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CO_2 BALANCE OF TROPICAL PEATLAND ECOSYSTEMS

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SUMMARY

To assess the CO_2 balance of tropical peatland ecosystems, we have measured CO_2 flux using the eddy covariance technique on three ecosystems (undrained forest, drained forest and drained burnt site) in Central Kalimantan, Indonesia since 2001 or 2004. Annual net ecosystem CO_2 exchange (NEE) was positive at all sites and in all years, which means that the all ecosystems functioned as CO_2 sources, including the relatively-intact undrained forest. The NEE showed a large interannual variation at forest sites. Annual NEE was large in ENSO years mainly because ecosystem respiration increased with decreasing ground water level.

KEY WORDS: Drainage, draught, eddy covariance technique, ENSO, fire

INTRODUCTION

Tropical peatlands are widely distributed worldwide and store up to 88.6 Pg of soil carbon, which account for 15-19% of global peat carbon (Page *et al.*, 2011). The huge carbon pool is presently disturbed on a large scale by land development and management and, consequently, has become vulnerable. Peat degradation occurs most rapidly and extensively in Indonesia, because of fires, drainage and deforestation of swamp forest (Couwenberg *et al.*, 2010; Hergoualc'h and Verchot, 2011; Hooijer *et al.*, 2010). Peat burning releases carbon dioxide (CO_2) intensively but occasionally, whereas drainage increases CO_2 emission steadily through the acceleration of aerobic peat decomposition. Tropical peatlands have a high potential to become a large carbon source. However, the ecosystem-scale carbon exchange between tropical peat ecosystems and the atmosphere is poorly understood. Therefore, we have measured CO_2 flux using the eddy covariance technique on three peat ecosystems (undrained forest (UF), drained forest (DF) and drained burnt site (DB)) with different disturbance conditions in Central Kalimantan, Indonesia since July 2004 at UF, November 2001 at DF or April 2004 at DB to assess their CO_2 balances.

MATERIAL AND METHODS

The three sites are located within 15 km of each other (2º20´S, 113º55´E-114º3´E) in a tropical peatland area in Central Kalimantan, Indonesia (Fig. 1). The UF had been logged selectively until the late 1990s. It retains a relatively intact peat swamp forest. Although no large canal has been excavated, a network of small canals, excavated for illegal logging remains, influencing forest hydrology (Page *et al.*, 2009). The DF is one of very few remaining forest areas in Block C of the former Mega Rice Project. The forest had been selectively logged until the end of the 1990s. A large canal that was excavated (outside of the forest) in the mid-1990s has caused drainage of the forest (Page *et al.*, 2009). Canopy heights were 23 and 26 m for UF and DF sites, respectively. The two forests were similar in their dominant tree species. The DB site was burnt in 1997 and 2002, and herbaceous plants were regrowing up to 0.5 m in June 2005.

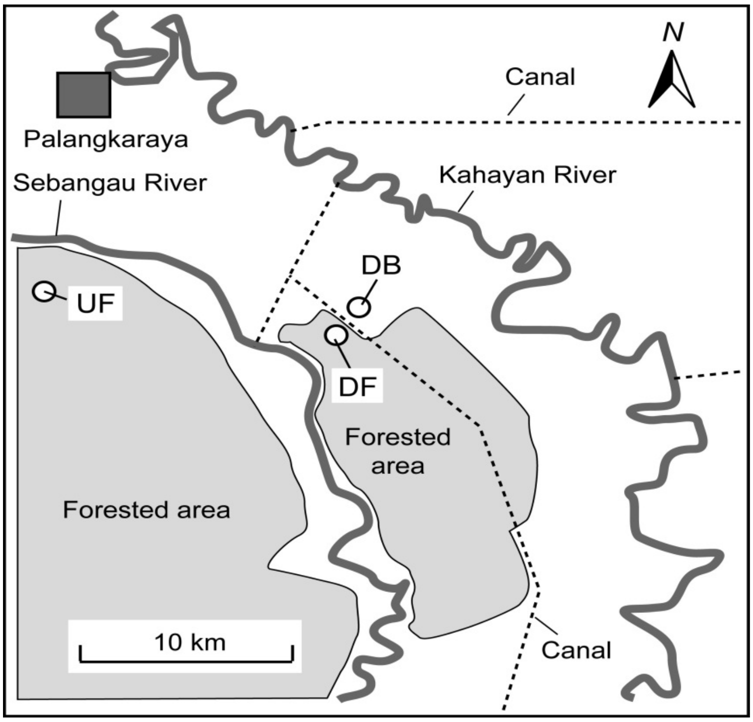

Fig. 1 Map of the study area.

At the sites, CO_2 fluxes were measured using the eddy covariance technique with a sonic anemometer/thermometer (CSAT3, Campbell) and an open-path CO_2/H_2O analyser (LI7500, Licor) installed at heights of 36.5, 41.3 and 3.0 m for UF, DF and DB, respectively. The output signals from the instruments were recorded at 10 Hz. Half-hourly mean eddy CO_2 flux was calculated from the data according to the following procedure: removal of noise spikes, planar fit rotation, covariance calculation using a block average and density fluctuation (WPL) correction. Net ecosystem CO_2 exchange (NEE) between the atmosphere and an ecosystem was determined as the sum of the eddy CO_2 flux and CO_2 storage flux in the air space below flux measurement height, which was calculated from the vertical profiles of CO_2 concentration. At DB, however, the CO_2 storage flux was ignored, because flux measurement height was low. The NEE was graded by wind direction, steady state condition and friction velocity for quality control, and was excluded, if its grade was below a threshold. The NEE was partitioned into ecosystem respiration (RE) and ecosystem photosynthesis (GPP) using a conventional method. Data gaps of RE and GPP, which resulted from system failures and quality control, were filled using look-up tables from meteorological data. The methods to measure and calculate CO_2 fluxes are described in detail in our previous paper (Hirano *et al.*, 2007). To calculate the annual sum of NEE, we defined a year as the period of 365 or 366 days starting on July 10 or 11 (DOY192) and ending on July 9 or 10 (DOY191). Annual NEE was calculated for four years of 2004-2008, six years of 2002-2008 and five years of 2004-2009 for UF, DF and DB, respectively.

RESULTS AND DISCUSSION

Generally, the dry season starts in June or July and lasts until October in this area. However, the length and the total precipitation of the dry season show a large interannual variation. Longer and rainless dry seasons appear in ENSO (El Niño and Southern Oscillation) years, such as 2002 and 2006. On the other hand, the dry season becomes obscure in a La Niña year, such as 2005 and 2007 (Fig. 2a). According to the precipitation pattern, groundwater level (GWL) decreases during the dry season and rises rapidly with the onset of the rainy season (Fig. 2b). The GWL was considerably lower at DF than UF. At DF, GWL never appeared aboveground even in the rainy season. At DB, however, such GWL decrease didn’t occur probably because of less transpiration from herbaceous vegetation. In ENSO years, GWL decreased more deeply.

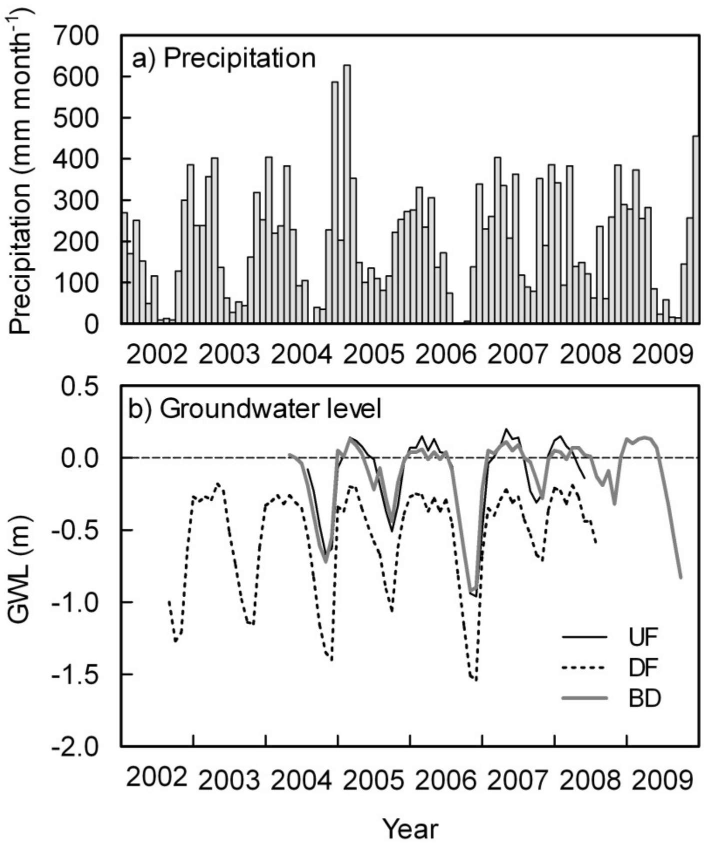

Fig. 2 Seasonal variations in monthly precipitation (a) and monthly mean groundwater level (GWL) (b).

Annual NEE was positive at all sites and in all years (Fig. 3), which means that all ecosystems functioned as CO_2 sources to the atmosphere on an annual basis. The NEE showed a large interannual variation in forest sites. Annual NEE was large in ENSO years with large GWL decrease, mainly because RE increased with decreasing GWL (Hirano *et al.*, 2009). Low GWL is normally accompanied by air dryness and peat fires, which emit a large amount of smoke. Such incidental phenomena decrease GPP thorough stomatal closure and shading (Hirano *et al.*, 2007; Hirano *et al.*, 2009). In 2005 and 2007, La Niña years, annual NEE decreased to less than 70 g C m^{-2} y^{-1} at UF. The CO_2 source intensity was largest at DB, drained burnt site, followed by DF and UF in order (Fig. 4). Two-way layout ANOVA showed significant differences among sites ($p < 0.01$) and years ($p < 0.05$). The positive NEE at UF was probably due to lowered GWL by a small-canal network (Page *et al.*, 2009) and shading by smoke from peat fires, which occur intensively in ENSO years.

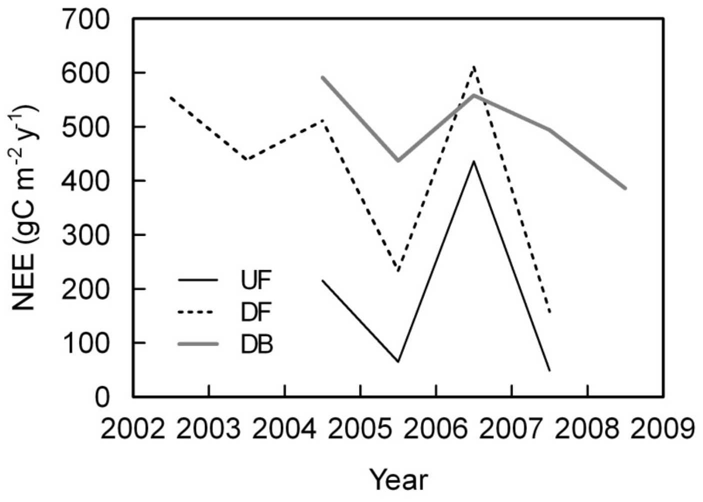

Fig. 3 Variations in annual NEE at the three sites.

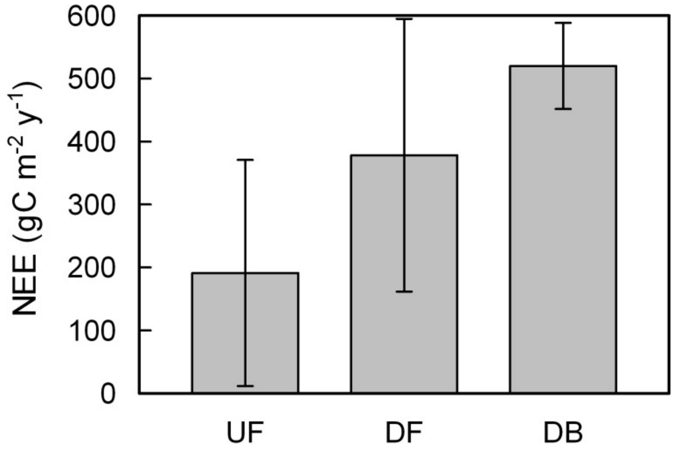

Fig. 4 Mean values of annual NEE for four years from 2004 to 2008 at the three sites. Vertical bars denote standard deciations (n = 4).

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