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Influence of Chemical Properties on Soil Carbon Storage of a Tropical Peat Swamp Forest

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Abstract: Problem statement: It is important to investigate the seriousness of degradation of peat swamp forest caused by skidding system in terms of its function as a carbon sink. In this study, we formulated assumptions that conditions of our research site before the introduction of skidding system were in their natural states, thus that changes measured are clearly caused by skidding system. The objective of this study was to determine soil carbon storage of a tropical peat swamp forest in their natural state. **Approach:** Peat soil samples and bulk density were taken at 0-15 cm in a 0.3 ha plot at Sibu, Sarawak, Malaysia. The soil samples were analyzed for acidity, organic matter content, total carbon and total nitrogen. The humic acid extraction was also done and soil carbon storage values obtained by calculation. The calculation of carbon storage was by the bulk density method. Correlation analysis was used where applicable using Statistical Analysis System (SAS) version 9.1. **Results:** The results indicated that this tropical peat swamp forest rich in soil organic matter (97.645 %) but had extreme acidic environment (pH 3.737), thereby inhibiting organic matter decomposition rates. This tropical peat swamp forest also had large amounts of total carbon (48.823 %), low mineral nitrogen (0.896 %) and high C/N ratio (58.427). Stable carbon (soil carbon storage) positively correlated with unstable carbon ($p<0.01$, $r = 0.43$). The value of soil carbon storage was found to be 67.550 Mg Ha^{-1} (±61.49 % of unstable carbon). Furthermore, soil carbon storage positively correlated with soil organic matter ($p<0.01$, $r = 0.43$), total carbon ($p<0.01$, $r = 0.43$) and humic acid yield ($p<0.01$, $r = 1.00$). However, soil carbon storage negatively correlated with soil acidity ($p<0.01$, $r = -0.55$). **Conclusion:** From the results, it can be concluded that the tropical peat swamp forest indicates its specific natural state. This natural tropical peat swamp forest plays an important role as a sink rather than a source of carbon. The soil carbon storage in this natural tropical peat swamp forest was derived from unstable carbon and sensitive to soil acidity.

Key words: Peat swamp forest, soil acidity, soil organic matter, total carbon, C/N ratio, carbon sink, humic acid, soil carbon storage

INTRODUCTION

Carbon emissions to the atmosphere from land cover change and management are concentrated in the tropics and influence environmental services and human needs in various ways[1]. About 20 times more carbon is released to the atmosphere from the earth's vegetation and soils than is released from fossil fuels[2].

Peat swamp forests worldwide are recognized to play a vital role in maintaining carbon balance and maintaining ideal global temperature as well as one of the largest carbon stores of the world[3]. However, these ecologically vital forests are under various threats, particularly land use changes. For instance tropical peat swamp forests in Sarawak are steadily shrinking. The most threat to these ecosystems in Sarawak is caused by land use changes including deforestation.

There is little published data on the effect of skidding system on soil carbon storage of Sarawak's peat swamp forests. Furthermore, there is no study that compares the damage level caused by "kuda-kuda" system and conventional machine based system (excavator system) on peat swamp forests. Hence, it is important to investigate the seriousness of degradation of peat swamp forest caused by skidding system in terms of its function as a carbon sink. In this study, we formulated

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assumptions that conditions of our research site before the introduction of skidding system were in their natural states, thus that changes measured are clearly caused by skidding system. Therefore, the objective of this study was to determine the soil carbon storage of tropical peat swamp forest in their natural state.

MATERIALS AND METHODS

Peat soil samples and bulk density were taken at 0-15 cm in a 0.3 ha plot at Sibu, Sarawak, Malaysia. The soil pH was determined by the method outlined by Matthiessen[4]. The loss on ignition method was used to determine total C[3]. Total nitrogen was determined by standard Kjeldahl method[5]. The humic acid extraction was carried out by the methods of Stevenson[6] and Susilawati *et al*.[7]. The calculation of carbon storage was done by the bulk density method. The correlations between variables were analyzed statistically using Statistical Analysis System (SAS) version 9.1.

RESULTS

The bulk density of the study site was 0.15 g cm^{-3}. The results in Table 1 show that all variables were found to be within the range except the C/N ratio[12,13].

The long term carbon storage in this peat swamp forest was found to be 67.550 Mg Ha^{-1} (Table 2).

Table 1: Soil chemical and physical properties of tropical peat swamp forest

Variable	Average obtained	Typical standard range
Bulk density (g cm^{-3})	0.150	0.1-0.2[8]
Soil acidity (pH)	3.737	3.2-4.0[11]
Soil organic matter (%)	97.645	>90.0[12]
C (%)	48.823	12.0-57.0[3]
N (%)	0.896	0.5-2.05[11]
C/N ratio	58.427	20.0[9]-46.3[13]

Table 2: Carbon sequestration in tropical peat swamp forest

Variable	Average obtained
Unstable C (Mg Ha^{-1})	109.851
Stable C (Mg Ha^{-1})	67.550

Table 3: Correlation between unstable C, stable C and some selected chemical properties of a tropical peat swamp forest

Variable	SOM	C	C/N ratio	Unstable C	Stable C
pH	-0.4400	-0.4400		-0.4400	-0.5500
	0.0034	0.0034		0.0034	0.0001
SOM		1.0000		1.0000	0.4300
		<0.0001		<0.0001	0.0040
C				1.0000	0.4300
				<0.0001	0.0040
N			-0.9600		
			<0.0001		
Humic				0.430	1.0000
acid				0.004	<0.0001
Stable C				0.430	
				0.004	

Note: The top value represents Pearson's correlation coefficient (r) and the bottom values represent the probability level

The correlations between variables is shown in Table 3. Both unstable and stable carbon positively correlated with soil organic matter, total carbon and humic acid yield (Table 3). Both unstable and stable carbon negatively correlated with soil acidity (Table 3).

DISCUSSION

The bulk density of organic soils is largely determined by the ash content and the degree of decomposition. The bulk density of the study site was typical of natural tropical peat swamp forest in Sarawak[8] with high sapric materials and very low ash content[9]. A high value of soil organic matter is another indication that this peat swamp forest has very low ash content. The high value of the soil organic matter suggests favorable accumulation of biota than their decay by microbial activities which lead to excessive CO_2 evolution[3]. Inversely, the decline of soil organic matter affects soil fertility and increases CO_2 emission into the atmosphere, which may lead to global climate change[10].

Another indication of the natural state of the tropical peat swamp forest in Sarawak is its pH. This soil acidity negatively correlated with soil organic matter. It suggests that the decline of soil organic matter increases soil pH and vice versa. This is because organic matter is a source of H^+ ions and contributes to acidify the soil. Organic matter contains numerous acid functional groups from which these ions can dissociate[3].

Total carbon positively correlated with soil organic matter. The total carbon also negatively correlated with soil acidity. This is because; in a peat soil large amounts of carbon accumulate as soil organic matter[3]. Hence, soil acidity has association with total carbon as well as with soil organic matter.

The nitrogen of this peat swamp forest was found to be within the range of shallow peat[11]. This also indicates that our research site has very low mineral nitrogen (NH_4^+ or NO_3^-) which is important for plant growth[3]. However, in this strongly acidic and anaerobic or flooded soil, the population of nitrifying bacteria is usually small or absent. Hence, the amount of ammonium-N in this soil was considerably greater than that of nitrate-N because of the low nitrification activity[10]. Furthermore, this low amount of nitrogen in surface peat is sensitive to water table level. Since our site has high total carbon and low total nitrogen value, thus the C/N ratio value was high. However, nitrogen was found to be fluctuating rather than carbon, thus the C/N ratio negatively correlated with total nitrogen. This high C/N ratio markedly slows the decomposition process and causing organic matter to accumulate while reducing the availability of nutrients. It also suggests

that the organic residues may have high contents of lignin and polyphenols[14].

Tropical peat swamp forests play a very important role in the global carbon balance and forecasting future CO_2 levels. In our preliminary research, we separated the carbon stores in peat swamp forest into unstable carbon and stable carbon. It was found that stable carbon positively correlated with unstable carbon. Availability of large amounts of the unstable carbon stocks tends to remain as stable carbon rather than decomposes and releases as carbon dioxide. Unstable carbon in the soil organic matter decomposes and releases carbon dioxide by oxidation and remaining the stable carbon. Stable carbon refers to a long term carbon which is sequester in soil[3].

It was found that 61.49% of unstable carbon remains in the soil as stable carbon. This high value of stable carbon agreed with the generally accepted idea that this natural tropical peat swamp forest plays an important role as a sink rather than a source of carbon.

Unstable carbon associated well with soil organic matter and total carbon whereas stable carbon associated well with humic acid yield. These findings suggests that humic acids are extremely stable form of soil organic matter[15]. Moreover, large amounts of stable carbon in the earth found as humic acids[16].

Stable carbon associated well with soil acidity. The acidic and anaerobic environments retard the rate of decomposition of organic materials. Thus, organic matter preserved as stable carbon in peat profiles for millennia and allow this ecosystem continue to represent a sink for carbon[17].

CONCLUSION

The tropical peat swamp forest indicates its specific natural state such as rich in soil organic matter but has extreme acidic environment, thereby inhibiting organic matter decomposition rates. This tropical peat swamp forest also has large amounts of total carbon, low mineral nitrogen and high C/N ratio.

The soil carbon storage in this tropical peat swamp forest relates to unstable carbon. Furthermore, a high value of soil carbon storage (±61.49% of unstable carbon) in this peat swamp forest soil indicates that this natural tropical peat swamp forest plays an important role as a sink rather than a source of carbon.

The soil carbon storage in this tropical peat swamp forest is derived from unstable carbon and sensitive to soil acidity wherein the acidic environment may preserve it for long term period and allow this ecosystem continue to store carbon.

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