Extended abstract 315

SEASONAL VARIATION OF CO_2 EXCHANGE FROM A SECONDARY TROPICAL PEAT SWAMP FOREST IN SARAWAK, MALAYSIA

Edward Baran Aeries[1], Ryuichi Hirata[2], Deniel Sang[1], Angela Che Ing Tang[1], Kevin Kemudang Musin[1], Lulie Melling[1]

[1]Tropical Peat Research Laboratory Unit (Chief Minister's Department), Jalan Badruddin, 93400, Kuching, Sarawak, Malaysia, +6082-241164, edward.b.aeries@gmail.com
[2]National Institute for Environmental Studies, Tsukuba, Japan

SUMMARY

This study examines seasonal variations and controlling factors in CO_2 exchange in a secondary tropical peat swamp forest in Sarawak, Malaysia using the eddy covariance method. Net ecosystem CO_2 exchange (NEE) was observed to be negative throughout the year, indicating that the ecosystem acted as a net carbon sink. However, it was observed that there was a decrease in CO_2 uptake during the dry season compared to the wet season in which there was a decrease in daytime uptake while night time emission remained constant. The diurnal NEE pattern at this study site was consistent with that of other studies in the Amazon and other peatlands.

KEY WORDS: tropical peat swamp forest, carbon dioxide, net ecosystem CO_2 exchange (NEE), eddy covariance, climate change

INTRODUCTION

Climate change is an issue of growing concern in Malaysia and around the world. Forests play an important role in mitigating climate change through their ability to absorb and sequester carbon (C) as carbon dioxide from the atmosphere. Thus, it is widely recognised as a potential means of offsetting elevated atmospheric greenhouse gas (GHG).

Tropical peat swamp forests are sensitive to temperature and rainfall pattern changes. Li *et al.* (2007) have shown that seasonality and climatic variability as a result of climate change may switch tropical peat swamp ecosystems from net C sinks to net C sources. In addition, Rieley *et al*. (2008) reported that tropical peat swamps act as both sequester and emitter depending on seasonal changes. The implications of climate change on tropical peat swamps are particularly important because of their large carbon stores.

The study of CO_2 exchange is important to clarify how seasonality affects the carbon balance in terrestrial ecosystems. The eddy covariance (EC) technique provides continuous, direct measurements of net CO_2 exchange (NEE) for a whole ecosystem. NEE in tropical peat swamp, which is largely determined by the net balance between CO_2 uptake for photosynthesis and CO_2 release through respiration, is important in order to provide information on peat C dynamics. However, there are very few published EC studies addressing NEE of tropical peat swamp forests (Suzuki *et al.*, 1999; Hirano *et al.*, 2009). Thus, the objective of this study was to examine seasonal variations in CO_2 exchange and the factors controlling this exchange in a secondary tropical peat swamp forest in Sarawak, Malaysia.

MATERIAL AND METHODS

Site description

The study site is located in the Betong Division, Sarawak, Malaysia (01°24’01.6’’N, 111°23’54.0’’E) and characteristically experiences a wet (September to March) and dry (April to August) season. The topography of the tower-based observation site is almost flat, at an elevation of 8 m above mean sea level and with peat 10 m deep. The Padang Paya swamp forest that formerly occupied the site had been selectively harvested about 10 years ago and then left to regenerate naturally. The site now supports forest with a canopy height of 25 m, dominated by *Litsea* spp.

Flux and supporting meteorological measurements

The NEE study using the EC method was started in January 2011. The EC system consisted of a sonic anemometer-thermometer (CSAT3; Campbell Sci.) and an open-path CO_2/H_2O analyser (LI-7500; Licor). The instruments were located on a tower 41 m above the ground (16 m above the forest canopy) and were extended by 1 m from the edge of the tower using a boom aligned to 135°, as the predominant winds in the region are from the southeast. The EC data were measured at a frequency of 10 Hz using a datalogger (CR3000; Campbell Sci.) and half-hourly mean eddy CO_2 flux was calculated. CO_2 concentrations were measured using a closed-path system (LI-820; Licor) at heights of 0.5, 1.0, 3.0, 10.0, 20.0 and 41.0 m. NEE values were calculated as the sum of eddy CO_2 flux (F_C) and the rate of change in CO_2 storage below the height of the eddy covariance system (F_S).

$$\mathrm{NEE} = F_C + F_S$$

Meteorological data were also measured. A net radiometer (CNR4; Kipp & Zonen) was installed at 41 m to measure downward and upward short-wave and long-wave radiation. Downward and upward photosynthetic photo flux densities (PPFD) were measured at 41 m using quantum sensors (LI-190; Licor). Wind velocity and direction were measured using a wind vane and a three-cup anemometer (03001-5; R.M. Young Co.) at 42 m. Relative humidity and air temperature were measured at 41 and 11 m with a temperature and relative humidity sensor (CS215; Campbell Sci.). Rainfall was measured at 1 m above ground using a tipping-bucket rain gauge (TE525; Campbell Sci.). Soil temperatures were measured at depths of 5 and 10 cm using a thermocouple thermometer while soil moistures were measured at 10 and 30 cm using time-domain-reflectrometry (TDR) sensors (CS616; Campbell Sci.). In addition, water table depth was recorded near the tower at hourly intervals using a water level logger (DL/N; Sensor Technik Sirnach AG). All measuring systems, except the water level logger, were powered by solar energy.

RESULTS AND DISCUSSION

Annual and seasonal means of NEE, air temperature at 41 m (T_{air}), vapour pressure deficit (VPD), photosynthetic photon flux density (PPFD), cumulative precipitation (PT) and the water table (WT) are shown in Table 1.

Table 1. Annual and seasonal means of air temperature at 41 m (T_{air}), vapour pressure deficit (VPD), photosynthetic photon flux density (PPFD), cumulative precipitation (PT) and water table depth (WT).

	Mean				
	T_{air} (°C)	VPD (kPa)	PPFD (µmol m^{-2} s^{-1})	PT (mm)	WT (cm)
Annual	25.9	0.41	345	2940.3	-12.4
Wet season	25.3	0.33	326	2143.5	-9.1
Dry season	26.7	0.49	368	797.8	-15.6

Rainfall in the wet season (September to February) and dry season (March to August) accounted for 72.9% and 27.1% of the cumulative rainfall, respectively. Annual mean air temperature was 25.9ºC. During the same period the average air temperatures for the warmest month (July) and the coldest month (February) were 27.1ºC and 24.1ºC, respectively. Mean PPFD varied between 326 µmol m^{-2} s^{-1} during the wet season (with maximum PPFD of 1137 µmol m^{-2} s^{-1}) and 368 µmol m^{-2} s^{-1} during the dry season (with maximum PPFD of 1302 µmol m^{-2} s^{-1}). VPD was lower in the wet season than in the dry season. The seasonal change in the depth of the water table was a direct consequence of rainfall and showed a distinct seasonal pattern. The highest seasonal mean WT (-9.1 cm) was recorded in the wet season whereas the lowest mean WT (-15.6 cm) was recorded in the dry season.

As shown in Fig. 1a, the site was found to be a sink for atmospheric CO_2 during the day. There is a peak in positive NEE just after sunrise. The peak in positive NEE is attributable to the flushing out of the CO_2 stored overnight beneath and within the canopy (Araújo *et al.*, 2002). The peak in positive NEE is then followed by an increase in CO_2 uptake. This is indicated by successively lower NEE values down to a minimum value of -16.2 µmol m^{-2} s^{-1}, reached at 13:00 local time (MYT). This uptake was relatively lower than the -19.0 µmol m^{-2} s^{-1} recorded by Goulden *et al.* (2004) in old-growth tropical forest. From Fig. 1b, it is observed that CO_2 uptake increased with PPFD and reached maximum uptake at around 13:00 and 12:30 MYT for the wet season and dry season, respectively. In both seasons CO_2 uptake had declined steadily through the afternoon, passing compensation point (where uptake is zero) at around 17:30 MYT. NEE decreased later in the day and reached the compensation point late in the afternoon. The pattern of an afternoon negative peak in NEE and subsequent decline later in the day at this site is similar to findings reported by Carswell *et al.* (2002) and Goulden *et al.* (2004).

The decline in NEE after midday could be due to a combination of several factors such as the light response characteristics of the vegetation together with increased air temperature and VPD (Shurpali *et al.*, 1995). Air temperature and VPD were significantly higher in the afternoon (Fig. 1c, 1d). Goulden *et al.* (2004) had postulated that the afternoon decline in CO_2 uptake might be due to either stomatal closure in response to evaporative demand, or a change in photosynthetic biochemistry with elevated temperature, or a combination of both mechanisms.

A mean daytime NEE (07:00 to 18:30 MYT) of -6.4 µmol m^{-2} s^{-1} was recorded for the wet season while a less negative value of -5.4 µmol m^{-2} s^{-1} was recorded for the dry season. Daytime NEE follows the rate of photosynthesis closely (Goulden *et al.*, 1996). High seasonal VPD (> 1.2 kPa) and temperature (> 30ºC) in the dry season resulted in reduction in photosynthesis; hence a less negative daytime NEE. No differences in night time (19:00 to

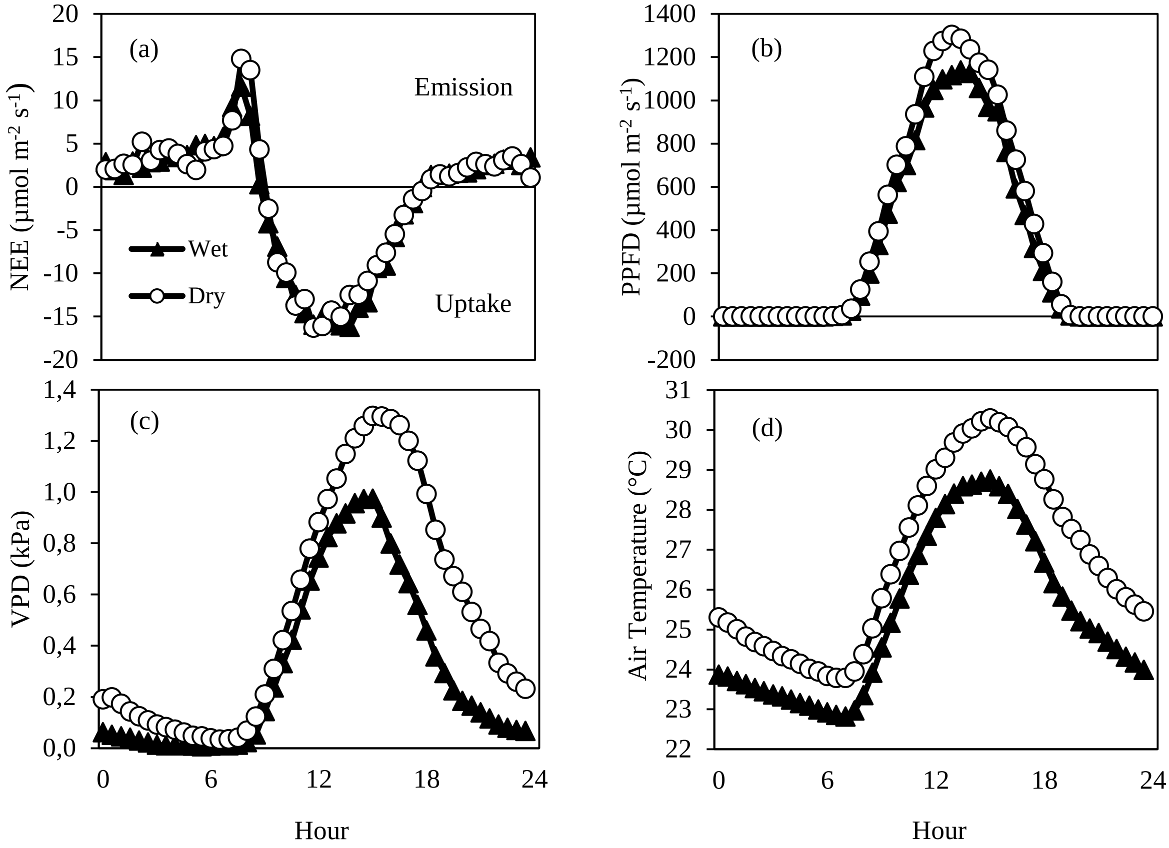

Fig. 1. Diurnal patterns of seasonally averaged (a) NEE; (b) PPFD; (c) VPD; and (d) air temperature.

06:30 MYT) NEE (which is strongly related to respiration) could be detected over the year whereby values were constantly about 3.0 µmol m^{-2} s^{-1} in both seasons (Goulden *et al.*, 1996). Fig. 2 shows the daily NEE to be less negative in the dry season than in the wet season, with July being the least negative (-0.5 µmol m^{-2} s^{-1}). The decrease in CO_2 uptake during the dry season may be attributed to a decrease in photosynthesis.

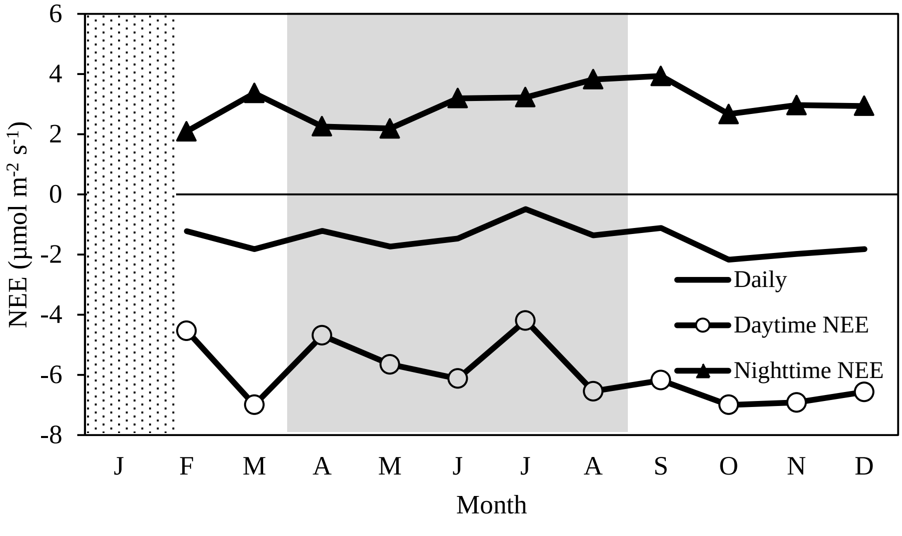

Fig. 2. Seasonal variation of daily NEE, daytime (07:00 to 18:30 MYT) NEE and night time (19:00 to 06:30 MYT) NEE. Shaded area represents dry season. Dotted area represents missing data.

CONCLUSIONS

This study shows the importance of seasonality and climatic variability on the C dynamics of a tropical peat swamp forest. Even though there were seasonal variations in CO_2 exchange in this secondary tropical peat swamp forest the ecosystem was a net carbon sink throughout the year. The higher CO_2 uptake in the wet season may be due to the higher photosynthesis rate. The diurnal pattern at this study site was consistent with that of other studies in the Amazon and other peatlands in the world. More intensive and long-term measurements are needed for a better understanding and accurate interpretation of CO_2 exchange from a secondary tropical peat swamp forests.

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