Chemistry and Microstructure of Surface Peat Soils: Implications of Pineapple Cultivation

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Abstract—Conversion of peatland into agricultural lands resulted in modification of peatland physical, chemical and biological properties [1] and has been reported in various studies [2]-[4]. Some study highlighted drainage construction changed the water table level of natural peat resulting in subsidence and release of CO₂ [5]; excessive fertilization resulted in eutrophication [6]; locations of agricultural activity as well as types of crops planted contribute towards CO₂ and N₂O emissions [5], [3]. Despite the fact most of these studies have covered various consequences related to peat land conversion; however, limited studies were conducted on tropical peat soils especially in Malaysia. In the country, approximately 50% of total peat land declared as permanent reserves while the remaining land has been opened for various purposes mainly agriculture activities and housing areas [7]. Even though some research has studied the effects and contribution of pineapple cultivation on properties changes in peat soils [8]-[10], however, most of them were conducted on well-established and large-scale pineapple plantations and additionally, microscopic study was not included. Therefore, this study was conducted to monitor the changes of chemistry and microstructures of peat soils in small scale pineapple farm. Results were compared with natural peat so the differences clearly identified.

I. INTRODUCTION

Conversion of peatland into agricultural lands resulted in modification of peat physical, chemical and biological properties [1] and has been reported in various studies [2]-[4]. Some study highlighted drainage construction changed the water table level of natural peat resulting in subsidence and release of CO₂ [5]; excessive fertilization resulted in eutrophication [6]; locations of agricultural activity as well as types of crops planted contribute towards CO₂ and N₂O emissions [5], [3]. Despite the fact most of these studies have covered various consequences related to peat land conversion; however, limited studies were conducted on tropical peat soils especially in Malaysia. In the country, approximately 50% of total peat land declared as permanent reserves while the remaining land has been opened for various purposes mainly agriculture activities and housing areas [7]. Even though some research has studied the effects and contribution of pineapple cultivation on properties changes in peat soils [8]-[10], however, most of them were conducted on well-established and large-scale pineapple plantations and additionally, microscopic study was not included. Therefore, this study was conducted to monitor the changes of chemistry and microstructures of peat soils in small scale pineapple farm. Results were compared with natural peat so the differences clearly identified.

II. MATERIALS AND METHODS

Soil samples were collected at natural peat (P1) and pineapple-cultivated peat (P2) plot on monthly basis, from January to June 2012, in a small scale pineapple farm registered under Department of Agriculture (DOA) Klang, Selangor. Samples were taken from six sampling points for each plot at a depth of approximately 0-25 cm. The samples then mixed to produce single homogenized samples and sealed tightly in air-sealed plastic bags. In laboratory, samples were oven-dried at 30°C, crushed and passed through 2mm sieves for chemical properties analysis specifically soil pH, conductivity, Cation Exchange Capacity (CEC), exchangeable K, Na, Ca and Mg, total N, total C and available P. The lab analysis was carried out at Department of Agriculture (Soil and Plant Analytical Lab), Kuala Lumpur. For FESEM study, a small portion of oven-dried samples from both plots were placed onto aluminium stub covered with double-sided carbon tape without coating as there was no surface charging occurred after initial test done. Then, the stubs were placed into Carl Zeiss, Supra 40VP FESEM (Germany) to analyze the microstructure of peat samples using 5 different magnification specifically 300x, 500x, 1.00Kx, 5.00Kx and 10.00Kx.

III. RESULTS

Table I shows the chemical composition of soil samples for both studied plots whereas Fig. 1 illustrates peat microstructure of P1 and P2 field, detected under FE-SEM using different magnification.

In natural peat (P1), water table was fluctuated at 2-40 cm during study period. Soil pH was highly acidic, ranged between pH 2.28 – pH 3.28, explained the low concentration of nutrient elements specifically total N, available P, exchangeable K, Ca, Mg and Na as shown in Table I. Microstructure analysis illustrates apparent image of elongated plant cell walls (Img. A) and peat crumbs (Img. B, C, D and E), with high amount of carbon (Table I), suggesting a slow peat decomposition. In June, a collapsed of peat structure was visible followed by noticeable released of carbon. In pineapple cultivated peat (P2), ditches constructed by farmers were approximately at 30 cm depth, with a water table fluctuating at 30-70 cm. Despite occurrence of cultivation activity, soil pH was very acidic, ranged between pH 2.61 – pH 3.56, with a significant variation in April and May

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This acidic environment restricted nutrient availability, enlightened by low concentration of nutrient elements (Table I). Evidence of peat degradation was visible in entire studied months (Img. G – Img. L), with significant peat disintegration detected in April (Img. J) and June (Img. L), illustrated by breakdown of unidentifiable plant material. In later months, most of peat structures demolished as a result of peat burning.

**TABLE I.** (1), (2). CHEMICAL COMPOSITION OF PEAT SOILS IN P1 AND P2 THROUGHOUT STUDY PERIOD

<table>
<thead>
<tr>
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<th>Jan (ppm)</th>
<th>Feb (ppm)</th>
<th>Mar (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conductivity (µS/cm)</strong></td>
<td>263±4.8 *</td>
<td>138.75 ±0.25 *</td>
<td>296.67 ±64.8 b</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>3.28±0.29 a</td>
<td>3.41±0.17 a</td>
<td>3.09±0.41 a</td>
</tr>
<tr>
<td><strong>Total C (%)</strong></td>
<td>50.54 ±15.86 a</td>
<td>48.56 ±15.49 a</td>
<td>56.48 ±9.45 a</td>
</tr>
<tr>
<td><strong>C/N ratio</strong></td>
<td>33.67 ±5.93 a</td>
<td>29.04 ±6.66 a</td>
<td>50.39 ±17.97 a</td>
</tr>
<tr>
<td><strong>CEC (cmol/kg)</strong></td>
<td>46.67 ±11.33 a</td>
<td>43.67 ±20.33 a</td>
<td>47.67 ±6.33 a</td>
</tr>
</tbody>
</table>

**TABLE I.** (1), (2). CHEMICAL COMPOSITION OF PEAT SOILS IN P1 AND P2 THROUGHOUT STUDY PERIOD

<table>
<thead>
<tr>
<th></th>
<th>Apr (ppm)</th>
<th>May (ppm)</th>
<th>Jun (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conductivity (µS/cm)</strong></td>
<td>323.65 ±173.75 b</td>
<td>316.9 ±185.55 b</td>
<td>319.35 ±122.25 b</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>3.20±0.36 a</td>
<td>2.82±0.26 a</td>
<td>2.28±0.29 a</td>
</tr>
<tr>
<td><strong>Total C (%)</strong></td>
<td>51.50 ±5.47 a</td>
<td>55.82 ±2.29 a</td>
<td>57.23 ±8.81 a</td>
</tr>
<tr>
<td><strong>C/N ratio</strong></td>
<td>38.42 ±18.8 a</td>
<td>54.10 ±18.37 a</td>
<td>46.84 ±16.03 a</td>
</tr>
<tr>
<td><strong>CEC (cmol/kg)</strong></td>
<td>51.33 ±5.33 a</td>
<td>28.67 ±10.67 a</td>
<td>45.33 ±16.67 a</td>
</tr>
</tbody>
</table>

Notes: i) P1= Plot 1, ii) P2= Plot 2, iii) Means followed by the same letter in the same row are not significantly different to each other at p>0.05.
Conversion of peat land into agricultural land has been understood in altering peat chemistry and morphology. Soil pH for both areas in this study was highly acidic, with an average pH of less than 4. This acidic environment restricted the nutrient availability in peat soils, demonstrated by low concentration of total N, available P, exchangeable K, Ca, Mg and Na. Since natural peat exhibit high water table, it is believed microbial activity was inhibited for decomposition, owing to acidic condition and low oxygen content, which has been discussed briefly by [1] in his study. In pineapple cultivated area, exposure of surface peat to aerobic environment enable active decomposition process (Image G – Image L). The later image showed the effects of peat burning, which is the routine activity of the farmer on sampling site. Disastrous collapsed and demolished of
peat microstructure donated by this activity offers a short-lived enhancement of peat soil pH, total N, available P and exchangeable bases [1], as shown in Table I. The findings was almost similar with those of [11], [12] which explain the increase of pH as well as N, P and K is owing to the increased of decomposition rate which assists in the transformations of stored nutrient into available forms. Additionally, findings by [13] demonstrate higher basic cations specifically Ca, Mg and K were released upon burning process, contributed by the burning ashes. Despite the improvement, consequences of peat burning was discussed by [1], indicates a significant peat subsidence. However, it was not thoroughly studied in this study.

Distribution of nutrients is assumed to be higher in pineapple cultivated plot as active decomposition suggested to release some nutrients into the soil through mineralization. However, the finding shows low total N, available P, exchangeable K, Ca, Mg and Na compare to natural area, as shown in Table I. Despite of low acidity, it would be due to rapid disintegration of peat materials, which reduces easily degradable compound and leaving the hardly decomposed material on the surface. Some amount of these elements may have been taken up and used by the crops without enough recovery back into the soils. Leaching possibly is one of the factors on the losses of these elements as findings from [8]-[10] demonstrated elements specifically P, K, Ca and Mg resulted from burning of pineapple residue under fertilized treatment were loss through leaching. In a study by [2], the comparison between deforested and non-deforested area had produces the similar findings even though the area and climatic factors were slightly differed. Compare to other elements, total N in peat soils under pineapple cultivation is constantly decreased throughout study period, with a loss of approximately ±0.71% and show absence of N returned to the soil. This indicates the negative balances of total N in the area, enlightened the deficiency for crops uptake. Another finding from this study reveals amount of carbon loss from burning activity in pineapple cultivated plot (±2.41%) is far lesser compare to the amount released due to water table drawdown (±12.24%) in natural peat of the same month. At this point of time, the recorded depth of water table during sampling at pineapple cultivated plot was shifted from 44 cm (May) to 67cm (June) while the natural peat recorded a shifts of 14 cm (May) to 37cm (June) of water table depth. It is typical that under anaerobic condition, amount of carbon is generally high and acted as carbon sink rather than sources. The later was briefly discussed by [14] in their study of tropical peat swamp forest. One of the reasons behind this is suggested due to characteristics of carbon under both areas; by which natural peat tend to have more persistent carbon since it was under saturated condition for almost all of the time compare to pineapple cultivated peat which is believed to have a younger carbon compound as decomposition is continuously presence. Since the former carbon is more sensitive to temperature changes [15], it is believed temperature variation created upon drawdown of water table enhance carbon loss into atmosphere.

V. CONCLUSION

This study suggested peat chemistry and microstructure had experienced a modification upon opening for pineapple cultivation. Microscopic study verified samples from pineapple field demonstrate a highly degradable peat materials compared to natural peat. Despite the presence of fertilization in pineapple plot, nutrient availability specifically total N, available P, and exchangeable K, Ca, Mg and Na is much lower than natural plot, indicating application of fertilizer in acidic environment without liming is inefficient.

ACKNOWLEDGMENT

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REFERENCES

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