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NET ECOSYSTEM CO_2 EXCHANGE OF A TROPICAL PEAT SWAMP FOREST IN SARAWAK, MALAYSIA

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SUMMARY

This paper presents the results of a year-long study of the net ecosystem CO_2 exchange (NEE) of a tropical peat swamp forest in Sarawak, Malaysia using the eddy covariance method. The diurnal pattern of NEE showed that a peak that typically occurred between 07:30 and 08:00 LT was higher during the dry season (14.9 µmol m^{-2} s^{-1}) than the wet season (11.5 µmol m^{-2} s^{-1}) whereas the average daytime and nighttime NEE did not vary markedly between seasons. The seasonal variation of this forest revealed that NEE was generally negative during the wet season and mostly positive in the dry season.

KEY WORDS: Net ecosystem CO_2 exchange (NEE), tropical peat swamp forest, eddy covariance

INTRODUCTION

Tropical peatlands occupy a total area of 33-49 Mha, equivalent to 9-12% of the global peatland area (Immirzi *et al.*, 1992). With their thick peat deposits and high vegetation biomass, tropical peat swamp forests have been regarded as efficient ecosystems for the sequestration and storage of vast amounts of carbon and function as carbon sinks. Maltby and Immirzi (1993) estimated that tropical peatlands store about 15% of the global peat carbon pool and hence potentially play an important role in the carbon cycle at the regional and global levels. Long-term continuous measurements of net ecosystem exchange (NEE) of CO_2 are required in order to assess the sink-source and budget status of an ecosystem and to analyse how NEE varies in response to different environmental conditions. However, to date, few reports of studies relating to CO_2 exchange on tropical peatland are available (e.g. Hirano *et al.*, 2007). There remain great uncertainties and large knowledge gaps as to the precise amounts of carbon sequestered in tropical peatlands and the role of tropical peatlands in the global carbon cycle. The eddy covariance method which emerged in recent decades has become the most useful tool for evaluating the CO_2 balance in terrestrial ecosystems (Valentini *et al.*, 2000). Therefore, direct measurements of CO_2 fluxes were conducted using the eddy covariance method in a tropical peat swamp forest in Sarawak, Malaysia. This paper presents the results of the first year study of NEE including the diurnal and seasonal NEE variations.

MATERIALS AND METHODS

Site description

The study was carried out in a peat swamp forest at Maludam National Park, Sarawak, Malaysia (01º27'14.8"N, 111º8'45.3"E). Sarawak is located on the northwest of Borneo Island close to the equator, and has a hot and humid tropical climate with two monsoon regimes. The northeast monsoon brings the dry season from April to September whereas the southwest monsoon is typically associated with a wet season from November to February. The study site has a relatively flat topography with a peat elevation of about 8.5 - 9 m above mean sea level and is accessible from the northeast of the riverbank of Batang Lupar by a 4.5 km concrete path. The site supports Alan Batu Forest dominated by *Shorea albida* with an average height of 30 - 35 m and a dense understory mainly comprising *Pandanus tectorius*. A 40 m tower built at the study site has a fetch of between 600 and 1000 m in all directions. The peat thickness is about 8 m around the tower.

Measurements

The eddy covariance method was used to measure the exchange of CO_2, heat, and water vapour fluxes between the forest ecosystem and the atmosphere starting in January 2011. The eddy covariance system consisted of a 3D sonic anemometer (CSAT3, Campbell Scientific, USA) and an open-path CO_2/H_2O analyzer (LI-7500A, Li-Cor Inc., USA) mounted on a 1 m long boom oriented towards the prevailing wind direction (southwest) at 41 m above the forest floor. Signals from these sensors were logged on a data logger (CR3000, Campbell Scientific Inc., USA) at a rate of 10 Hz. The CO_2 concentration profile was measured using a closed-path CO_2 analyzer (LI-820, Li-Cor Inc., USA) at six different heights (0.5, 1.0, 5.0, 11.0, 21.0, and 41.0 m).

A variety of meteorological measurements was also recorded at the same site. Net radiation and photosynthetically active radiation (PAR) were measured at 41 m above the ground surface with a net radiometer (CNR4, Kipp & Zonen, Delft, The Netherlands) and a quantum sensor (LI-190, Li-Cor Inc., USA), respectively. Air temperature and relative humidity were measured at two levels (11 and 41 m) with a temperature and relative humidity probe (CS215, Campbell Scientific Inc., USA). A 3-cup anemometer and wind vane (01003-5 R.M. Young Co., Traverse, MI, USA) was installed at a height of 41 m on the tower to measure wind speeds and wind directions.

Underground measurements were also conducted in the vicinity of the tower. Soil temperature was measured with copper-constantan thermocouples at 5 and 10 cm below the ground surface. The volumetric soil water content was measured at a depth of 30 cm using a time domain reflectometry (TDR) (CS616, Campbell Scientific Inc., USA) sensor set horizontally in the soil. Precipitation was collected by a tipping-bucket rain gauge (TE525, Campbell Scientific Inc., USA) positioned 1 m above the ground surface in an open area. All these meteorological variables were continuously recorded at a sampling frequency of 5 min and averaged over each 30 min period. Groundwater level (GWL) was monitored on an hourly basis using a water level logger (DL/N 70 STS Sensor Technik Sirnach AG, Sirmarch, Switzerland).

Data processing

NEE was calculated as the sum of CO_2 flux (F_c) measured at the top of the tower and the canopy CO_2 storage F_s (NEE = $F_c + F_s$). Corrections including the removal of spikes, double rotation and transfer function were performed. Gap-filling with friction velocity (u*) threshold was not applied. There was an observation gap of 4 days in January and 51 days from August to October 2011.

RESULTS AND DISCUSSION

Meteorological conditions over the measurement period are illustrated in Figure 1. Two seasonal periods were observed at the study site during 2011, namely a dry (April-September) and a wet (October-March) season (Fig. 1a). Annual precipitation was 3290 mm. Precipitation during the dry season (6 months) accounted for 31% of the annual precipitation. Strong variations in precipitation generally result in changes in PAR, air temperature and vapour pressure deficit (VPD) (Figs. 1a, b). As shown in Fig. 1a, the PAR decreased during the wet season. The average air temperature at 41 m height was 26.5ºC (Fig. 1b). VPD showed a seasonal trend with maximum values of 0.54 kPa in June (Fig. 1b).

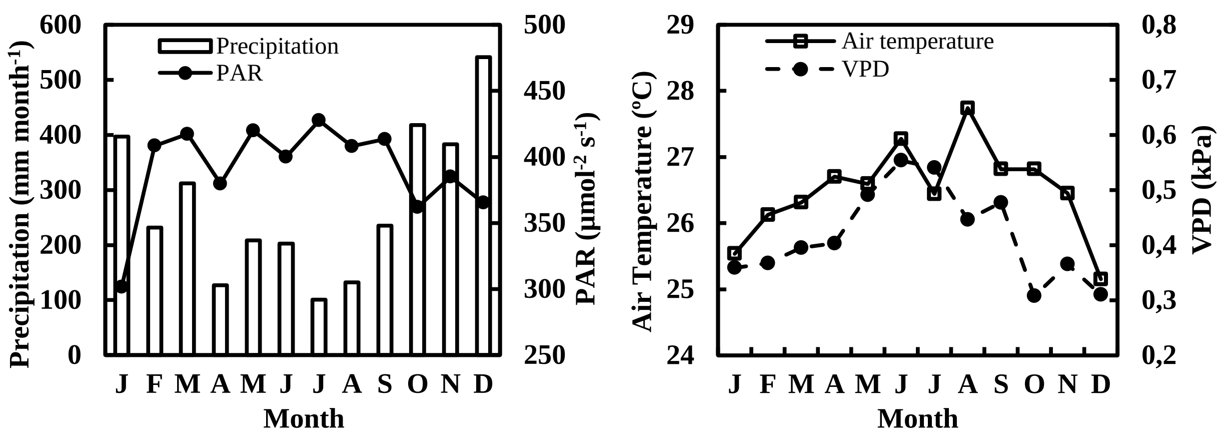

Figure 1. Seasonal variations in monthly means of: (a) precipitation and incoming photosynthetically active radiation (PAR), (b) air temperature and vapour pressure deficit (VPD) at 41 m height from January to December 2011

Fig. 2 shows the diurnal cycle of NEE for the dry and wet seasons. A peak in NEE that typically occurred between 07:30 and 08:00 LT was probably due to the flushing out of the CO_2 stored overnight beneath and within the canopy (Araújo *et al*., 2002). Likely due to the higher air temperature, the magnitude of peak in NEE was found to be higher during the dry season (14.9 µmol m^{-2} s^{-1}) than the wet season (11.5 µmol m^{-2} s^{-1}). The average daytime (07:00 – 18:30 LT) and nocturnal (19:00 – 06:30 LT) NEE did not vary markedly between seasons. The maximum rates of daytime NEE at this site (13 µmol m^{-2} s^{-1}) was relatively lower than maximum rates reported for other tropical forests (18 µmol m^{-2} s^{-1}) (Malhi *et al*., 1998; Loescher *et al*., 2003). Decreased CO_2 uptake in stands might be attributable in part to the infertility of the peat, which could have resulted in lower photosynthetic rates.

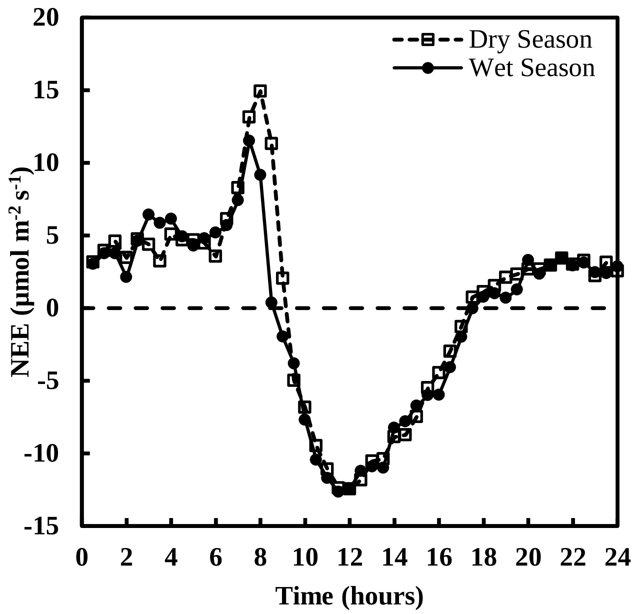

Figure 2. Diurnal variation of net ecosystem CO_2 exchange (NEE) for dry and wet seasons

Fig. 3 presents the seasonal variations of monthly NEE, daytime NEE and nighttime NEE. In general, monthly average NEE was negative in the wet season (October-March) and mostly positive in the dry season (April-September). Negative NEE values of -0.82 and -0.23 µmol m^{-2} s^{-1} were respectively observed for two months of dry season (May and July) coincided with decreases of air temperature (Fig. 1b). In the early wet season (October), NEE remained positive but gradually decreased and became negative over the following months. A notable increase in NEE by approximately 2 µmol m^{-2} s^{-1} in April could be related to increased peat decomposition attributable to reduced precipitation followed by the decrease in groundwater level. On average NEE was higher during the dry season (0.21 µmol m^{-2} s^{-1}) than during the wet season (-0.34 µmol m^{-2} s^{-1}), mostly attributed to the lower precipitation coupled with temperature increases that may accelerate the decomposition rates.

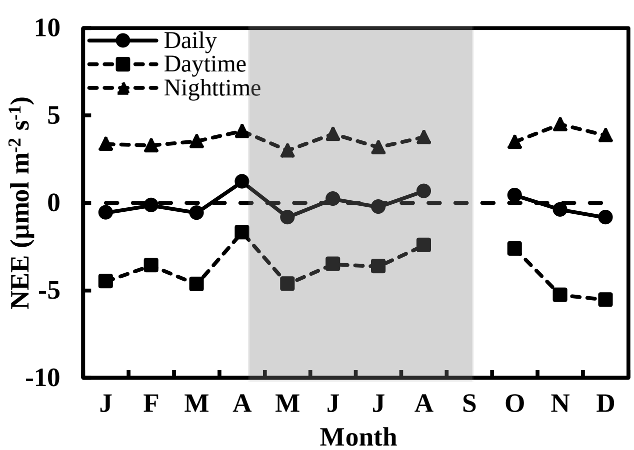

Figure 3. Seasonal course of monthly net ecosystem CO_2 exchange (NEE), daytime NEE and nighttime NEE (shaded area indicates the dry season)

CONCLUSION

This study has yielded some insights into the NEE of CO_2 of a tropical peat swamp forest in Sarawak. The seasonal variation showed that NEE was generally negative during the wet season and mostly positive in the dry season. Also, from this preliminary result, it was observed that the NEE of this ecosystem varied on the diurnal and seasonal time scales. Long-term measurements and robust analyses are still needed to comprehensively evaluate the carbon dynamics in tropical peat swamp forest.

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