2nd International Conference on Forests and Water in a Changing Environment

CO_2 exchanges over a teak plantation in northern Thailand

Yasunori Igarashi, Nobuaki Tanaka, Takanori Sato, Natsuko Yoshifuji, Katsunori Tanaka, Chatchai Tantasirin, Masakazu Suzuki

Graduate School of Agriculture And Science, The University of Tokyo

Background

In the last two decades, networks investigating CO_2 exchanges over forests using the eddy covariance method (EC) have been well developed in the world.

For example, net ecosystem exchange (NEE), ecosystem respiration (RE) and gross primary products (GPP) have been reported for many tropical forests in equatorial regions of Amazon and South-east Asia.

However,

The CO_2 exchanges over tropical deciduous forests were less studied despite their large expansion (FAO 2001).

In a deciduous tropical forest in Asian Monsoon climate, Yoshifuji et al. (2006) reported that growing season length for the studied deciduous forest varies considerably between years, and implies a large inter-annual variations in annual GPP.

Given that growing season length controls annual NEE, RE and GPP, it is important to understand how leaf phenology affects CO_2 exchanges in tropical deciduous forests.

Objective

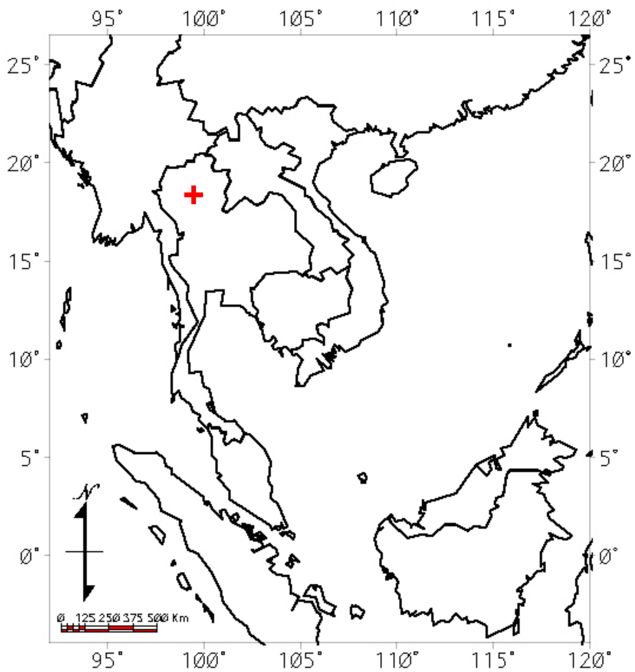
Objectives of this study are:

1. to examine diurnal and seasonal variations in CO2 exchanges over a tropical deciduous forest in Asian monsoon climate, and factors controlling these variations
2. to estimate annual CO_2 exchanges over the studied forest

Site

Mae Moh plantation

Location: Lampang province, Thailand (18’25’ N, 99’43’ E)
Elevation: 380 m
Vegetation: 37 years old teak plantation(*Tectona grandis* Lim. f.)
Vegetation height: 20 m
Average DBH: 22 cm
Soil type: clay loam
(~3 m depth)



Map of Thailand
(+): locations of our study site

Rainy season (July, 2008)

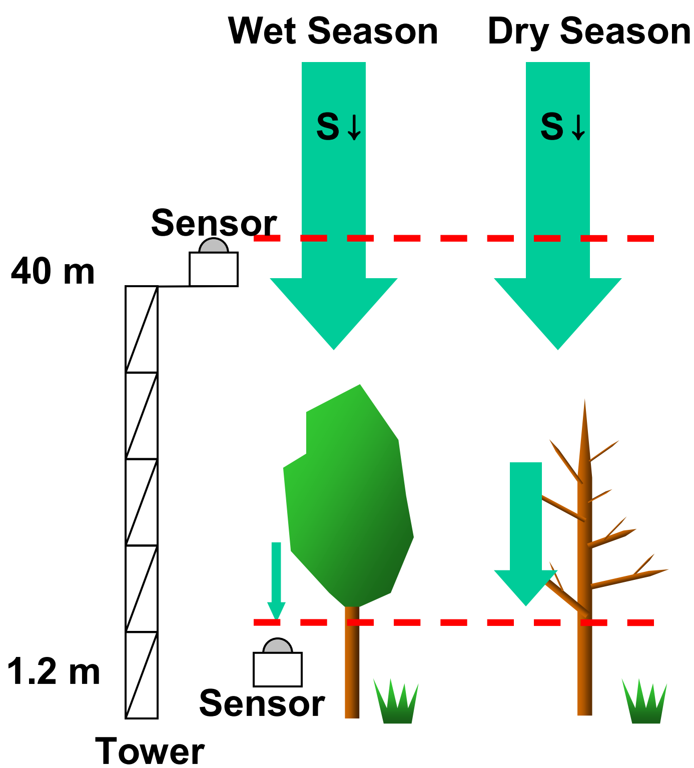
Dry season (March, 2009)

Method

rPAI

$$rPAI = -\log\left(\frac{S\downarrow ground}{S\downarrow tower\ top}\right)$$

S↓ground : Solar radiation (1.2 m), S↓tower top : Solar radiation (40 m), (S↓ground, S↓tower top > 0)



NEE

$$NEE = Fc + Fs$$

where

$$Fs = \int_0^{Zr}\left(\frac{\delta c}{\delta t}\right)dz$$

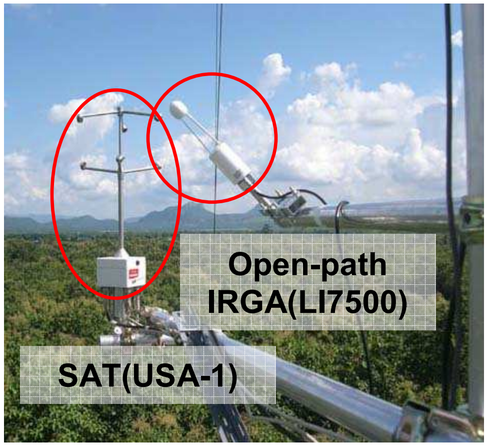
NEE : Net ecosystem exchange , *Fc* : CO_2 flux above canopy (Eddy covariance method) *Fs* : CO_2 storage flux in the air below canopy, *Zr* : top of canopy , c : CO_2 concentration , *t* : time

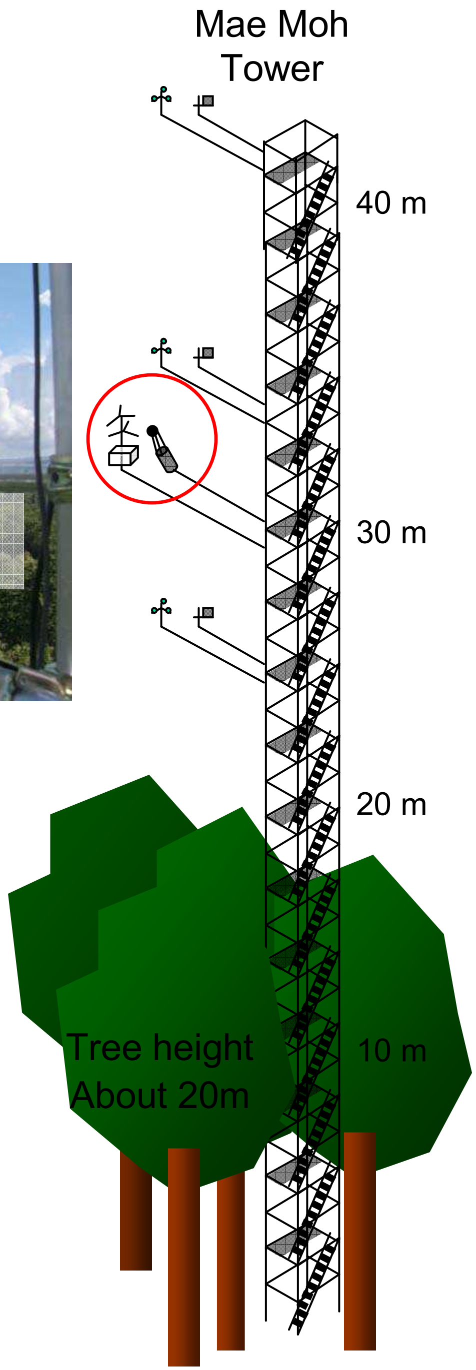
Observation

Eddy flux measurements

CO_2 flux above canopy : (Fc)

CO_2 storage flux below the flux measurement height : (Fs)





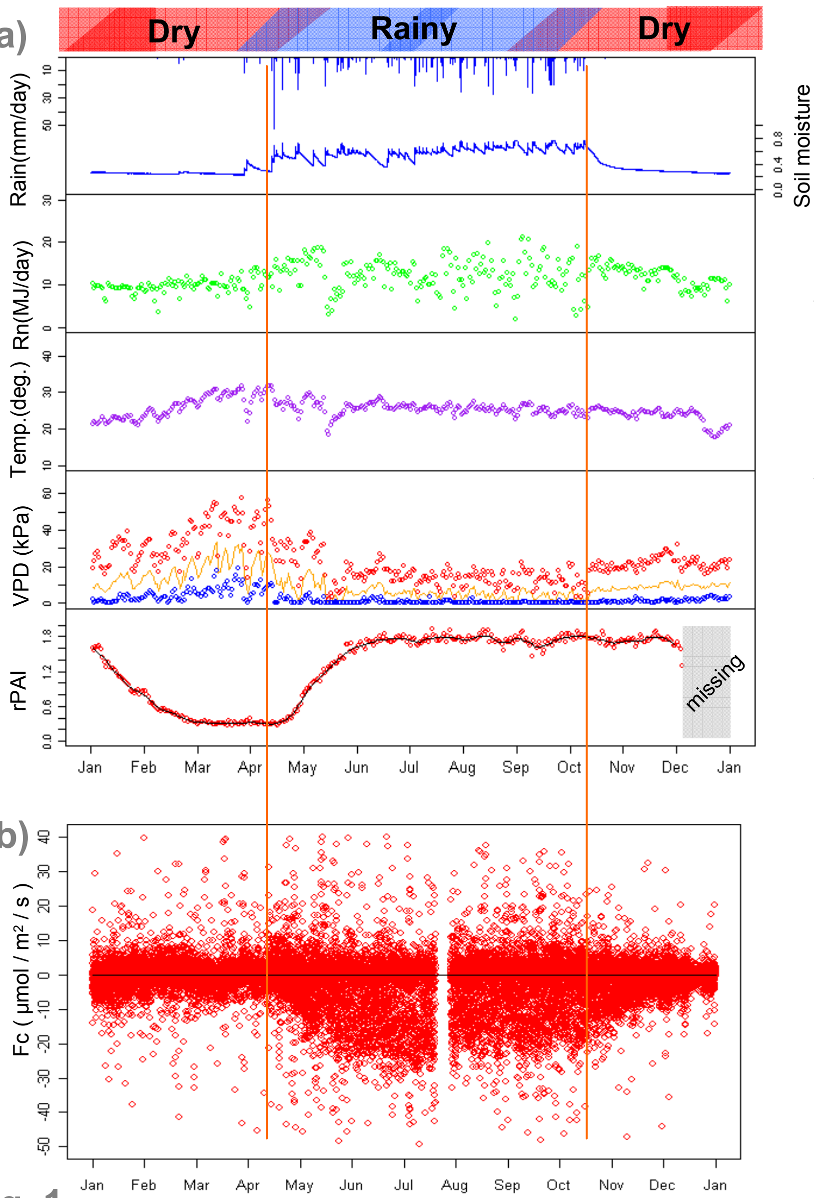
Meteorological measurements

Item	High
Temp and humidity	40, 28, 20, 14, 8, 2 m
Wind speed	39, 31, 20 m
Wind direction	39, 31, 20 m
Short wave radiation	Upward 41.4 m ; Downward 36.6 m
Long wave radiation	Upward 41.4 m ; Downward 36.6 m
Pressure	37.3 m
Rain	37.3 m

Results

Seasonal changes in above canopy micrometeorology and NEE

(a)



(b)

Fig. 1

Rain and Soil moisture

The Rainy season continued from the middle of April to middle of October.Rain and Soil moisture corresponded.

Net radiation(Rn)

Dry season > Rainy season

A decline in Rn during the rainy season was due to the cloud.

Temperature

Dry season > Rainy season

VPD

Dry season > Rainy season

(●:daily max., - :daily mean, ●daily min.)

rPAI

From the end of April to middle of June, rPAI was increasing

From November to March, rPAI was decreasing.

NEE

In the dry season, amplitude of NEE is smaller.

This was mainly due to decrease both in the photosynthesis and ecosystem respiration.

In the rainy season. NEE is larger.

This was mainly due to large increase in the photosynthesis.

Results

Daytime variations of NEE

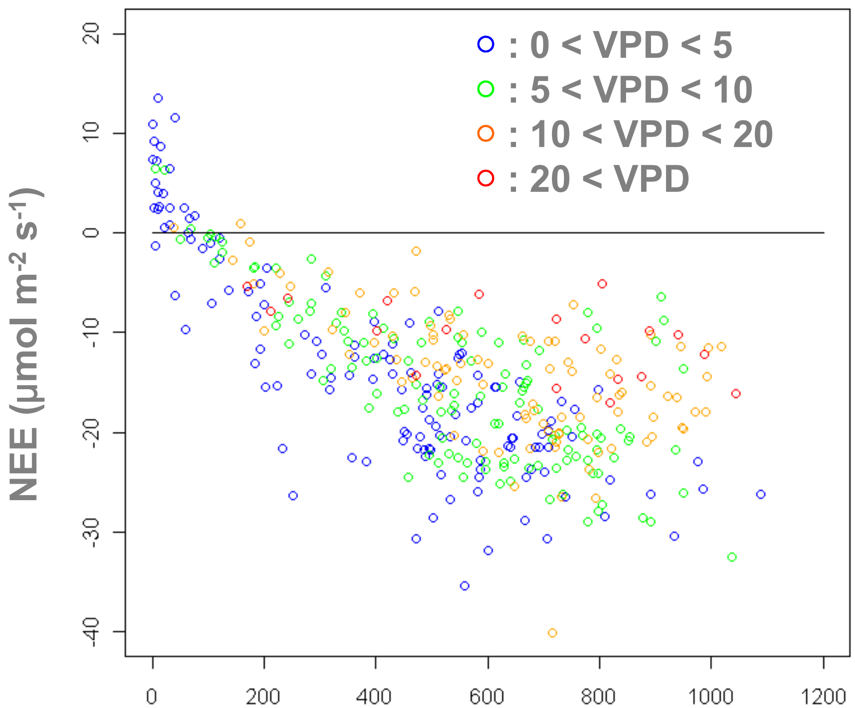


Fig. 2 (a) *Sd* (W m^{-2})

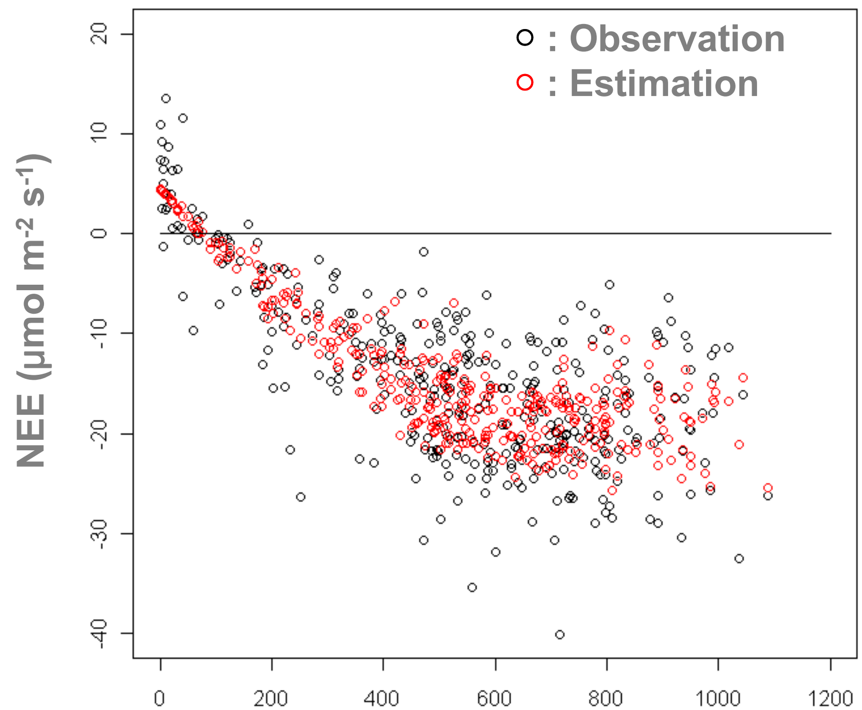


Fig. 2 (b) *Sd* (W m^{-2})

The daytime NEE was estimated by the light-curve equation below.

$$NEE = -\frac{(\varepsilon \cdot Sd + P\max) - \sqrt{(\varepsilon \cdot Sd + P\max)^2 - 4 \cdot m \cdot \varepsilon \cdot P\max}}{2m} \cdot (1 - VPD \cdot \beta) + R$$

Sd : Solar radiation, *VPD* : Vapor pressure deficit

*P*max : , ε: parameter, *m* : parameter, β: parameter, R: daytime ecosystem respiration

Results

Seasonality of rPAI to Pmax

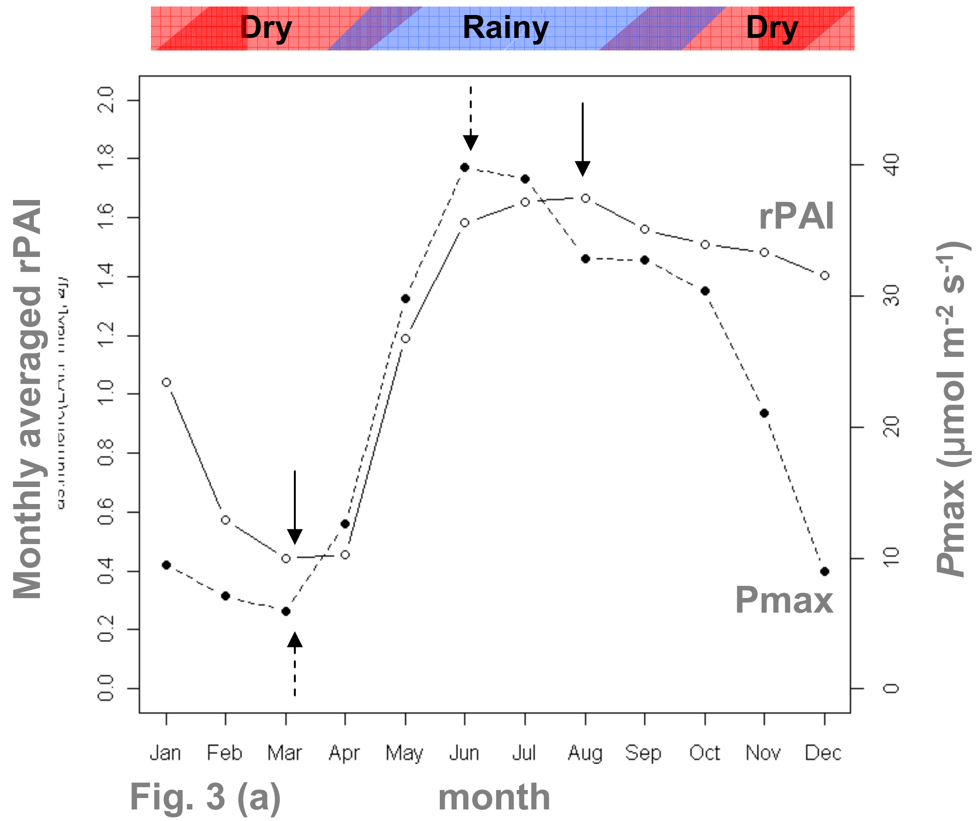


Fig. 3 (a)

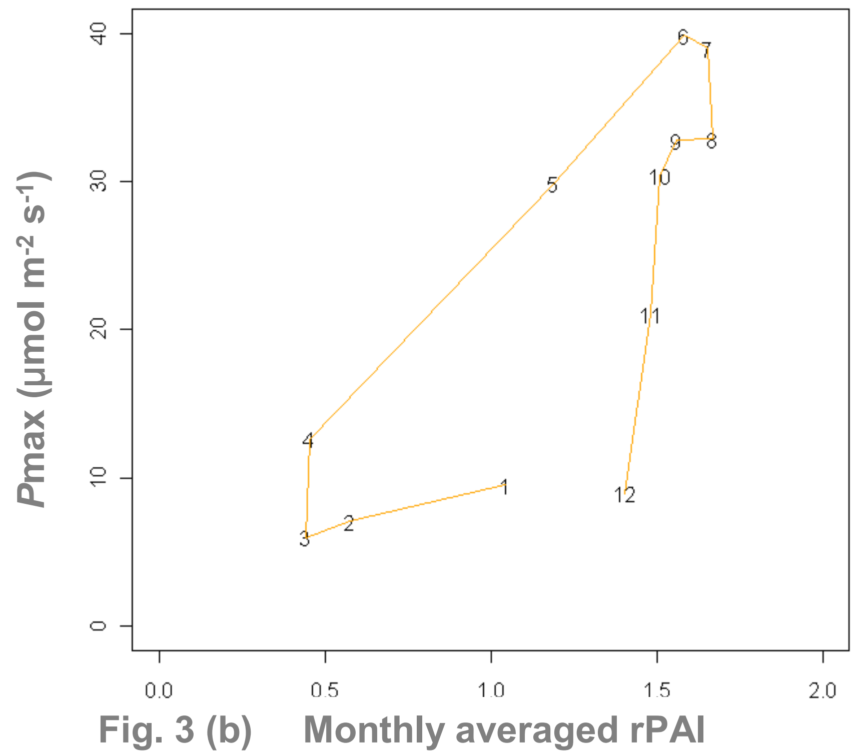


Fig. 3 (b)

Monthly averaged rPAI and *P*max

In March, Pmax and rPAI are lowest.

While, Pmax and rPAI peaked in June and August, respectively

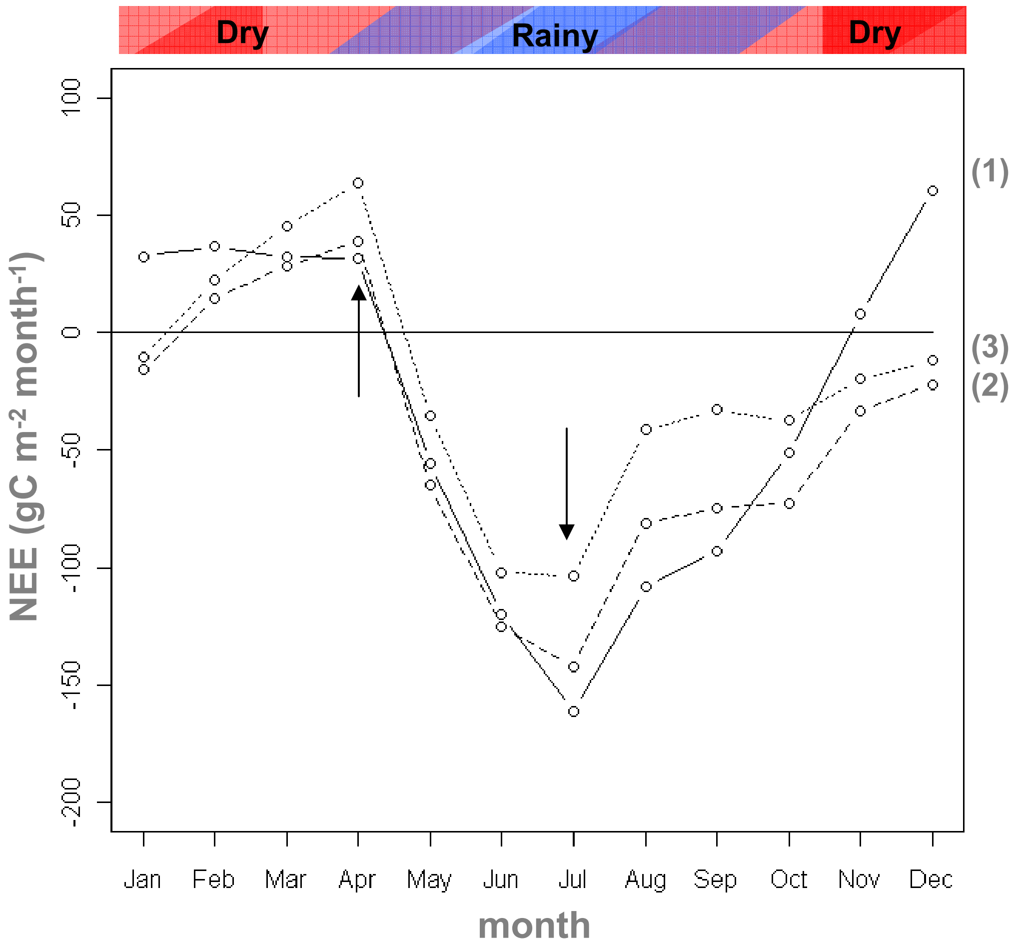
Relationship between rPAI to *P*max

From April to June, a relation between rPAI and Pmax is linear.

But, from June to December, decrease in Pmax is larger than in rPAI.

Results

Estimation of NEE in teak plantation



Gap filling method

- Daily gap was filled by using a light-curve.
- Night time NEE was corrected by 3 ways.
  (1) u* correction (u*> 0.2)
  (2) Rsoil * 1.5
  (3) Rsoil * 2.5

It means that a proportion of Soil respiration in ecosystem respiration is 0.6 or 0.4, respectively.

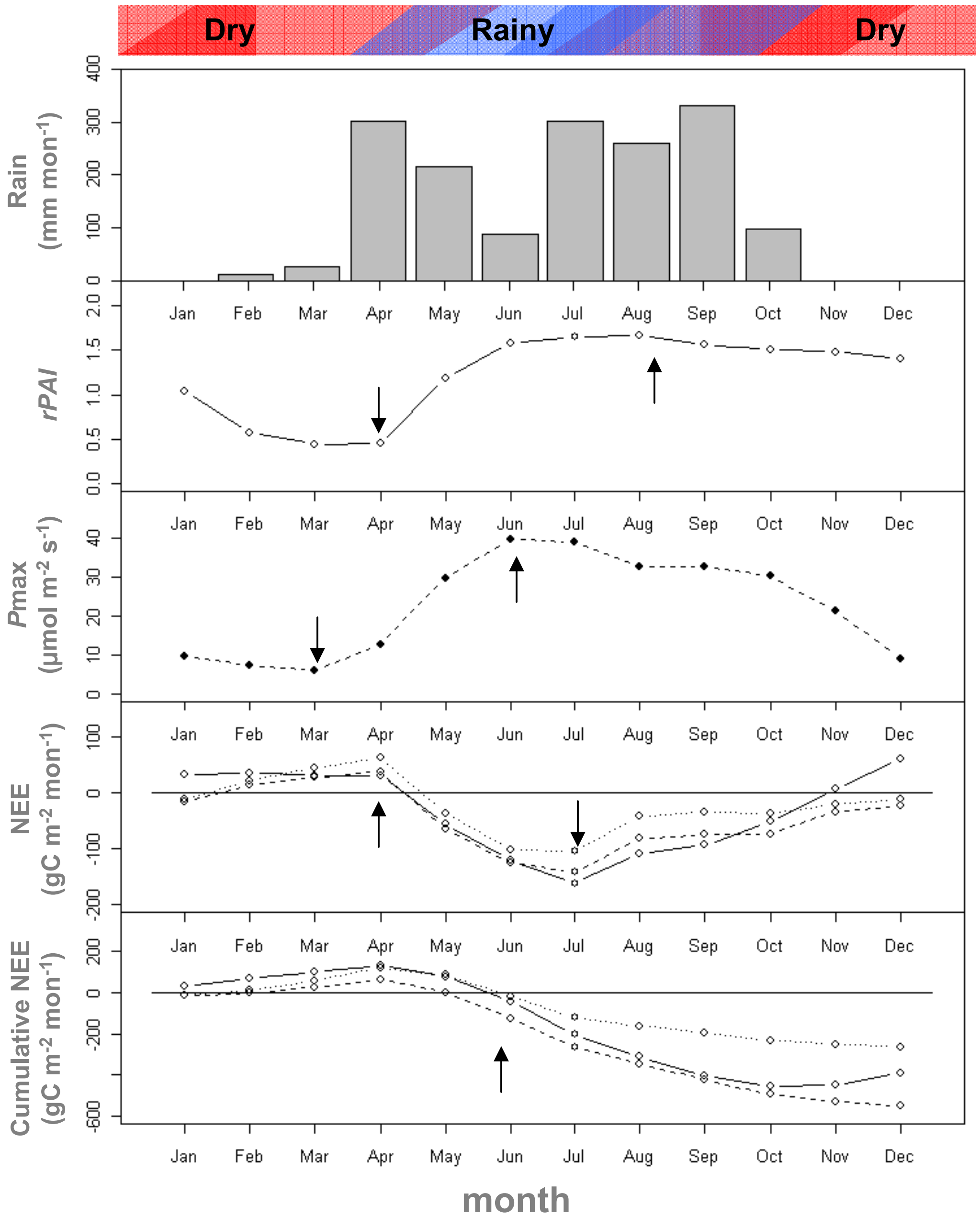
Soil respiration(Rsoil) was estimated using a equation below.

$$Rsoil = 8.8 * TDR10 + 0.2 * Ts10 – 6.2$$

TDR10 : Soil moisture 10cm depth
Ts : Soil temperature 10cm depth

- The maximum and minimum monthly NEE appears in July and April, respectively.

What factors affect NEE?



Asian monsoon

Seasonality of rainfall and soilmoisture

Leaf amount (leaf-ouf, leaf-fall)

During Leaf-out:
Pmax and rPAI coresponded

During Leaf-fall:
Pmax and rPAI don't coresponded

NEE

– 409 ± 143(SD) gC m^{-2} yr^{-1}

(3) - 280 gC m^{-2} yr^{-1}

(1) - 462 gC m^{-2} yr^{-1}

(2) - 569 gC m^{-2} yr^{-1}

Concluding remarks

This study clarifies

1. The diurnal and seasonal variations in CO_2 exchanges over a teak deciduous forest in Asian monsoon climate.
    1. Diurnal NEE variation in the growing season was controlled mainly by incident radiation and VPD
    2. Seasonal NEE variation is largely affected by leaf phenology like leaf-out and leaf-fall, but, in the late growing season, NEE declined despite large leaf amount.

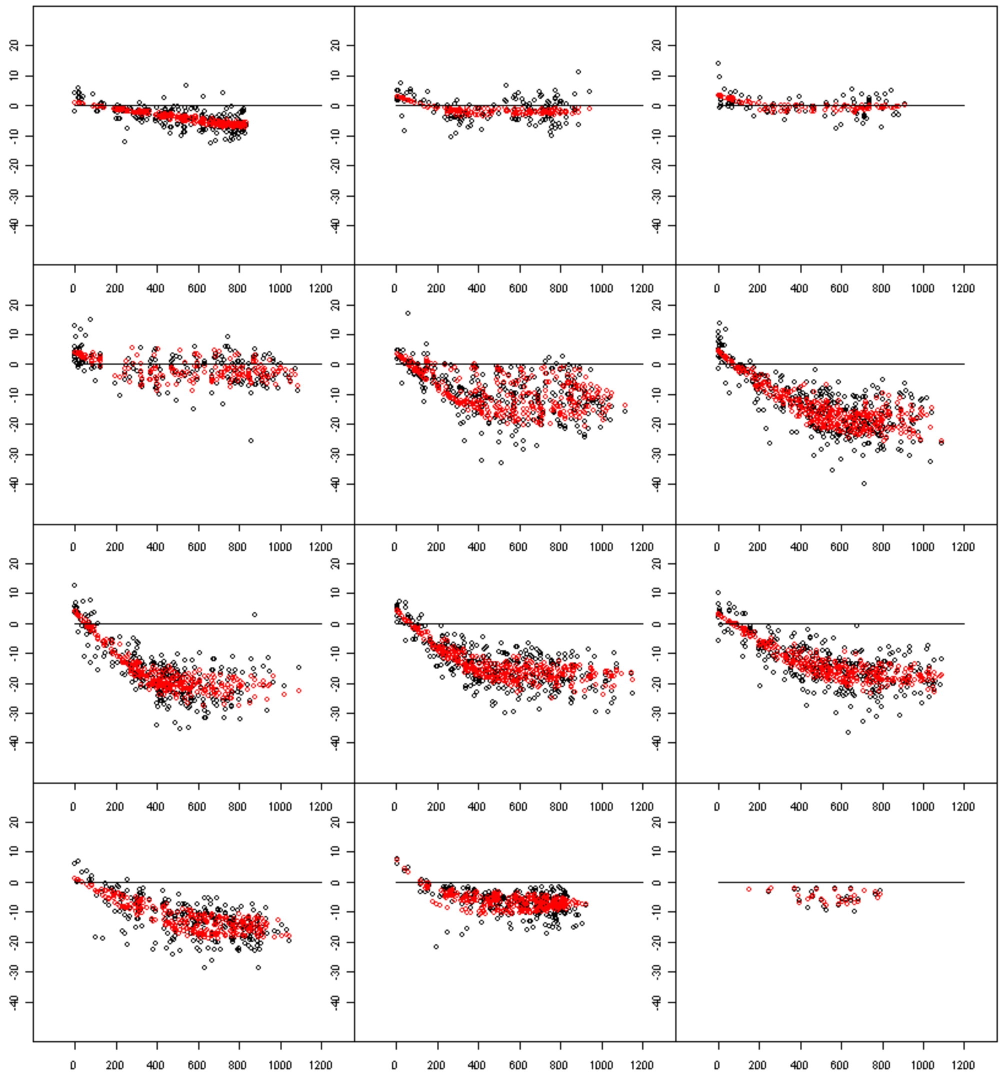
2. The annual CO_2 exchanges over the studied forest.
    1. Annual NEE was estimated at

NEE : - 409 ± 143 (S.D.) gC m^{-2} yr^{-1}

RE : - 2030 ± 498 (S.D.) gC m^{-2} yr^{-1}

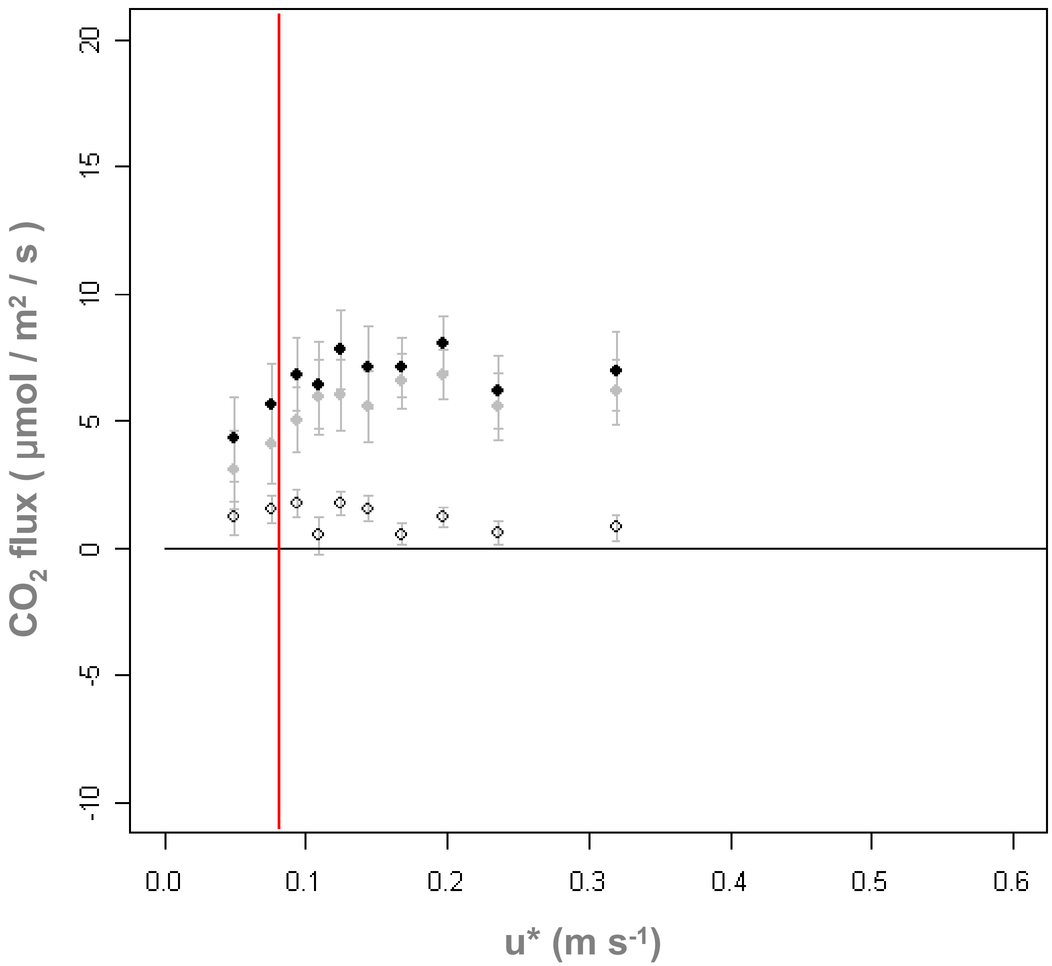
GPP : - 2369 ± 220 (S.D.) gC m^{-2} yr^{-1}

Appendix
Fitting light curve



Appendix

Estimation of a night time respiration using u*.
(Ecosystem respiration)



Appendix

Relationship between daily averaged GPP to rPAI