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ENERGY FLUX MEASUREMENTS AND METEOROLOGICAL OBSERVATIONS IN AN OIL PALM PLANTATION ON TROPICAL PEATLAND IN SARAWAK, MALAYSIA

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SUMMARY

Land use change plays an important role in influencing the energy fluxes in terrestrial ecosystems. A 40 m micrometeorological observation tower was constructed to study the energy fluxes in an oil palm plantation ecosystem on tropical peatland in Sarawak. The preliminary results have shown that the sensible and latent heat fluxes did not show a marked seasonal variability. The average Bowen ratio was 0.13, indicating that latent heat flux dominated over sensible heat flux. Long term measurements are needed to allow better evaluation of the diurnal, annual and inter-annual variations of energy fluxes and meteorological variables which will lead to a better understanding of carbon dynamics and energy budgets in the oil palm ecosystem on tropical peatland.

KEY WORDS: Tropical peatland, oil palm, energy fluxes

INTRODUCTION

Recently there has been great concern on the impact of land use change on greenhouse gas emissions, especially with the increasing cultivation of oil palm on tropical peatland. In Sarawak, tropical peatland is the last frontier of arable land for agricultural development. However, peat soil is the least researched of the tropical soils and thus the least understood. A monoculture plantation (such as oil palm) has a different canopy height and structure from the ecosystem that it replaced. This results in a different micrometeorological environment that could influence the energy fluxes, and thus the carbon (C) flux in the ecosystem. The effects of meteorological changes on energy fluxes in tropical peatland are still poorly understood. To date, there are few reports of long term studies using the eddy covariance method to measure gas fluxes continuously in agricultural land converted from tropical peat swamp forest. The objective of this study is to assess the diurnal and seasonal variations of sensible and latent heat fluxes in an oil palm plantation ecosystem on tropical peatland.

MATERIAL AND METHODS

Site description

The study site is an eight (8)-year old oil palm plantation, with 8 m tall palms on tropical peatland located in Sarawak, Malaysia (N2°11'12.0" E111°50'31.9"). This location experiences an equatorial, climate characterised by both a dry season (April to October) and a wet season (November to March). Peat soil at the site is about 6 m deep and is classified as Typic Topofibrist in the USDA soil classification system (Soil Survey Staff, 1992).

Flux and supplementary measurements

A 40 m tall observation tower was used in the determination of the energy fluxes and meteorological variables. Flux and meteorological variables were measured every 10 Hz and 5 min, respectively, from January to December 2011. The flux measurement system consisted of a fast-response three-dimensional sonic anemometer-thermometer (CSAT3, Campbell Scientific, USA) and a fast-response open-path infrared gas analyzer (LI-7500, LI-COR, Inc., Lincoln, NE, USA). These were used to measure half-hourly fluxes of *H* and LE. There was an observation gap of 28 days (February). Eddy flux sensors were installed at 21 m above ground level (about 12 m above the canopy) with a maximum fetch area of 1.3 km.

A set of supporting meteorological variables was measured. These included air temperature (T_a), relative humidity (RH), net radiation (R_n) and its components and precipitation (*P*). T_a and RH were measured at 21 m above the ground using temperature-humidity sensor (HMP45A; Vaisala Inc., Helsinki, Finland). R_n, downward and upward long- and short-wave radiations (Rl_dn, Rl_up, Rs_dn, and Rs_up, W m^{-2}) were measured using Kipp & Zonen CNR-4 net radiometers at 41 m (Kipp & Zonen USA Inc., Bohemia, NY, USA). Rainfall was measured by rain gauge. There was an observation gap of 59 days (January to February). Analog signals from all sensors were sampled by a data logger (CR3000, Campbell Scientific, Utah, USA).

RESULTS AND DISCUSSION

A notable seasonal trend in precipitation was apparent (Fig. 1a). Annual precipitation was 2625 mm (except missing data in February). The climate showed little seasonal variation in air temperature with an average of 25ºC in the wet season and 26ºC in the dry season (Fig. 1b). The highest monthly peak of vapour pressure deficit (VPD) (1.34 kPa) was detected in February (Fig. 1b). VPD was slightly lower during the wet season (0.35kPa) than the dry season (0.38 kPa).

The diurnal patterns of sensible heat and latent heat fluxes, which are closely related to the intensity of net radiation were symmetrical about noon, with average peak values of 570 (13:00 LT), 60 (11:30 LT) and 330 W m^{-2} (13:30 LT), respectively (Figs. 2a, b, c). Net radiation, sensible heat and latent heat fluxes did not show any distinct diurnal variation between dry and wet seasons. The net radiation reached its maximum around 12:30 LT and 13:00 LT during the dry (580 W m^{-2}) and wet (565 W m^{-2}) seasons respectively (Fig. 2a). The diurnal pattern showed that sensible heat flux was clearly positive in daytime, indicating warm air rising upward but typically negative during the late afternoon and night time (Fig. 2b). The latent heat flux reached a maximum shortly before noon during the dry season (11:30 LT) and after noon during the wet season (13:30 LT), and approached zero at night (Fig. 2c).

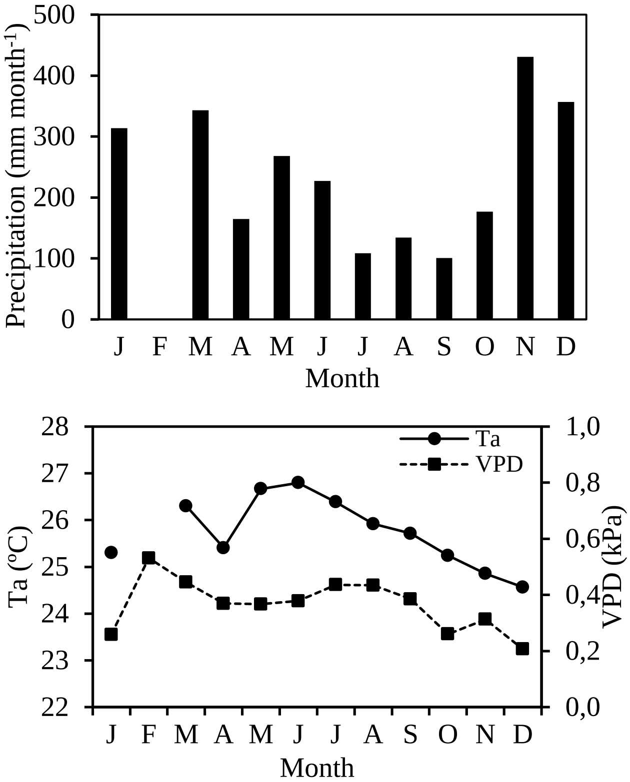

Fig. 1 Seasonal variations in monthly means of: (a) precipitation and (b) air temperature (Ta) and vapor pressure deficit (VPD) at 21 m height

The peak latent heat flux was slightly higher in the wet season (340 W m^{-2}) than in the dry season (320 W m^{-2}), despite the similar values in net radiation. This result is similar to the findings of Malhi *et al.* (2002) who reported that the peak latent heat flux in an Amazonian rain forest was higher in the wet season than the dry season, irrespective of reduced net radiation. It can also be observed that, during daytime, latent heat flux accounted for a large fraction of the net radiation.

Monthly time series of sensible and latent heat flux generally changed corresponding to the variation of net radiation but did not show clear signs of seasonality (Figs. 3a, b, c). Likewise, averages of net radiation, sensible and latent heat fluxes did not vary markedly between seasons. Despite the high precipitation and lower air temperature recorded in December, sensible heat flux increased up to 18 W m^{-2} and latent heat flux declined (Figs. 1a, 1b, 3b, 3c). This may be partially caused by the high wind speeds and large temperature difference between the air and the surface. Latent heat flux was relatively low in January, mostly attributed to the low water vapour pressure deficit caused by high precipitation and lower air temperature, which in turn results in low evaporation rates (Figs. 1a, 1b, 3c). The decline in latent heat flux by 20% in August may be partially due to low rates of evaporation resulting from low wind speeds in combination with high relative humidity. The average Bowen ratio (0.13) was broadly comparable between dry (0.13) and wet (0.12) seasons, indicating latent heat flux dominated over sensible heat flux throughout the year and most of the radiation was used for evapotranspiration.

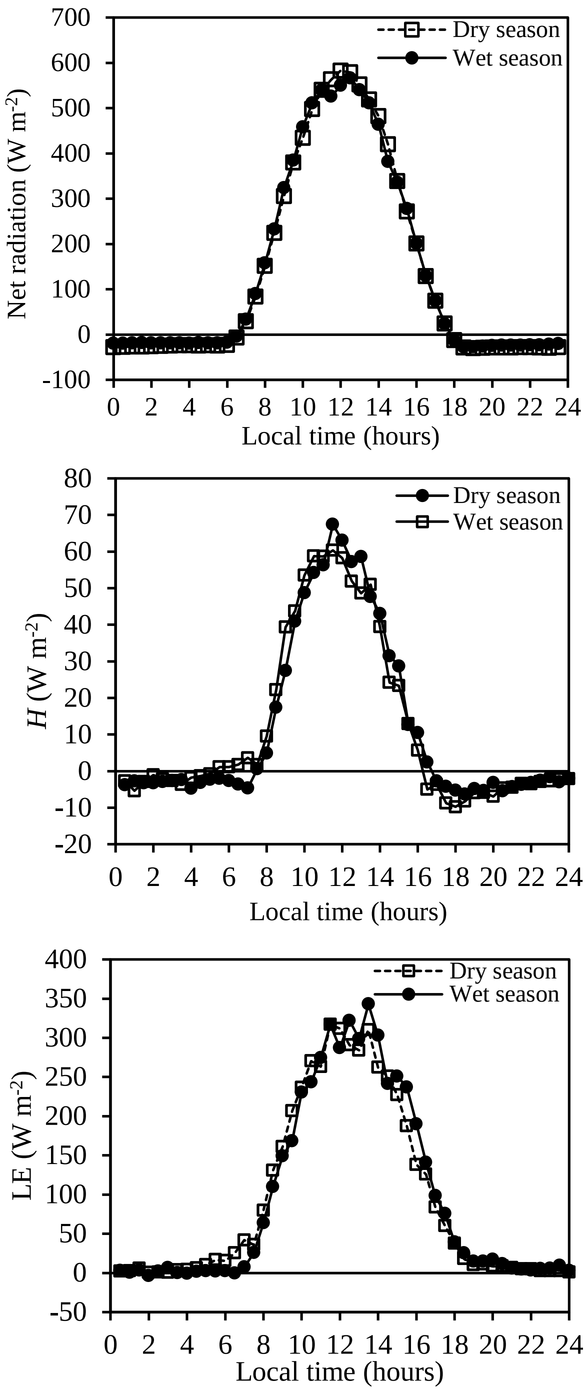

Fig. 2 The mean diurnal cycles of (a) net radiation (Rn), (b) sensible heat flux (*H*) and (c) latent heat flux (LE) for the dry (April-October) and wet (November-March) seasons

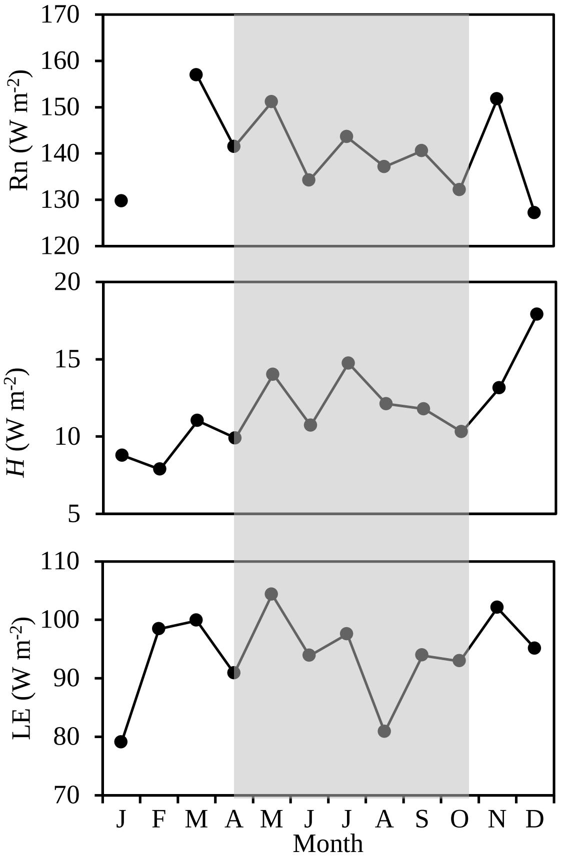

Fig. 3 Seasonal course of monthly mean (a) net radiation (Rn), (b) sensible heat flux (*H*) and (c) latent heat flux (LE) from January to December 2011 (shaded areas indicate the dry season)

CONCLUSION

The preliminary results have shown that sensible and latent heat fluxes did not vary markedly between seasons. It was also observed that latent heat flux dominated over sensible heat flux throughout the year. Long term continuous measurements are required for a better understanding of the carbon dynamics and energy budgets in the oil palm ecosystem on tropical peatland.

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