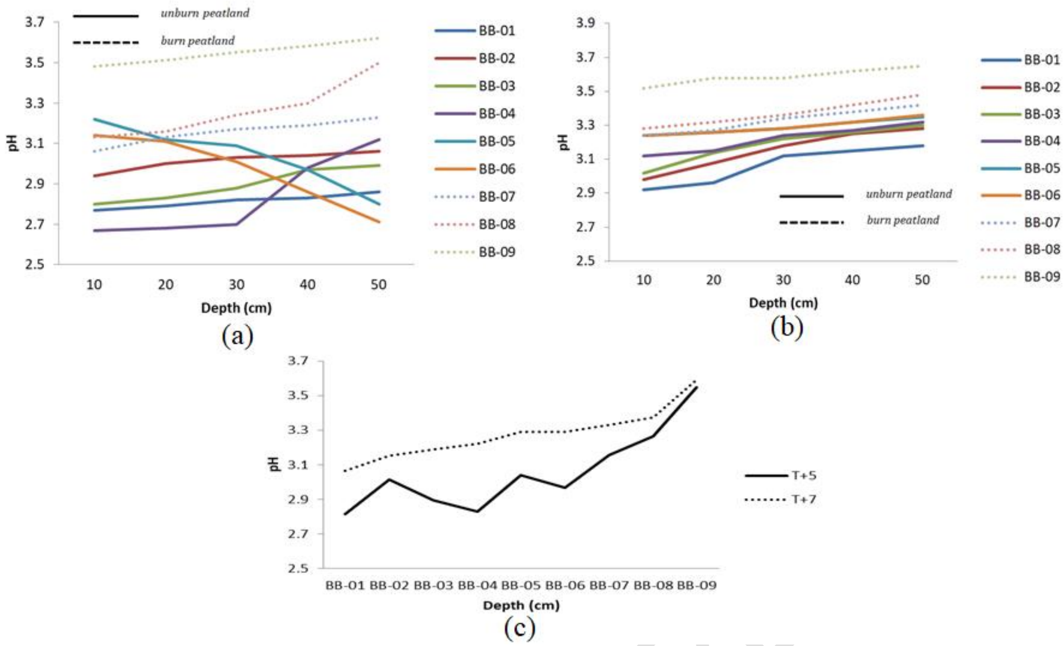

Fig. 2. (a) The pH of each location at T+5, (b) The pH of each location at T+7, (c) Changes in pH values at T+5 and T+7

Fig. 3 (a) shows that the value of water content at burned locations of (T+5) (BB-01; BB-02; BB-03; BB-04; BB-05 and BB-06) shows an average value of 270.94%, which is smaller than the unburned locations (BB-07; BB-08 and BB-09) with an average value of 342.60%. Meantime, Fig. 3 (b) shows that the value of water content at burned locations of (T+7) (BB-01; BB-02; BB-03; BB-04; BB-05 and BB-06) shows an average value of 288.22%. Which are smaller (more acidic) with locations that are unburned (BB-07; BB-08 and BB-09) with an average value of 349.94%. Fig. 3 (c) shows changes in the increase in the value of water content in soil samples from five years after the fire (T+5) and seven years after the fire (T+7). The data explains that the value of water content at several locations has increased from T+5 to T+7. Changes in the increase in the value of the water content in post-fire BB-01 land; BB-02; BB-03, BB-04; BB-05 and BB-06 by 5.99% and on land that did not experience fires BB-07; BB-08 and BB-09 by 2.10%.

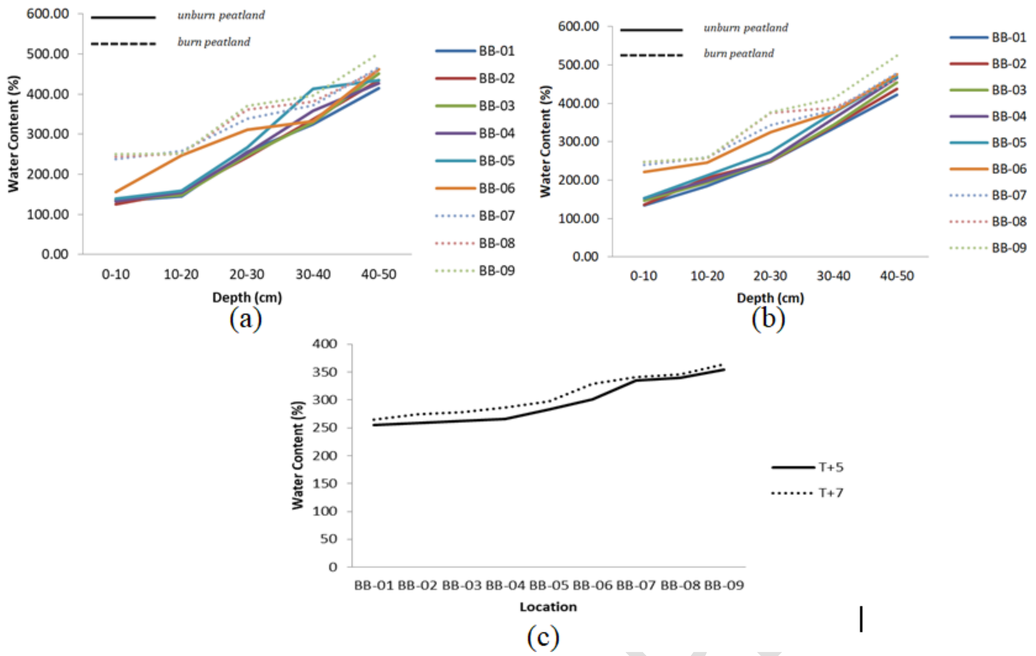

Fig. 3. (a) Water content for each location at T+5, (b) Water content for each location at T+7, (c) Changes in water content values at T+5 and T+7

Fig. 4 (a) shows that the bulk density values at the burned locations in 2015. The five years (T+5) post fire test result (BB-01; BB-02; BB-03; BB-04; BB-05 and BB-06) show an average value average 0.225 g cm^{-3} which is smaller than the unburned locations (BB-07; BB-08 and BB-09) with an average value of 0.098 g cm^{-3}. In the interval, Fig. 4 (b) shows that the bulk density values at the burned locations of (T+7) (BB-01; BB-02; BB-03; BB-04; BB-05 and BB-06) show an average value smaller average 0.165 g cm^{-3} with unburned sites (BB-07; BB-08 and BB-09) with an average value of 0.082 g cm^{-3}.

Fig. 4 (c) shows changes in the decreased in bulk density values in soil samples from five years after the fire (T+5) and seven years after the fire (T+7). The data explains that the bulk density value at several locations has decreased from T+5 to T+7. Changes in the decreased in the bulk density value in post-fire BB-01 land; BB-02; BB-03, BB-04; BB-05 and BB-06 of 36.29% and on land that did not experience fires BB-07; BB-08 and BB-09 of 19.51%.

This research is not only showing peat soil physical properties five and seven years between after burning and unburn condition, but also showing recovery of those physical properties in two years. Fig. 5 (a) (pH condition), Fig. 5 (b) (water content condition) and Fig. 5 (c) (bulk density condition) show those recoveries of the peat soil physical properties for two years in detail. Gaps of those graphs getting smaller after two years in which displaying the burn soil naturally become getting close to the unburn condition.

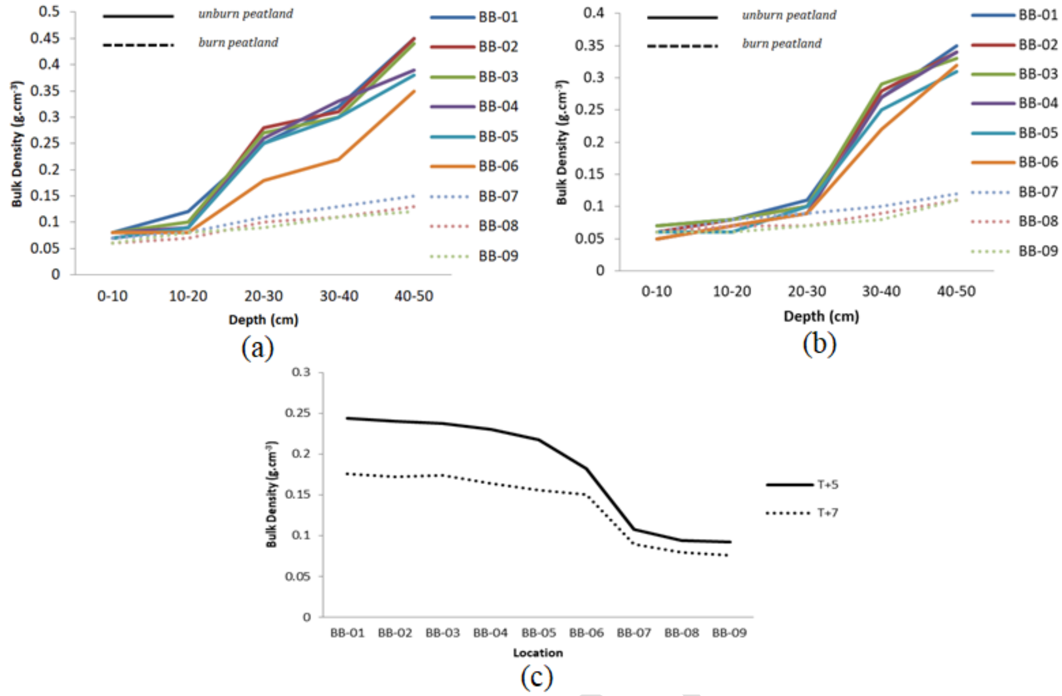

Fig. 4. (a) Bulk density for each location at T+5, (b) Bulk density for each location at T+7, (c) Changes in humidity values at T+5 and T+7

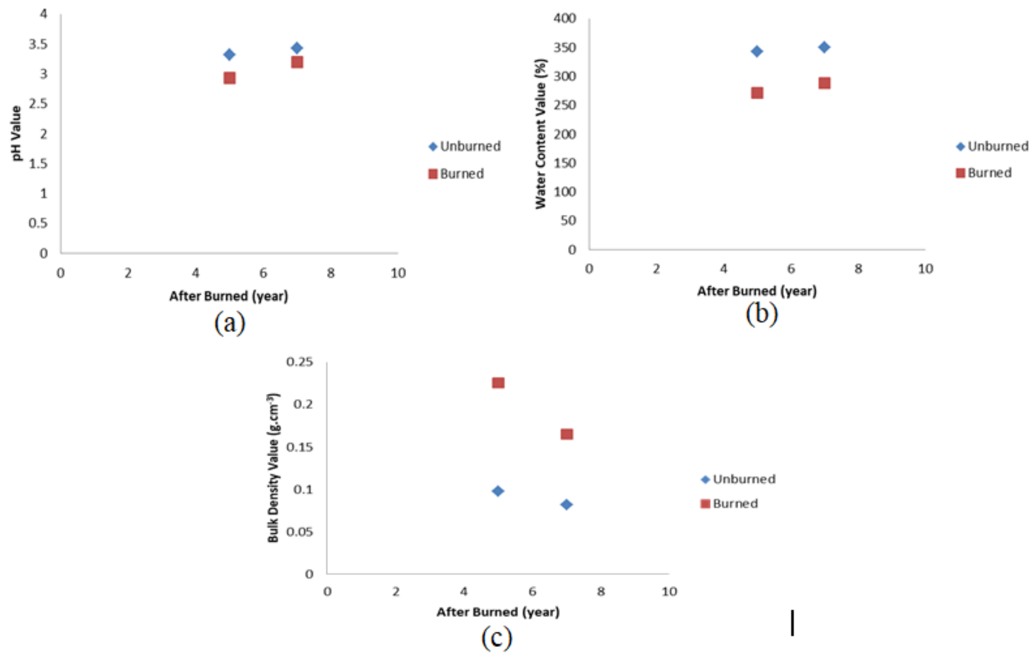

Fig. 5. (a) Soil pH recovery after fire at T+5 and T+7, (b) Post-fire recovery of soil water content at T+5 and T+7, (c) Post-fire recovery of soil bulk density at T+5 and T+7

4. CONCLUSION

This research shows recovery rate of post-fire peatlands in the Balangan River-Batangalai River, South Kalimantan. The peat soil samples tested came from peatlands after the 2015 fires and those that had not experienced fires in the timeline of five years (T+5) and seven years (T+7) afterwards. The peatland changes in the value of physical properties for five years and seven years after the fire for the pH value increased by 3.13%; the value of water content also increased by 2.10% and the value of bulk density decreased by 19.51%. To sum up, this research is able to present that the post fire peat soil naturally become getting close to the unburn condition even though it still in a degraded condition.

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