Application of Eddy Covariance for Carbon Dynamics Monitoring in Two Contrasting Tropical Forests in Thailand

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Abstract

The eddy covariance technique ascertains the exchange rate of carbon dioxide (CO_2) across the interface between the atmosphere and a plant canopy by measuring the covariance between fluctuations between vertical wind velocity and CO_2 mixing ratio. Meteorological parameters were also measured for understanding the environmental conditions for ecosystem carbon cycle. To compare carbon balance of two contrasting tropical forests in Thailand, dry evergreen (DEF) and mixed deciduous (MDF) forests, net ecosystem exchange (NEE) was estimated and the choice of a friction velocity (u*) correction for the estimation of flux on calm night and other corrections were applied for data quality control. The change in NEE as a function of the u* threshold was marked, and some of the measured nocturnal data were eliminated by using the 0.4 and 0.25 m s^{-1} u* threshold for DEF and MDF respectively. Data gap filling was applied with linear interpolation, mean diurnal variation and non-linear correlation with temperature and photosynthetically flux density as appropriate. The daily and seasonal trend of CO_2 exchange and its factors affecting was evident and the annual NEE reflected carbon gain in these two forests with corresponding values of -2.68 and -3.62 tC ha^{-1} yr^{-1} respectively.

Introduction

Carbon dioxide (CO_2) exchange between terrestrial ecosystem and the atmosphere is one of the key process that affects atmospheric CO_2 concentration. In order to assess the role of the terrestrial ecosystem in the global CO_2 budget at present, and to predict its changes in the future under global warming situations, long-term observation of CO_2 exchange has been done in various ecosystems in the world (Aubinet et al., 2001), mostly located in forest ecosystems because they are believed to be the most significant terrestrial ecosystem contributing to the global CO_2 budget. Particularly, tropical forests disappear more rapidly, and deteriorate much faster than temperate forests because they are more accessible by human being, and population pressure is much stronger than in other forest forests.

Gas fluxes can be measured using many methods and Eddy Covariance Technique is rather new method which does not interfere with process of gas exchange between the surface source and the atmosphere (Baldocchi, 2003). The technique ascertains the exchange rate of CO_2 across the interface between the atmosphere and a plant canopy by measuring the covariance between fluctuations between vertical wind velocity and CO_2 mixing ratio and many studies have been published (REF). This study is aiming at comparing carbon balance in term of net ecosystem exchange (NEE) of two contrasting tropical forests in Thailand, dry evergreen (DEF) and mixed deciduous (MDF) forests.

Methodology

Two contrasting tropical forests in Thailand, dry evergreen (DEF) and mixed deciduous (MDF) forests were studied. The DEF at Sakaerat site is located in the Sakaerat Environmental Research Station (SERS), Thailand Institute of Scientific and Technological Research (TISTR). The observation tower, 14°29’29’’ N, 101°55’05’’ E, and 535 MSL, is about 45 m tall and located where *Hopea ferrea* (Dipterocarpaceae) is predominant. The MDF at Maeklong site exists in the Maeklong Watershed Research Station, National Park, Wildlife and Plant Conservation Department. The observation tower (14°34'34’’ N, 98°50’37’’ E, and 160 m MSL) is located in the MDF where the forest is consisted of various deciduous tree species.

On each site, tower flux estimates of CO_2 gas exchange, aggregated at half hour intervals, were obtained by the eddy correlation (eddy covariance) method. The standard eddy flux systems consisted of a three-dimensional sonic anemometer (Wind Master, Gill) and a closed-path type infrared gas analyzer (LI-6262, LI-COR) installed at 45 m height on the tower to measure fluctuations of wind and CO_2 and water vapor concentrations respectively at a sampling rate of 4 Hz. Meteorological parameters were also measured for understanding the environmental conditions influencing each ecosystem carbon cycle. All flux and meteorological datasets were quality checked, outliers and measurements made during the wet periods were removed and calculations of average 30-min fluxes were undertaken through Eddy Pro Software. Furthermore, removal of spikes and the choice of a friction velocity (u*) correction for the estimation of flux on calm night and gap filling were applied for data quality control and data gaps were filled with linear interpolation, mean diurnal variation and non-linear correlation with temperature and photosynthetically flux density (PPFD) as appropriate.

Results and Discussion

To compare CO_2 flux of DEF and MDF, NEE was estimated, some of the measured nocturnal data were eliminated by using the 0.4 and 0.25 m s^{-1} u* threshold respectively and gap filling was applied as appropriate. The data sets of the DEF and MDF in 2011 were analyzed for the daily trend of CO_2 flux as presented in Fig.1. It can be inferred that the fluxes of CO_2 were always positive during night hours, whereas during the day time the flux was negative. Normally during the day time plant photosynthesis leads to uptakes of CO_2 from the atmosphere and releases of CO_2 to the atmosphere through plant and heterotrophic respiration. On the other hand, respiration at night leads to an efflux of CO_2 to the atmosphere. In addition, seasonal variation in daily trend of CO_2 flux was evident (Figure 1),

Figure1 also shows variations of daily mean CO_2 flux in 2011. The values obtained in the DEF where trees did not shed their leaves but rather minimized leaf activity in the dry season varied considerably with changes in climatic factors, while the MDF values were largely scattered. The annual NEE values were -2.68 and -3.62 tC ha^{-1} yr^{-1} respectively reflecting significant carbon sinks in these two forests. The result is in contrast with Gamo et al. (2005) and Hirata et al. (2008) which indicated ecosystem carbon sources and small ecosystem carbon sink observed in these two forests during 2000-2004. However, the seasonal or interannual variation in CO_2 flux depended largely on ecosystem respiration which, in turn, was affected by seasonal changes in water resources (Gamo et al., 2005). Simulation of NEE with climatic factors influencing and its partitions such as gross primary production and ecosystem respiration is therefore essential to get insights into interaction of environmental factors and ecosystem carbon balance.

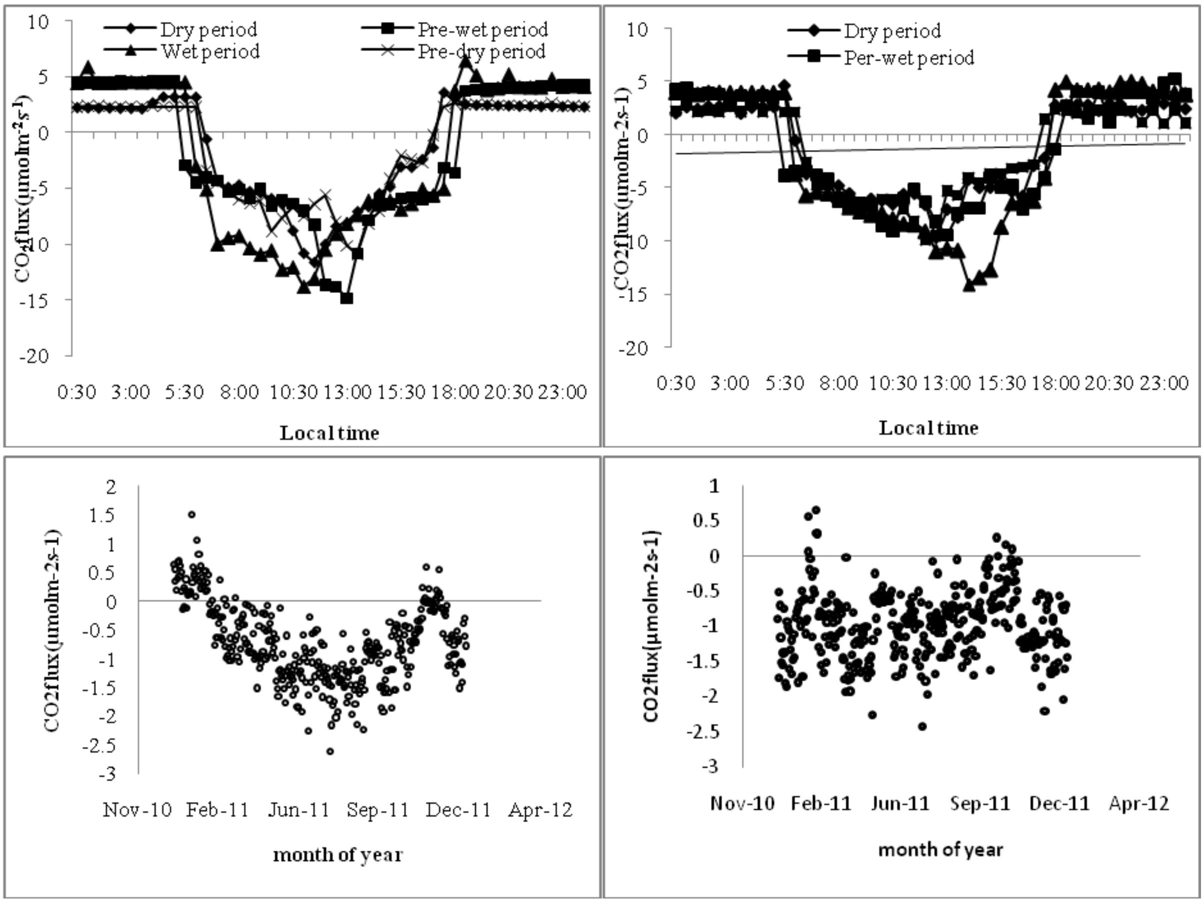

Figure 1 Daily and seasonal trend of CO_2 flux in dry evergreen and mixed deciduous forests

Conclusion

The daily and seasonal trend of CO_2 exchange and its factors affecting was remarkable probably due to tree phenology and changes in associated climatic factors. The seasonal variation in CO_2 flux observed in the DEF seemed to be affected by tree phenology and climatic factors but that of the MDF was more scattered. Overall, the annual NEE reflected carbon gain in the DEF and MDF but correlation between NEE with climatic factors influencing and its partitions such as gross primary production and ecosystem respiration could be applied to get insights into interactions of environmental factors and ecosystem carbon balance estimates.

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