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# Effect of Precipitation Fluctuation on Soil Carbon Storage of a Tropical Peat Swamp Forest

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**Abstract: Problem statement:** It is important to compare the effect of extremely different rainfall conditions on soil carbon storage of lowland tropical peat swamp forest. Therefore, under these natural rainfall gradient, the objectives of this study were to determine whether rainfall affects soil carbon storage of a tropical peat swamp forest and to determine what correlations between variables occurs which stimulate soil carbon storage changes of a tropical peat swamp forest. **Approach:** Soil sampling was conducted in two different plots (0.3 ha each plot) to a depth of 15 cm under two extremely different mean rainfall at Sibu, Sarawak, Malaysia. The soil samples were analyzed for acidity, organic matter content, total carbon, total nitrogen and total phosphorus. The humic acid extraction was also done and soil carbon storage values were obtained by calculation. The calculation of carbon storage was by the bulk density method. Comparison between paired means of soil carbon storage under two different rainfall gradients were tested using paired t-test and correlation analysis was used to correlate variables (pH, soil organic matter, total carbon, total nitrogen, total phosphorus, C/N ratio, C/P ratio, humic acid yield, unstable carbon and stable carbon). **Results:** The percentage of stable carbon count of unstable carbon was 42.93% under lower rainfall, while that of higher rainfall was 62.69 %. It suggests that this natural tropical peat swamp forest plays an important role as a sink rather than a source of carbon under higher rainfall but inversely under lower rainfall. It also suggests that soil organic matter tends to decompose and releases $CO_2$ by oxidation under lower rainfall. Stable carbon positively correlated with humic acid yield for the two areas with different rainfall ($p<0.01$, $r = 1.00$). However, under higher rainfall, stable carbon also positively correlated with soil organic matter ($p<0.05$, $r = 0.42$) and total carbon ($p<0.05$, $r = 0.42$). It was found that stable carbon negatively correlated with soil acidity on both higher ($p<0.05$, $r = -0.51$) and lower rainfall areas ($p<0.01$, $r = -0.54$). However, that association appeared prominent under lower rainfall. **Conclusion:** Anaerobic environment is more prominent under higher rainfall and may facilitate high value of soil carbon storage in the soil profile of tropical peat swamp forest and allow this ecosystem to function as a carbon sink. During lower rainfall, water availability in tropical peat swamp forest may stimulate this ecosystem to maintain its soil acidity by releasing more $CO_2$ in soil air and becomes a source rather than a sink of carbon.

**Key words:** Peat swamp forest, soil acidity, soil organic matter, soil organic carbon, nitrogen, phosphorus, carbon sink, humic acid, soil carbon storage, rainfall

## INTRODUCTION

Conditions in peatland where anaerobic frequently persists, poor drainage and aeration are unfavorable for decomposition, resulting in high carbon densities[8]. In tropical peat swamp forest, those conditions also occur, because substantial rainfall provide appropriate condition for such condition and substrate acidification also may occur[11]. Tropical peat swamp forests in Sarawak are influenced by a climate that is hot and humid throughout the year with annual rainfall exceeding 2000 mm with little temperature variation (27±5°C). Under these conditions, aerobic degradation may become more prominent compared to temperate regions[9]. Furthermore, that temperature of tropical

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peat swamp forest considered high and it is ideal for efficient gas formation throughout the year. Although that temperature can be equable, the amounts of rainfall varies markedly daily and annually[11]. According to Chimner[12], tropical peatlands are constantly subject to relatively high temperatures compared to cooler seasonal climate areas, therefore show a potentially higher carbon release in decomposition. However, the water level has more important role than temperature in the abiotic control of gas fluxes between the peat and the atmosphere in the tropical region[11].

Water is a resource that modulates ecosystem processes such as diffusion within the soil and leaching of materials across ecosystem boundaries. Water also has indirect effect on biotic processes such as altering of pH, nutrient availability, soil oxygen, soil weathering and mineralogy[10]. As the main product of decomposition in soil, $CO_2$ is almost entirely produced from root respiration and microbial decomposition of organic matter. Both, root respiration and microbial decomposition are subject to water limitation[8]. Moreover, hydrological conditions are one of the most dominant carbon release controlling factor. Tropical peat swamp forest is sensitive to water table changes. When the precipitation frequency is smaller, lowered water table occur and could increase substrate availability for $CO_2$ releasing decomposition processes[11]. Therefore, when studying soil carbon storage alteration on tropical peat swamp forest, it is relevant to focus on precipitation.

We compared the effect of extremely different rainfall conditions on soil carbon storage of lowland tropical peat swamp forest. Therefore, under these natural rainfall gradient, the objectives of this study were (i) To determine whether rainfall affects the soil carbon storage of a tropical peat swamp forest and (ii) To determine what correlations between variables occurs which stimulate soil carbon storage changes of a tropical peat swamp forest.

## MATERIALS AND METHODS

Soil sampling was conducted in January and March 2008 on two different plots (0.3 ha each plot) to a depth of 15 cm at Sibu, Sarawak, Malaysia. Mean rainfall on January was 6.6 mm $day^{-1}$ while in March, it was 12.0 mm $day^{-1}$.

The potentiometric method was used to determine soil pH[1]. The loss on ignition method was used to determine total C[1]. Total nitrogen was determined by Kjeldahl method[3]. Total phosphorus was determined by Aqua Regia method and Murphy and Riley method[15]. Humic acid extraction was carried out by the methods of Stevenson[4] and Susilawati *et al*[5]. The calculation of carbon storage was done by the bulk density method. Comparison between paired means of soil carbon storage under the two different rainfall gradients were tested using paired t-test and correlation analysis was used to correlate variables (pH, soil organic matter, total carbon, total nitrogen, total phosphorus, C/N ratio, C/P ratio, humic acid yield, unstable carbon and stable carbon). The Statistical Analysis System (SAS) version 9.1, was used for the aforementioned analysis.

## RESULTS

The bulk density of the study site was 0.15 g $cm^{-3}$. The selected soil chemical properties showed little variation except total phosphorus and C/P ratio (Table 1).

The percentage of stable carbon count of unstable carbon was 42.93 % in January, while that of March was 62.69 % (Table 2).

The correlation between variables is shown in Table 3.

Table 1: Selected soil chemical properties under different gradient rainfall

| | Mean | |
|---|---|---|
| Variable | January | March |
| Soil acidity (pH) | $3.696^a$ | $3.676^a$ |
| Soil organic matter (%) | $97.319^a$ | $97.695^a$ |
| C (%) | $48.659^a$ | $48.847^a$ |
| N (%) | $0.960^a$ | $0.896^a$ |
| P (%) | $0.034^a$ | $0.022^b$ |
| C/N ratio | $55.654^a$ | $59.268^a$ |
| C/P ratio | $1457.619^a$ | $2625.861^b$ |

**Note:** Means with the same letter are not significantly different at p = 0.05 using paired t-test

Table 2: Carbon storage in tropical peat swamp forest

| | Mean (Mg $Ha^{-1}$) | |
|---|---|---|
| Variable | Jan | Mar |
| Unstable C | $109.483^a$ | $109.907^a$ |
| Stable C | $47.004^a$ | $68.898^b$ |
| Stable C/Unstable C (%) | 42.930 | 62.690 |

**Note:** Means with the same letter are not significantly different at p = 0.05 using paired t-test

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

| Variable | pH | SOM | C | P | C/N ratio | Unstable C | Stable C |
|---|---|---|---|---|---|---|---|
| **January** | | | | | | | |
| pH | | -<br>- | -<br>- | | | -<br>- | -0.5400<br>0.0063 |
| SOM | | | 1.0000<br><0.0001 | | | 1.0000<br><0.0001 | -<br>- |
| C | | | | | | 1.0000<br><0.0001 | -<br>- |
| N | | | | | -0.9500<br><0.0001 | | |
| P | | -0.5700<br>0.0036 | -0.5700<br>0.0036 | | | -0.5700<br>0.0036 | |
| C/P ratio | | 0.5700<br>0.0036 | 0.5700<br>0.0036 | -0.9900<br><0.0001 | | 0.5700<br>0.0036 | |
| Humic acid | -0.5400<br>0.0063 | -<br>- | -<br>- | | | -<br>- | 1.0000<br><0.0001 |
| Stable C | | | | | | - | |
| **March** | | | | | | | |
| pH | | -0.4900<br>0.0160 | -0.4900<br>0.0160 | | | -0.4900<br>0.0160 | -0.5100<br>0.0118 |
| SOM | | | 1.0000<br><.0001 | | | 1.0000<br><.0001 | 0.4200<br>0.0425 |
| C | | | | | | 1.0000<br><0.0001 | 0.4200<br>0.0425 |
| N | | | | | -0.9600<br><.0001 | | |
| P | | -<br>- | -<br>- | | | -<br>- | |
| C/P ratio | | -<br>- | -<br>- | -0.9200<br><.0001 | | -<br>- | |
| Humic acid | -0.5100<br>0.0118 | 0.4200<br>0.0425 | 0.4200<br>0.0425 | | | 0.4200<br>0.0426 | 1.0000<br><0.0001 |
| Stable C | | | | | | 0.4200<br>0.0425 | |

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

## DISCUSSION

Mean rainfall almost doubled from 6.6 mm $day^{-1}$ in January to 12.0 mm $day^{-1}$ in March. Furthermore, there was more rainfall in March and it fluctuated considerably than that in January (Fig. 1). This fluctuation seems to increase C/P ratio, but decreased total phosphorus (Table 1).

It was found that under higher rainfall, soil acidity negatively correlated with soil organic matter (Table 3). 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[1]. The soil acidity also negatively correlated with total carbon (Table 3). This is because; in peat soils large amounts of carbon accumulate as soil organic matter[1]. Hence, soil acidity has association with total carbon as well as with soil organic matter. Obviously, those observations did not occur for low rainfall. However, this ecosystem still maintained its soil acidity (Table 1). During this time, high level of $CO_2$ is produced in soil air by root and microbial decomposition of soil organic matter. Further,

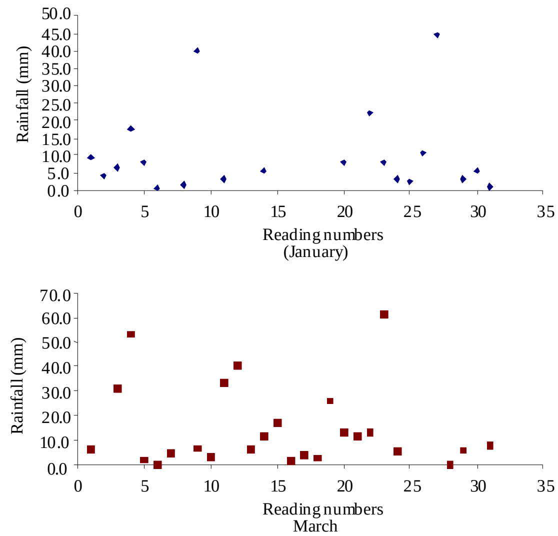


Fig. 1: Daily rainfall fluctuation for January and March

$CO_2$ dissolves in water and acidify the soil[1]. The association between total carbon and soil organic matter seems not to be influenced by rainfall. In all sites, total carbon positively correlated with soil organic matter (Table 3).

Since our site had high total carbon and low total nitrogen value, thus the C/N ratio value was high. However, nitrogen was found to be fluctuating instead of carbon, thus the C/N ratio negatively correlated with total nitrogen (Table 3). 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[2].

It was found that under lower rainfall, soil organic matter and total carbon negatively correlated with total phosphorus but positively correlated with C/P ratio (Table 3). Moreover, unstable carbon negatively correlated with total phosphorus but positively correlated with C/P ratio under lower rainfall (Table 3). It suggests that increase in phosphorus under lower rainfall (Table 1) appears to increase the decomposition rate[14] and may drive soil organic matter and soil carbon losses[13], particularly unstable carbon. Decomposition rates increase stimulates soil carbon losses by supplying soil oxygen availability to biological processes. Moreover, the most important effect of variation in water on carbon cycling appears to be its control on the diffusion of oxygen into the soil[10]. Total phosphorus in January and March was significantly different, while total carbon similar (Table 1). Thus, the C/P ratio negatively correlated with total phosphorus on both gradient of rainfall (Table 3).

It was found that stable carbon positively correlated with unstable carbon under higher rainfall (Table 3). Availability of large amounts of the unstable carbon stocks tends to remain as stable carbon instead of $CO_2$ evolution through decomposition. Unstable carbon in the soil organic matter decomposes and releases carbon dioxide by oxidation and remaining being stable carbon. Stable carbon refers to the long term carbon which is sequestered in the soil[1]. However, stable carbon had no association with unstable carbon under lower rainfall.

The high value of stable carbon under higher rainfall (Table 2) suggests that this natural tropical peat swamp forest plays an important role as a sink rather than a source of carbon. Inversely, this ecosystem has role as a source of carbon under lower rainfall. It also suggests that soil organic matter tends to decompose and releases $CO_2$ by oxidation under lower rainfall.

Under higher rainfall, both unstable and stable carbon positively correlated with soil organic matter, total carbon and humic acid. However, unstable carbon associated well with soil organic matter and total carbon whereas stable carbon associated well with humic acid (Table 3). Furthermore, under lower rainfall, the association of unstable carbon with soil organic matter and total carbon was prominently (Table 3). Stable carbon also associated well with humic acid under lower rainfall (Table 3). These findings suggest that humic acids are extremely stable form of soil organic matter[6]. Moreover, large amounts of stable carbon on earth is found as humic acids[7].

It was found that under higher rainfall, both unstable and stable carbon negatively correlated with soil acidity. However, stable carbon associated well with soil acidity (Table 3). Stable carbon and soil acidity also negatively correlated under lower rainfall (Table 3). However, that association appeared prominent in January (Table 3). It suggests that more anaerobic environments (more additional water) play an important role in retarding the rate of decomposition of organic materials to represent a sink for carbon rather than acidic condition.

## CONCLUSION

Anaerobic environment is more prominent under higher rainfall and may facilitate high value of soil carbon storage in the soil profile of tropical peat swamp forest and allow this ecosystem to function as a carbon sink.

During lower rainfall, water availability in tropical peat swamp forest may stimulate this ecosystem to maintain its soil acidity by releasing more $CO_2$ in soil air and becomes a source rather than a sink of carbon.

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