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Energy Balance of a Tropical Peat Swamp Forest in Central Kalimantan, Indonesia

By

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Summary

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Tropical peat swamp forests grow over tropical peatlands, which are widely distributed in flat lowlands in Southeast Asia. Recently, however, deforestation and drainage are in progress on a large scale because of growing demands for timber and farmland. In addition, the El Niño drought and its consequent fires are accelerating the forest devastation. The forest devastation alters energy balance and will influence regional climate. Thus, we have measured eddy energy fluxes above a tropical peat swamp forest left in a devastated peatland in Central Kalimantan, Indonesia since November 2001. Both in the rainy and dry seasons, latent heat flux (lE) considerably exceeded sensible heat flux (H). Net radiation (R_n) was mainly used by evapotranspiration (ET). The El Niño event occurred in 2002, and the consequent drought caused large-scale peatland fires in Central Kalimantan. A large amount of smoke emitted from the fires decreased R_n from mid-August through October. Bowen ratio (H / lE) decreased gradually from January through July in the range of 0.20–0.35. Although Bowen ratio decreased to a minimum of 0.15 in late September, it continued to increase during the late fire period and was high at 0.35–0.45 after the fires. ET accounted for 67% of precipitation (1856 mm) on an annual basis in 2002. Annual mean daily ET was 3.4 mm d^{-1}.

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Introduction

Tropical peat swamp forests grow over tropical peatlands, which are widely distributed in flat lowlands in Southeast Asia. Recently, however, deforestation and drainage are in progress on a large scale because of growing demands for timber and farmland. In addition, the El Niño drought and its consequent fires are accelerating the forest devastation. The devastation alters the energy balance of peatlands and will influence regional climate, whereas there were no field data on the energy balance of tropical peat swamp forests. Thus, we have measured eddy energy fluxes and micrometeorology above a tropical peat swamp forest left in a devastated area in Central Kalimantan, Indonesia since November 2001. We herein report the energy balance in 2002, an El Niño year.

Material and Methods

Study site

The study site is a tropical peat swamp forest left in Area B of the Mega Rice Project near Palangkaraya, Central Kalimantan, Indonesia (RIELY & MUHAMAD 2002). The forest is located between the Sebangau River and a channel running from the north to the south. Water table in the forest was zonally reduced near the channel. A tower of 50 m height was constructed about 300 m inside from the northeast corner of the forest (2° 20' 41.6" S, 114° 2' 11.3" E). Dominant tree species of the forest are *Combretocarpus rotundatus*, *Cratoxylum arborescens*, *Buchanania sessifolia* and *Tetrameristra glabra* (TUAH & al. 2000), and rich shrubs grow in the trunk space. The height of the forest canopy is about 26 m, and plant area index (PAI) measured at 1.5 m height with a plant canopy analyzer (LAI2000, Licor) was 4.5 m^2 m^{-2} in late June 2002. Predominant wind direction is the south (SE-SW). Fetch is longer than 1 km for the southern wind. During the dry season of 2002, between mid-August and late October, peatland fires occurred in large areas around Palangkaraya because of the El Niño drought. However, the forest did not burn.

Measurement of eddy energy fluxes and micrometeorology

Sensible heat (H), water vapor (latent heat (lE)) and CO2 fluxes have been measured since November 2001 at 41.7 m with a sonic anemometer-thermometer (CSAT3, CSI) and an open-path CO_2/H_2O analyzer (LI7500, Licor), which face south. Sensor signals were recorded with a data logger (8421, HIOKI) at 10 Hz. Half-hourly mean fluxes were calculated from the data according to the following procedures: 1) removal of noise spikes, 2) planar fit rotation (WILCZAK & al. 2001), 3) covariance calculation using block averaging, 4) WPL correction (WEBB & al. 1980). Data during rain and north winds were eliminated to maintain data quality. In addition, a friction velocity (u*) threshold of 0.15 m s^{-1} was applied diring the nighttime. Their resultant gaps of eddy energy dluxes were filled using look-up tables (FALGE & al. 2001).

Micrometeorology has been measured since July 2001 on the tower. Net radiation (R_n) was measured at 40.6 m with a radiometer (CNR-1, Kipp & Zonen). Precipitation (P) was measured at 41 m with a tipping-bucket rain gauge (TE525, CSI). Air temperature and relative humidity were measured at 41.7 and 2 m with platinum resistance thermometers and capacitive hygrometers (HMP45, Vaisala). Sensor signals were measured every 30 seconds, and half-hourly means were recorded with a data logger (CR10X, CSI).

Results and Discussion

In Kalimantan, the rainy season expands from November through April on an average (HAMADA & al. 2002). P for the 6 months of the rainy season summed up to 1529 mm, which accounted for 82% of the annual sum (1856 mm) in 2002 (Fig. 1a). Daytime vapor pressure deficit (VPD) was smaller in the rainy season than the dry season, which expands from May through October (Fig. 1b). However, daily mean air temperature showed no seasonal pattern; it ranged between 25 and 28°C with the annual mean of 26.7°C (Fig. 1c).

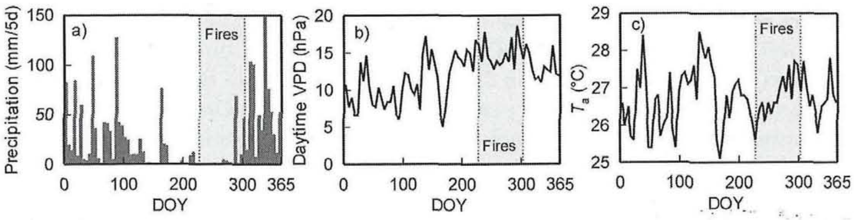

Fig. 1. Seasonal variations in 5-d means of (a) precipitation, (b) daytime vapor pressure deficit (VPD) and (c) air temperature (T_a) measured above canopy in 2002. The fire period is shaded.

Eddy energy fluxes (H + lE) accounted for 83% of R_n during the daytime on a half-hourly mean basis, judging from the slope of the linear regression between H + lE and R_n, which had an intercept of -6 W m^{-2}. WILSON & al. 2002 reported that the slope increased by 3% and 7% by considering soil heat flux and heat storage change, respectively, on the average from 26 forest sites in FLUXNET. Therefore, although soil heat flux and heat storage change were not measured, the energy balance closure was estimated to be 90% at least in this forest site. The ratio of the annual sum of H + lE to that of R_n was 0.90 in 2002 (Fig. 3b).

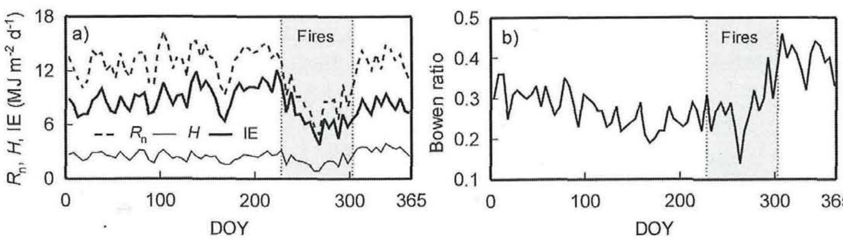

Fig. 2. Seasonal variations in 5-d means of (a) net radiation (R_n), sensible heat flux (H) and latent heat flux (lE), and (b) Bowen ratio (H / lE) in 2002. The fire period is shaded.

In spite of the dry season, R_n decreased between mid-August and late October because of the shading by the smoke emitted from large-scale peatland fires caused by the El Niño drought (Fig. 2a). H and lE varied almost in parallel with R_n. H ranged between 2 and 3 MJ m^{-2} d^{-1} before the fires, whereas it decreased below 2 MJ m^{-2} d^{-1} during the fires and exceeded 3 MJ m^{-2} d^{-1} after the fires. lE showed an increasing trend until the onset of the fires with fluctuations between 6 and 12 MJ m^{-2} d^{-1}, which are equivalent to 2.5–5.0 mm d^{-1} of evapotranspiration (ET), whereas it decreaed to a minimum of 4 MJ m^{-2} d^{-1} in late September during the fires. The increasing trend in lE was probably due to the seasonal variation of VPD (Fig. 1b). Bowen ratio (H / lE) decreased gradually from January through July in the range of 0.20–0.35 (Fig. 2b). Although Bowen ratio decreased to a minimum of 0.15 in late September, it continued to increase during the late fire period and was high at 0.35–0.45 after the fires. The decreasing pattern of Bowen ratio before the fires was due to increasing lE. On the other hand, increase in Bowen ratio from the late dry season through the early rainy season (October to December) was due to decreasing lE, which was probably caused by ecophysiological constraint under water stress in the dry season; the constraint may have continued until the end of December.

Cumulative ET reached about 96% of cumulative P at mid-October, whereas it was 67% at the end of 2002 (Fig. 3a). Annual ET and P were 1252 and 1856 mm, respectively. Annual mean daily ET was 3.4±1.0 (SD) mm d^{-1} in 2002, an El Niño year, which is compatible with 3.51 mm d^{-1} for an old-growth tropical forest in eastern Amazon (DA ROCHA & al. 2004).

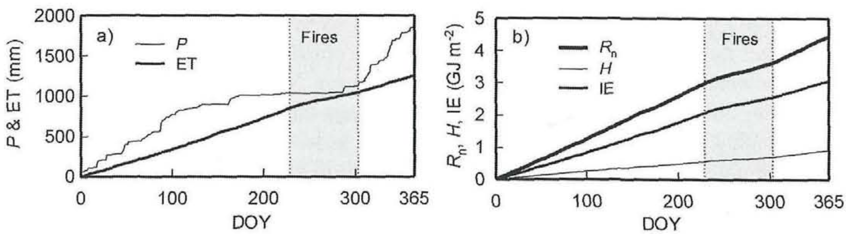

Fig. 3. Cumulative (a) precipitation (P) and evapotranspiration (ET), and (b) net radiation (R_n), sensible heat flux (H) and latent heat flux (lE) in 2002. The fire period is shaded.

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