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Effect of Tropical Peat Swamp Forest Clearing on Soil Carbon Storage

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Abstract: Problem Statement: Forest clearing in Tropical Peat Swamp Forest (TPSF) will affect forest soil carbon storage. Thus this study is essential to determine whether the effect of clearing of forest does to the nature of soil forest concentrating on soil carbon storage. The objectives of this study were to analyze carbon storage values in logged and clear cut TPSF and to compare these values to see whether clearing of forest will affect its soil in terms of carbon storage. **Approach:** Soil sampling was conducted in July 2009 on two different plots at Batang Igan, Sibu, Sarawak, Malaysia. The plots are secondary TPSF where this area has been logged but not been cleared while another plot is the clear cut area where the forest has been cut down and cleared for other land use. Soil samples were taken in each plot in the depth of 0-15 cm. Every sample was taken randomly by peat auger using bulking method. The soils were air dried, pounded using mortar and sieved. The bulk densities were determined by coring method. Total Carbon (TC), total Organic Matter (OM), Total Nitrogen (TN) and stable C estimation per hectare were determined from bulk density. The soil pH was determined using pH meter by using water and KCl. SOM, TC and stable C in Humic Acid (HA) were determined by loss-on ignition method. TN was determined using Micro-Kjeldahl method followed by steam distillation and titration. HA was extracted and purified using distilled water. Then, the HA were oven dried in 40^{o}C. The E_4/E_6 ratio by using spectrometer was used. Total acidity of HA which consists of carboxylic (-COOH) and phenolic (-OH) functional group were analyzed. The statistical analysis and comparison was using t-test to compare between two means. **Results:** The variables that showing the significant differences between two plots were pH water and KCl, soil OM, total C and HA yield. The insignificant differences were bulk density, total N, C/N ratio, E_4/E_6, phenol, carboxyl, total acidity and stable C. **Conclusions:** There is no significant difference between clear cut and TPSF in terms of carbon storage although TPSF had higher HA.

Key words: Forest clearing, peat swamp forest, soil carbon storage, humification

INTRODUCTION

Land use in Sarawak is developing due to changes in rural economy and transmigration of native people to big cities. Deforestation is a serious problem in Sarawak due to excessive logging, forest clearing for oil palm cultivation and mining. The changing of land cover (Salimin, 2010) mainly in tropics contributes to releasing of carbon to atmosphere from soils and vegetation (Davidson and Janssens, 2006). Environmental destruction due to logging operation should be our concern on sensitive forest site (Satrio, 2009).

About 3.3% of earth surface consists of peat lands (Firdaus, 2010) and this peat lands contain about 15-25% of earth terrestrial carbon and nitrogen (Satrio, 2009). About 2.5 million hectares of peat land can be found in Malaysia. A peat soils consists of three levels of decomposition. The fibrists are the low level of peat decomposition where the organic matter (OM) is less decomposed. Hemists are the condition where the OM is partly decomposed and saprists is the condition where the OM is mostly decomposed. Humic substances such as humic acid (HA), fulvic acid and humin are abundant in well decomposed peat soils.

In Tropical Peat Swamp Forest (TPSF), the rate of decomposition is lesser than rate of biomass production mainly from forest litter. This phenomenon is due to

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presence of high water table that prevents aerobic decomposition (Ywih, 2009; Jauhiainen *et al*., 2005). This also contributes to anaerobic decomposition where the level of oxygen present is low due to high water table. Almost all $C0_2$ are produced by root respiration and microbial decomposition of OM. But these factors are limited to water availability and abundance (Davidson and Janssens, 2006). TPSF is sensitive to water table changes. This is one of the factors that cause release of carbon.

Forest clearing will affect forest soil whether in physical, chemical and carbon storage. Thus this study is essential to determine the effect of clearing of forest on soil carbon storage. The objective of this study was to determined the effect of logging of TPSF on carbon storage.

MATERIALS AND METHODS

Soil sampling was conducted in July 2009 on two different plots at Batang Igan, Sibu, Sarawak, Malaysia. The plots were secondary TPSF where this area has been logged but not been cleared while another plot is the clear cut area where the forest has been cut down and cleared for other land use. Each area was divided into 3 plots where the size of each experimental plot was 25x50 m. Sixteen soil samples were taken in each plot in a depth of 0-15 cm. Every sample was taken randomly by using peat auger method. The soils were air dried, pounded and sieved using 2 mm sieve.

The bulk density of the soil was determined by the coring method. Total carbon (TC), total organic matter (TOM), total nitrogen (TN) and stable C estimation per hectare were determined by the bulk density method by (Firdaus, 2010). The soil pH was determined using pH meter by using water and KCl at ratio 1:2.5. SOM, TC and stable C in HA were determined by loss-on ignition method. TN was determined using Micro-Kjeldahl method followed by steam distillation and titration.

The methods of (Satrio, 2009) and modified (Susilawati *et al*., 2008) was used to extract HA using 4 h for extraction and 2 h for fractionation. For purification, modified method by (Ywih, 2009) using distilled water was carried out to purify HA. Then, the HA were oven dried at 40°C. The E_4/E_6 ratio by using spectrometer was used to determine the humification level of HA. The wavelengths used were 465 and 665 nm (Ywih, 2009). The methods of (Ywih, 2009) were used to determine the total acidity of HA which consisted of carboxylic (-COOH) and phenolic (-OH) functional group.

T-test was used to compare means. Statistical System Analysis (SAS) version 9.1 was used (SAS, 2001).

RESULTS

Table 1 shows the selected soil physical and chemical properties of TPSF in clear cut area and secondary TPSF. The pH of both areas are in the usual range of peat soils (Fiore, 2009). There were significant differences in both pH in both areas. For pH (water and KCl), the clear cut area was significantly higher than the secondary TPSF.

There were significant difference in the percentage of total C and OM. The total C and OM in the secondary TPSF were higher than that of clear cut.

The percentage of total N in both areas is not significant where the secondary TPSF contain high percentage of total N (1.04%) than in clear cut area (0.94%).

Total N, bulk density and C/N ratios of both areas were not significantly different (Table 1).

Table 1: Selected soil physical and chemical properties of TPSF in clear cut area and secondary TPSF

Variables	Clear cut	Secondary TPSF
pH water	3.22[a]	3.00[b]
pH KCl	2.54[a]	2.21[b]
Total N %	0.94[a]	1.04[a]
Total N (Mg/ha)	225.41[a]	270.96[a]
Bulk density (g cm^{-3})	0.16[a]	0.17[a]
Bulk density (Mg/ha)	240.56[a]	261.66[a]
Soil OM %	94.53[b]	96.84[a]
Soil OM (Mg/ha)	22740[b]	25338[a]
Total C %	47.26[b]	48.42[a]
Total C (Mg/ha)	11370[b]	12669[a]
C/N ratio %	52.66[a]	51.23[a]

Note: Means within column with different letters indicate significant difference between areas by independent t-test at $p \leq 0.05$

Table 2: Comparison of HA and carbon storage estimation from clear cut and secondary TPSF with related reports

Variables	Clear cut	Secondary TPSF	Range*
HA %	23.63[b]	25.93[a]	
HA (Mg/ha)	5684.9[b]	6785.9[a]	
E_4/E_6	7.75[a]	7.87[a]	6-8
Total acidity (cmol kg^{-1})	757.81[a]	754.69[a]	390-980
Phenol (cmol kg^{-1})	273.96[a]	276.04[a]	150-440
Carboxyl (cmol kg^{-1})	483.85[a]	478.65[a]	240-540
Stable C (Mg ha^{-1})	51.24[a]	61.88[a]	

Note: Means within column with different letters indicate significant difference between areas by independent t-test at $p \leq 0.05$

* (Anton, 2009),(Ywih, 2009)

Table 2 shows the comparison of HA and carbon storage for clear cut and secondary TPSF. The HA of the secondary TPSF was higher than clear cut area.

The stable C of HA, total acidity, E_4/E_6, phenolic and carboxylic functional groups were similar (Table 2).

Stable C of both sites was not significant. The stable C estimation of secondary TPSF were insignificantly higher than clear cut area.

DISCUSSION

pH of both areas using both methods gives higher pH values in clear cut area than in secondary TPSF. This phenomenon was due to leaching of basic cations in clear cut area due to removal of trees. Without forest trees to standardize the pH, the pH in soil of clear cut area was high. The pH was found in range from 3.0-3.22 reported by (Ywih, 2009). The high acidic values in pH of KCl method show that the KCl was efficient in replacing hydrogen ions. The variations which is significant between both sites were due to specific locations of peat swamp (Andriesse, 1988). The low pH was due to thickest section of peat compared to the shallow organic soils near the edge.

The bulk density of both sites ranging from 0.07-0.17 g cm^{-3} suggests that the peat is partially decomposed. The higher bulk density values in secondary TPSF than in clear cut were due to the soil was compacted in natural order due to presence of trees. When the trees were removed due to logging, the soil was slightly but not significantly compact anymore. Usage of heavy machinery in secondary TPSF to take out the logged trees also contributed to the slightly higher but not significant bulk density values in secondary TPSF.

The soil OM in secondary TPSF was higher than in clear cut area were due to high organic matter that still not well decomposed. The presence of unlogged trees, low temperature and also high water table contribute to the low rate of decomposition. Different observations were found in clear cut area. There are high rate of decomposition of OM due to absence of forest trees, high temperature and dry soil.

There were significant differences in total C of both sites. The total C in secondary TPSF was higher than TC in clear cut area. This observation can be ascribed to the same significant difference in soil OM. According to (Satrio, 2009), this observation was consistent that soil OM is a major source of carbon source and sink.

The total N of both sites was not significant. The value of TN in secondary TPSF was slightly higher but not significant than clear cut area. The high value in secondary TPSF was due to accumulation of N. The accumulation mainly contributes from the presence of still unlogged forest trees that regulates the N content in the soil. While the low value of total N in clear cut area showed that the N content in the soil was leached. This leached N mainly due to unavailable of forest trees that is essential for regulating and stabilizing soil N content. The released of N to atmosphere in ammonia (NH_3) gaseous form also contribute to the low level of total N.

The level of humification in both sites was not significant based on its C/N ratio. While it is not significant, the C/N ratio in clear cut area was higher than in secondary TPSF. This can be explained due to the leaching of N in clear cut and accumulation of N in secondary TPSF.

The percentage of HA yield in both area was statistically different. Yield of HA in secondary TPSF were higher compared to clear cut area. These findings were mainly because the level of soil OM also corresponds to HA yield. When OM increase, the HA yield also increase and vice versa. Efficient conversion of organic C to humus C or also called biomass humification process mostly depends on low total N. But different cases were recorded in this experiment. In clear cut area, total N were low but not significant when compared to secondary TPSF. Since low total N should give more humification and then more yield of HA, but yield of HA in clear cut were low. This is because lack of vegetative plants that inhibits in this area and may influence the release of N to atmosphere in the form of ammonia gases. Type of peat also contribute to the low N and low HA yield. Since low N should give higher HA yield, the result shows differently. These were caused by the woody peat in clear cut area. Peat that have slow rate of decomposition due to hardness of wood makes the OM and HA present in that area as shown in the results. Low OM level in clear cut also influence the HA yield.

Stable C estimation was essential in determining the carbon storage values in the soil. Stable C is the carbon that most stable in the soil. It was extracted from HA yield where HA also is the most stable organic compound in the soil. Thus, this variable is the most important variable that needs to determine in this study.

E4/E6 values in secondary TPSF were slightly higher but insignificant than values in clear cut. This means that presence of aliphatic compounds in HA of secondary TPSF were slightly higher but not significant than in clear cut HA (Ywih, 2009).

The carboxylic-COOH, phenolic-OH and total acidity values of HA in secondary TPSF and clear cut are in range reported with other researchers (Fong and Mohamed, 2007). This parameters were done to check the HA purity. Since the values are not significant between both areas, the HA produced were pure supported by the values are in standard range.

CONCLUSION

There is no significant difference between clear cut and TPSF in terms of carbon storage although TPSF had higher HA.

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REFERENCES

Andriesse, J.P., 1988. Nature and management of tropical peat soil. FAO Soils Bulletin 59. FAO., Rome. ISBN: 92-5-102657-2, pp: 178.

Davidson, E.A. and Janssens, I.A., 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Rev. Nat. Publish. Group, 440: 165-173. DOI: 10.1038/nature04514

Fiore, S. and M.C. Zanetti, 2009. Sorption of phenols: Influence of groundwater pH and of soil organic carbon content. Am. J. Environ. Sci., 5: 547-555. DOI**:** 10.3844/.2009.547.555

Firdaus, M.S., S. Gandaseca, O.H. Ahmed and N.M.A. Majid, 2010. Effect of Converting Secondary Tropical Peat Swamp Forest into Oil Palm Plantation on Selected Peat Soil Physical Properties. Am. J. Environ. Sci., 6: 402-405. DOI**:** 10.3844/.2010.402.405

Fong, S.S. and M. Mohamed, 2007. Chemical characterization of humic substances occurring in the peats of Sarawak, Malaysia. Organ. Geochem., 38: 967-976. DOI: 10.1016/j.orggeochem.2006.12.010

Jauhiainen, J., H. Takahashi, J.E.P. Heikkinen, P.J. Martikainen and H. Vasanders, 2005. Carbon fluxes from tropical peat swamp forest floor. Global Change Biol., 11: 1788-1797. DOI: 10.1111/j.1365-2486.2005.01031.x

Salimin, M.I., S. Gandaseca, O.H. Ahmed and N.M.A. Majid, 2010. Comparison of selected chemical properties of peat swamp soil before and after timber harvesting. Am. J. Environ. Sci., 6: 164-167. DOI**:** 10.3844/.2010.164.167

SAS., 2001. SAS/STAT Software. SAS Institute, Cary, NC. ISBN: 10: 1580258506

Satrio, A.E., S. Gandaseca, O.H. Ahmed and N.M.A. Majid, 2009. Effect of precipitation fluctuation on soil carbon storage of a tropical peat swamp forest. Am. J. Applied Sci., 6: 1484-1488. DOI**:** 10.3844/.2009.1484.1488

Susilawati, K., O.H. Ahmed, A.B. Nik Muhamad and M.Y. Khanif, 2008. Simple method of purifying humic acids isolated from tropical hemists (peat soil). Am. J. Applied Sci., 5: 1812-1815. http://www.scipub.org/fulltext/ajas/ajas5121812-1815.pdf

Ywih, C.H., O.H. Ahmed, N.M.A. Majid and M.B. Jalloh, 2009. Effects of Converting Secondary Forest on Tropical Peat Soil to Oil Palm Plantation on Carbon Storage. Am. J. Agri. Bio. Sci., 4: 123-130. DOI: 10.3844/.2009.123.130