ROLE OF SOIL TEMPERATURE AND MOISTURE ON SOIL RESPIRATION IN A TEAK PLANTATION AND MIXED DECIDUOUS FOREST IN THAILAND

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WANGLUK S, BOONYAWAT S, DILOKSUMPUN S & TONGDEENOK P. 2013. Role of soil temperature and moisture on soil respiration in a teak plantation and mixed deciduous forest in Thailand. This study aimed to estimate and compare diurnal and seasonal variations of soil respiration in a teak (*Tectona grandis*) plantation and a mixed deciduous forest in Thailand, and to investigate the role of soil temperature and soil moisture in affecting soil respiration. Soil respiration was determined by closed-chamber technique with three replicates in each experimental plot and was measured twice in a month from April 2010 till March 2011. This study showed that land cover change had no effect on soil diurnal and seasonal respiration behaviour. Diurnal variation in soil respiration was largely fluctuated in teak plantation compared with mixed deciduous forest. Seasonally, soil respiration values were 326.8 and 313.2 g C m^{-2} $year^{-1}$ (136.7 and 131.0 mg CO_2 m^{-2} $hour^{-1}$) in the teak plantation and mixed deciduous forest respectively. There were seasonal variations in soil respiration at both sites; soil respiration in the wet season was significantly higher than that in the dry season ($p = 0.011$ and 0.005 in teak plantation and mixed deciduous forest respectively). On the other hand, differences in soil respiration between teak plantation and mixed deciduous forest were not significant in the wet and dry seasons. Soil moisture was a major factor influencing seasonal variation of soil respiration while soil temperature played a key role in controlling diurnal variation. Soil respiration in mixed deciduous forest was more sensitive to change in soil temperature ($Q_{10} = 2.02$) than that in teak plantation ($Q_{10} = 1.63$) due to large soil respiration variation in mixed deciduous forest observed during the early wet season.

Keywords: Diurnal variation, Q_{10} value, seasonal variation, soil carbon dioxide emission, tropical deciduous forest

WANGLUK S, BOONYAWAT S, DILOKSUMPUN S & TONGDEENOK P. 2013. Peranan suhu serta kelembapan tanah terhadap respirasi tanah di ladang jati serta hutan campur daun luruh di Thailand. Kajian ini bertujuan untuk menganggar dan membandingkan variasi harian serta bermusim respirasi tanah di ladang jati serta hutan campur daun luruh di Thailand, dan menyiasat kesan suhu serta kelembapan tanah terhadap respirasi tanah. Respirasi tanah ditentukan secara teknik kebuk tertutup dengan tiga ulangan dalam setiap plot eksperimen. Ukuran dibuat dua kali sebulan dari April 2010 hingga Mac 2011. Kajian ini menunjukkan bahawa perubahan penutup bumi tiada kesan terhadap kelakuan respirasi tanah harian mahupun bermusim. Variasi harian bagi respirasi tanah turun naik dengan banyaknya di ladang jati berbanding dengan hutan campur daun luruh. Mengikut musim, nilai respirasi tanah adalah masing-masing 326.8 g C m^{-2} $tahun^{-1}$ dan 313.2 g C m^{-2} $tahun^{-1}$ (136.7 mg CO_2 m^{-2} jam^{-1} dan 131.0 mg CO_2 m^{-2} jam^{-1}) di ladang jati dan hutan campur daun luruh. Variasi bermusim berlaku di kedua-dua tapak. Namun, respirasi tanah semasa musim tengkujuh lebih tinggi secara signifikan berbanding dengan musim kering ($p = 0.011$ di ladang jati dan $p = 0.005$ hutan campur daun luruh). Sebaliknya, perbezaan respirasi tanah antara ladang jati dengan hutan campur daun luruh tidak signifikan pada kedua-dua musim tengkujuh dan kering. Kelembapan tanah merupakan faktor utama yang mempengaruhi variasi bermusim respirasi tanah sementara suhu memainkan peranan penting dalam mengawal variasi harian. Respirasi tanah di hutan campur daun luruh lebih sensitif terhadap perubahan suhu tanah ($Q_{10} = 2.02$) berbanding dengan ladang jati ($Q_{10} = 1.63$). Ini diakibatkan oleh variasi besar dalam respirasi tanah di hutan campur daun luruh pada awal musim tengkujuh.

INTRODUCTION

Soil respiration, the carbon dioxide (CO_2) emission from soil surface, is an important component of carbon (C) balance in terrestrial ecosystems. Soil respiration originates are products of both autotrophic respiration (root respiration and respiration of root exudates by rhizospheric microbes) and heterotrophic respiration (soil microorganisms that decompose the organic matter) (Kuzyakov 2005). Annual soil respiration rate across ecosystem was estimated

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at about 0.91 kg C m^{-1} $year^{-1}$ (Chen et al. 2010). Soil respiration contributes 50–95% of the total ecosystem respiration (Xu et al. 2001, Wang et al. 2004), most of which comes from tropical ecosystem (Raich et al. 2002). Mean annual soil respiration in tropical ecosystem is 1286 ± 633 g C m^{-2} (Bond-Lamberty & Thomson 2010). Carbon dioxide emission from soil is a major component of greenhouse gas emission. Consequently, a small change in soil respiration as a response to environmental change can have great effects on the concentration of atmospheric CO_2.

Soil respiration is sensitive to biotic and abiotic variables of soil (Bain et al. 2005). These include vegetation type, substrate supply, soil temperature, soil moisture, soil oxygen, litter quality (carbon:nitrogen ratio), soil bulk density, soil texture and soil pH (Luo & Zhou 2006). The relative effects of these limiting factors vary with climate and vegetation types (Ohashi et al. 2008). In temperate regions, soil temperature is the most important factor in temporal variation of soil respiration (Luan et al. 2012). For tropical regions, variations in both soil temperature and moisture are recognised as the main factors (Ohashi et al. 2008, Adachi et al. 2009, Hanpattanakit et al. 2009). Thus, detailed information on spatial and temporal variations of soil respiration in different landuse types is necessary to construct regional carbon budgets. Knowledge of soil respiration, especially in teak (*Tectona grandis*) plantations and mixed deciduous forest, is still very poor.

Conversion from forest to agricultural landuse and plantation or changing management practices (e.g. plowing, fertilisation, irrigation) has often led to a net loss of soil carbon. It has also affected soil respiration by altering the input of substrate supply and increase in decomposition of soil organic matter (Wiriyatangsakul et al. 2006, Moscatelli et al. 2007). Estimates of annual global CO_2 emission due to deforestation and landuse change are about 1.6 Gt C or 5.9 Gt of CO_2 (1 Gt = 10^{15} g) that accounts for approximately 17% of total CO_2 emissions (IPCC 2007). In Thailand, conversion of natural mixed deciduous forest to teak plantations occurred throughout the northern region, especially in Lampang province due to high commercial value of teak (Takahashi et al. 2009). In 2010, teak plantation area throughout Thailand was 985.43 km^2, of which 833.13 km^2 (84.54%) were scattered throughout the northern region (FIO 2010). However, there is lack of information on the effect of landuse conversion on soil respiration. Furthermore, the role of soil temperature and soil moisture in teak plantations remain poorly understood in Thailand.

A study on the temporal variation of soil respiration in teak plantations and mixed deciduous forest would provide insights into the role of soil temperature and soil moisture on soil respiration characteristics as affected by landuse change. We hypothesised that soil temperature and soil moisture would differently influence the temporal variation of soil respiration between these two landuses. In the current study, the main objectives were, therefore, to estimate and compare the diurnal and seasonal variations of soil respiration at both sites and to investigate the role of soil temperature and soil moisture in soil respiration.

MATERIALS AND METHODS

Study site and experimental design

The study site was carried out in the Mae-Moh district, Lampang province, located in northern Thailand (18° 40' N, 99° 47' E) at an elevation ranging from 300 to 350 m above mean sea level. The study site is characterised by a tropical climate with wet (April till October) and dry (November till March) seasons. The annual precipitation from April 2010 till March 2011 was 1382.6 mm and the annual mean air temperature was 25.3 °C, with monthly mean minimum values of 16.2 °C in January 2011 and maximum 39.0 °C in April 2010. Two experimental areas in Mae-Moh district were selected for the study of soil respiration. The teak plantation plot was planted with a spacing of 4 m inter-tree spacing in 1968 (aged 43 years at the time of study) and had been thinned (312 trees per ha^{-1}). The average height of teak was about 17 m with average diameter base height of 21.4 cm. Soil in the teak plantation at 0–30 cm layer had texture of clay loam (sand: 39%, silt: 27%, clay: 34%) and was acidic (pH 4.78). Bulk density of the soil was high (1.40 g cm^{-3}), organic matter moderate (2.31%), total carbon was 1.48%, total nitrogen 0.11% and C:N ratio moderate (13.62). A secondary natural mixed deciduous forest was located adjacent to the teak plantation. The dominant species were teak and bamboo. Soil texture in the 0–30 cm layer was clay loam (sand: 36%, silt: 28%, clay: 36%). The soil was also acidic (pH 4.85) and had high bulk density (1.29 g cm^{-3}) and organic matter (3.91%). Total carbon was 2.16%, total nitrogen 0.15% and C:N ratio was moderate (15.18). The two experimental areas were homogeneous soil. The teak plantation was a flat and uniform area with an average slope of 2.7%. Equilateral triangle experimental method design with 50-m spacing was used to collect data. The mixed deciduous forest was a hilly area with an average slope of 26.18%. Three experimental points with different elevation levels, i.e. high (490 m), middle (450 m) and low (400 m) were used in data collection (Figure 1).

Data collection and analysis

A closed-chamber technique was used for measurement of soil respiration using an opaque plastic chamber with diameter 20.32 cm and height 20 cm. The opaque chamber had two parts, a cover and base. The cover consisted of a rubber stopper that was designed to include a thermometer for measurement of air temperature in the chamber and an air sampling needle. The base was permanently installed into the soil at a depth of 3 cm where air sampling was conducted to investigate the CO_2 concentration. Soil respiration was measured with three replicates in each experimental plot and was measured twice monthly from April 2010 till March 2011. Measurements in the teak plantation were taken hourly from 7 till 6 p.m. while in the mixed deciduous forest, every two hours. Air in the chamber was sampled with a 10 mL syringe at 30, 45 and 60 min after the chamber was closed and the CO_2 concentration in chamber was analysed by an infrared gas analyser. Measurement data were calibrated with linear calibration curve of standard gas (CO_2). Soil respiration rate (mg CO_2 m^{-2} $hour^{-1}$) was then calculated using the relationship between basal area of the chamber, rate of change in CO_2 concentration inside the chamber and air temperature inside the chamber (Wetchayont 2004) as follows:

$$\text{Soil respiration rate} = 60 \times 10^{-6} \left((a \times p \times v) / s \right) \quad (1)$$

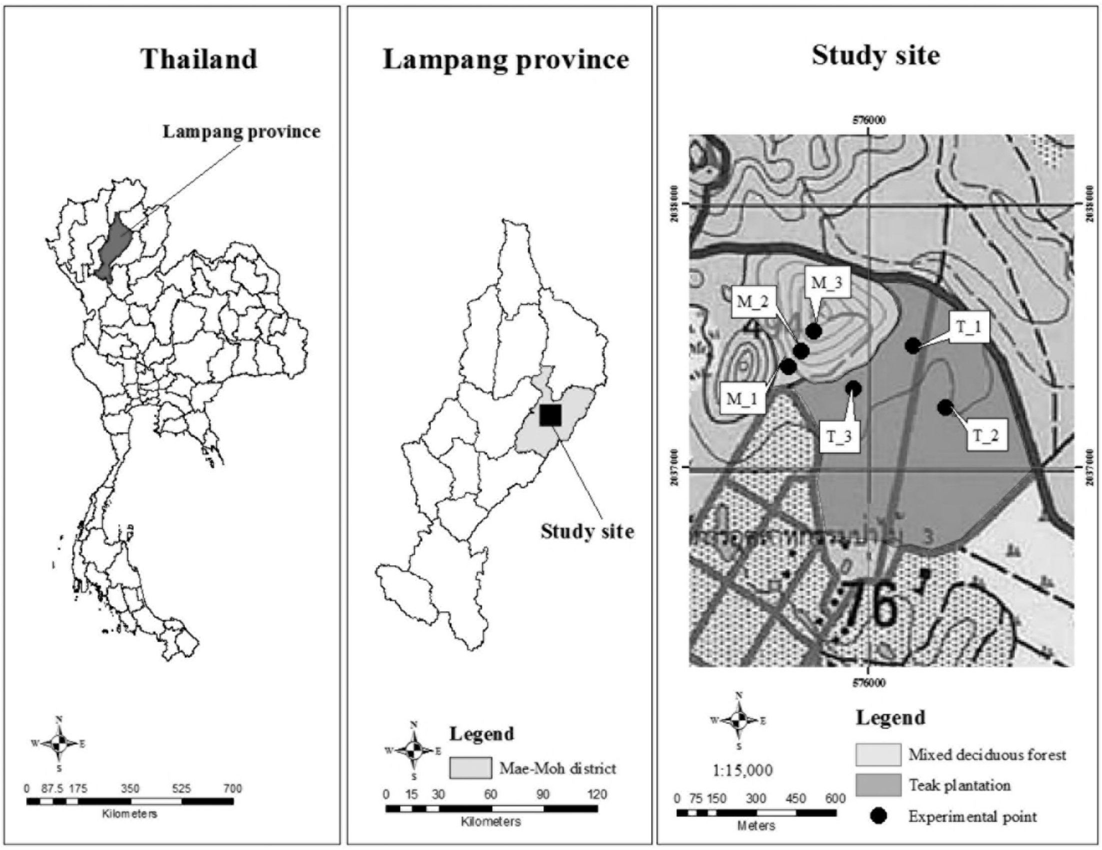

Figure 1 Location of study site in Thailand; M and T are experimental plots in mixed deciduous forest and teak plantation respectively

where a = rate of change of CO_2 concentration inside the chamber (μL L^{-1} min^{-1}), p = absolute air temperature inside the chamber (°C), v = volume of the chamber (m^3) and s = basal area of the chamber (m^2).

In addition to these measurements, soil temperature and soil moisture were measured at a depth of 5 cm close to the chamber at the same time as the soil respiration measurements were taken. Soil temperature was measured using a thermometer probe and soil moisture (% volume), a frequency domain reflectometry. All measurements were taken in triplicates.

Temperature sensitivity of soil respiration (Q_{10}) indicates the increase in the rate of soil respiration when temperature is increased by 10 °C (Van't Hoff 1898). An exponential function model was used to describe the relationship between soil respiration rate and soil temperature:

$$\text{Soil respiration} = \beta_0 e^{\beta_1 T} \quad (2)$$

where T = soil temperature (°C) and β_0 and β_1 = regression coefficients. The Q_{10} value was calculated as:

$$Q_{10} = e^{10\beta_1} \quad (3)$$

Q_{10} value was calculated monthly using mean soil respiration and mean soil temperature. Measurements were in triplicates at both sites.

Statistical analysis

Statistical analyses were performed with the SAS statistical package (SAS 9.1.3). Mean soil respiration value represented the diurnal variation at site. Mean values of three replicates within the month represented the seasonal variation. Student's *t*-test statistic, at 95% confidence interval, was used to determine the differences in the average soil respiration between site and during the wet and dry seasons of soil respiration at both sites. Non-linear regression analysis (r^2 values) was used to investigate the roles of soil temperature and moisture on soil respiration at both sites.

RESULTS AND DISCUSSION

Diurnal variation

Table 1 showed the average soil respiration at relevant times of the months. Diurnal variations of soil respiration at both sites were similar to changes in soil temperature (Figure 2). Soil respiration values were low in the early morning but increased in the late morning reaching a peak around 1–2 p.m. (Figure 2a) and 12–2 p.m. (Figure 2b) at the teak plantation and mixed deciduous forest respectively. The values gradually decreased in the afternoon until evening. These results indicated that diurnal variation in soil respiration depended on soil temperature during the day. Soil temperature in teak plantation ranged from 25.42–28.18 °C and 20.83–27.14 °C in July 2010 and February 2011 respectively while in mixed deciduous forest, 24.17–26.17 °C and 19.08–25.33 °C in July 2010 and January 2011 respectively. The temperature varied noticeably on a diurnal scale with solar radiation, air temperature, wind velocity, atmospheric pressure and relative humidity.

Similar results have been reported for a dry evergreen forest where maximum flux was observed in the afternoon between 2 and 3 p.m. (Wiriyatangsakul et al 2006). Soil respiration was also related to air and soil temperature in a dry dipterocarp forest (Hanpattanakit et al. 2009) where maximum value was attained around 2–3 p.m. After reaching a peak, soil respiration stayed at high level until around midnight, after which it decreased towards early morning.

Figure 2 shows an example of the diurnal variation of soil respiration observed in this study. It showed the same pattern in the dry season when the values were lower than those in the wet season for both sites. Soil moisture values in the wet season were 27.0 and 24.7% in teak plantation and mixed deciduous forest respectively, while in the dry season, 18.3 and 14.0% in teak plantation and mixed deciduous forest respectively. Such dry conditions could result in low soil respiration because of low biological activities. Our study also showed that diurnal variation in soil respiration was poorly correlated with soil moisture at both sites (Figures 3a and b).

Seasonal variation

Monthly variations in soil respiration were similar between the two sites (Figure 4). Average soil respiration values were 326.8 and 313.2 g C m^{-2} $year^{-1}$ (136.7 and 131.0 mg CO_2 m^{-2} $hour^{-1}$) in teak plantation and mixed deciduous forest respectively but the values were not significant ($p = 0.0545$, $n = 12$) despite the difference in

Table 1 Hourly average of soil respiration in teak plantation and mixed deciduous forest

Site/time	Average soil respiration (mg CO_2 m^{-2} $hour^{-1}$)												
	2010									2011			Mean
	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
Teak plantation													
7 a.m.	100.8	110.6	137.6	173.7	128.3	138.0	157.4	132.0	111.4	94.0	88.3	92.6	122.1
8 a.m.	109.6	116.9	152.5	177.6	127.5	142.0	161.5	141.0	113.1	94.5	88.9	93.1	126.5
9 a.m.	118.6	124.9	174.1	177.8	121.6	141.0	169.7	147.3	114.2	98.1	93.5	102.8	132.0
10 a.m.	125.4	124.7	178.3	174.7	133.2	142.1	173.5	145.7	120.3	94.8	94.9	99.5	133.9
11 a.m.	126.0	124.0	171.3	185.3	132.0	147.1	184.6	153.0	124.7	93.8	100.4	103.2	137.1
12 p.m.	132.3	133.6	184.9	193.7	133.9	151.7	188.2	164.8	124.9	105.2	104.2	111.3	144.1
1 p.m.	136.4	144.0	181.5	210.3	143.2	172.4	188.7	165.9	155.7	106.0	109.1	117.8	152.6
2 p.m.	130.4	141.3	183.9	201.7	143.0	177.1	184.0	155.3	151.3	109.4	109.6	125.2	151.0
3 p.m.	125.4	135.6	183.4	183.6	131.9	161.4	168.6	146.8	142.1	103.1	97.3	116.4	141.3
4 p.m.	108.1	137.9	160.0	181.8	130.4	156.2	164.6	144.2	142.5	102.2	97.1	111.2	136.4
5 p.m.	104.7	132.4	160.7	166.8	121.0	155.5	168.3	147.9	144.0	100.8	96.3	114.5	134.4
6 p.m.	102.1	119.2	163.5	170.8	112.2	151.2	159.7	146.3	133.8	98.8	90.2	103.6	129.3
Mean	118.3	128.8	169.3	183.2	129.9	153.0	172.4	149.2	131.5	100.0	97.5	107.6	136.7
Mixed deciduous forest													
8 a.m.	108.0	121.6	131.0	168.2	161.5	145.8	127.0	114.2	113.0	80.9	87.8	109.9	122.4
10 a.m.	123.0	128.7	131.8	178.6	164.3	155.2	169.0	117.3	116.1	82.6	95.5	112.8	131.2
12 p.m.	142.8	132.9	140.7	195.8	192.7	162.1	177.1	120.4	118.9	87.7	114.5	124.7	142.5
2 p.m.	141.4	150.7	142.4	200.6	184.3	164.0	175.4	127.7	153.8	98.6	114.7	133.1	148.9
4 p.m.	127.4	139.5	142.6	164.1	111.7	150.2	151.4	116.9	109.6	84.1	86.0	101.3	123.7
6 p.m.	137.0	122.3	129.6	167.0	102.2	124.4	150.3	109.2	99.9	80.3	82.6	98.4	116.9
Mean	129.9	132.6	136.3	179.0	152.8	150.3	158.4	117.6	118.5	85.7	96.8	113.4	131.0
p-value	0.481	0.831	0.098	0.797	0.560	0.883	0.423	0.025*	0.673	0.465	0.857	0.477	0.545

Values are the mean of three replicates in each experimental plot, mean values within row indicate significant differences in soil respiration between the two sites in each month, two-way ANOVA (*t*–test): * = significant difference between sites in the corresponding month at 95% confidence level

vegetation type. This might be because both sites showed no difference in soil characteristics and climatic factors (Wangluk 2011).

There was similar seasonal variation in soil respiration at both sites, with average soil respiration during the wet season being higher than that in the dry season. Average soil respiration values in teak plantation during the wet and dry seasons were 150.7 and 117.2 mg CO_2 m^{-2} $hour^{-1}$ respectively while in the mixed deciduous forest, 148.5 and 106.4 mg CO_2 m^{-2} $hour^{-1}$ respectively (Table 2). Seasonal variation in soil respiration was significant between seasons at both sites. These results implied that seasonal variation of soil respiration was affected by changes in soil moisture (Figures 5 and 6). At both sites, soil moisture values in the wet season (27.0 and 24.7% in teak plantation and mixed deciduous forest respectively) were higher than the dry season (18.3 and 14.0%). Similar results have been reported for *Eucalyptus* plantation in Congo (Epron et al. 2004). For dry tropical forest in Thailand, soil respiration during the wet season was about twice that during the dry season (Adachi et al. 2009). Soil respiration rate in mixed deciduous forest in western Thailand showed clear seasonal patterns, with maximum and minimum rates in rainy and dry seasons respectively (Takahashi et al. 2011).

In this study, soil moisture increased from February till July 2011 and consequently increased soil respiration at both sites. Average

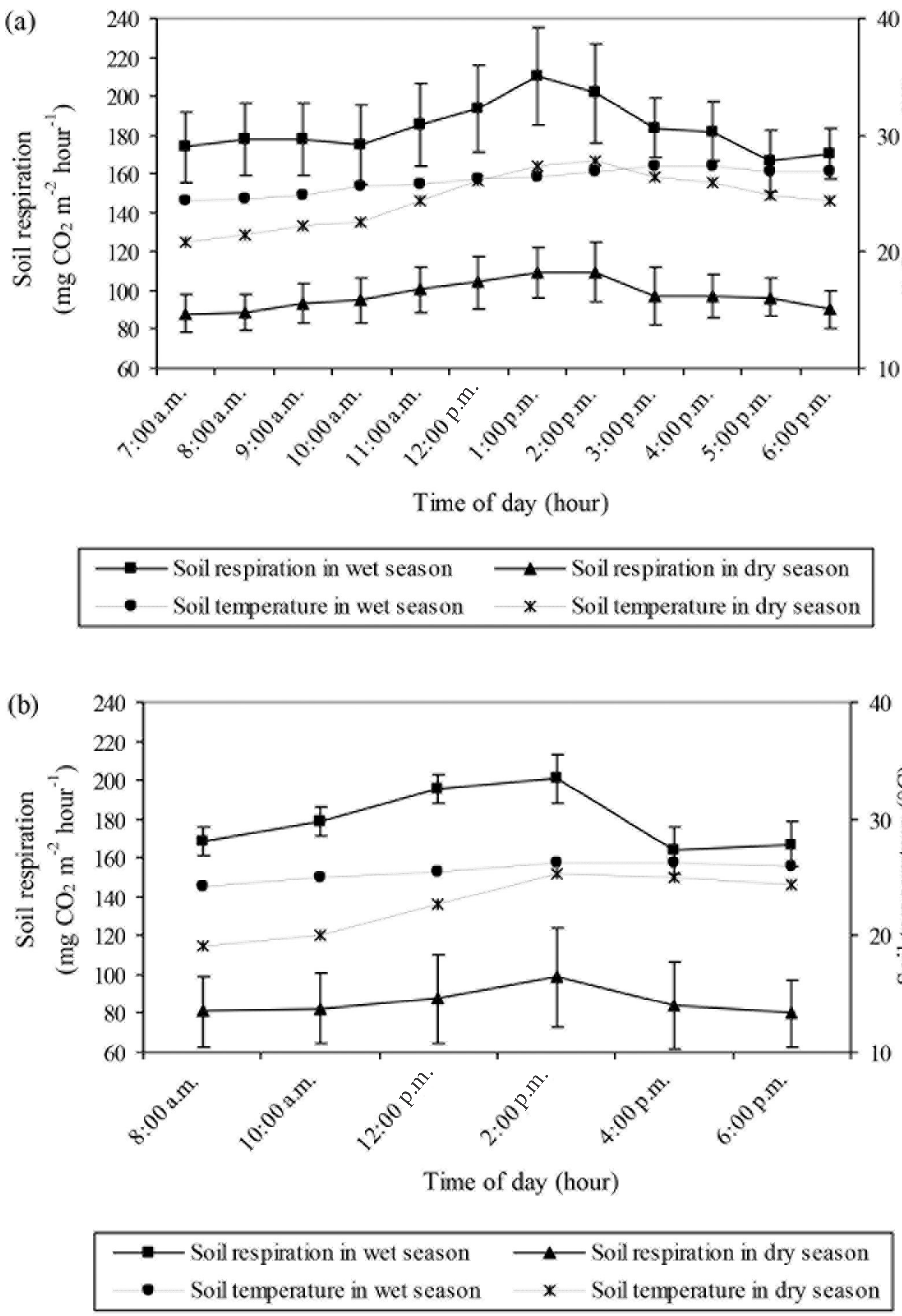

Figure 2 Diurnal variation of soil respiration in (a) teak plantation and (b) mixed deciduous forest; 28 July 2010 is an example of diurnal variation for wet season at both sites, 28 February 2011 and 28 January 2011 are examples of diurnal variation for dry season in teak plantation and mixed deciduous forest respectively; values are means and standard deviations (error bars) of three replicates within each hour between sites

soil respiration ranged from 97.5 to 183.2 mg CO_2 m^{-2} $hour^{-1}$ in teak plantation and 96.8 to 179.0 mg CO_2 m^{-2} $hour^{-1}$ in mixed deciduous forest. When soil moisture reached its maximum value (39.7% in teak plantation and 38.1% in mixed deciduous forest) in August, there was rapid decrease in soil respiration (Figure 4). This was probably due to an increase in dissolved substrate supply as soil moisture increased, thus, enhancing both root and microorganism activities. Conversely, at high soil moisture levels, oxygen diffusion rates limit respiration. At both sites, maximum soil respiration was observed in July when soil moisture contents were 28.7 and 28.3% in

Table 2 Comparison of the average soil respiration in wet and dry seasons between teak plantation and mixed deciduous forest

Season	Teak plantation			Mixed deciduous forest		
	Soil respiration (mg CO_2 m^{-2} $hour^{-1}$)	SD	CV (%)	Soil respiration (mg CO_2 m^{-2} $hour^{-1}$)	SD	CV (%)
Wet	150.7	22.9	15.2	148.5	16.7	11.3
Dry	117.2	20.0	17.1	106.4	13.4	12.6
p-value	0.0109*			0.0050**		

Average soil respirations are result of monthly data for three replicates in each experimental plot, standard deviation (SD) and coefficient of variation (CV) are results of monthly soil respiration, * = significant difference among seasons at 95% confidence level, ** = significant difference among seasons at the 99% confidence level

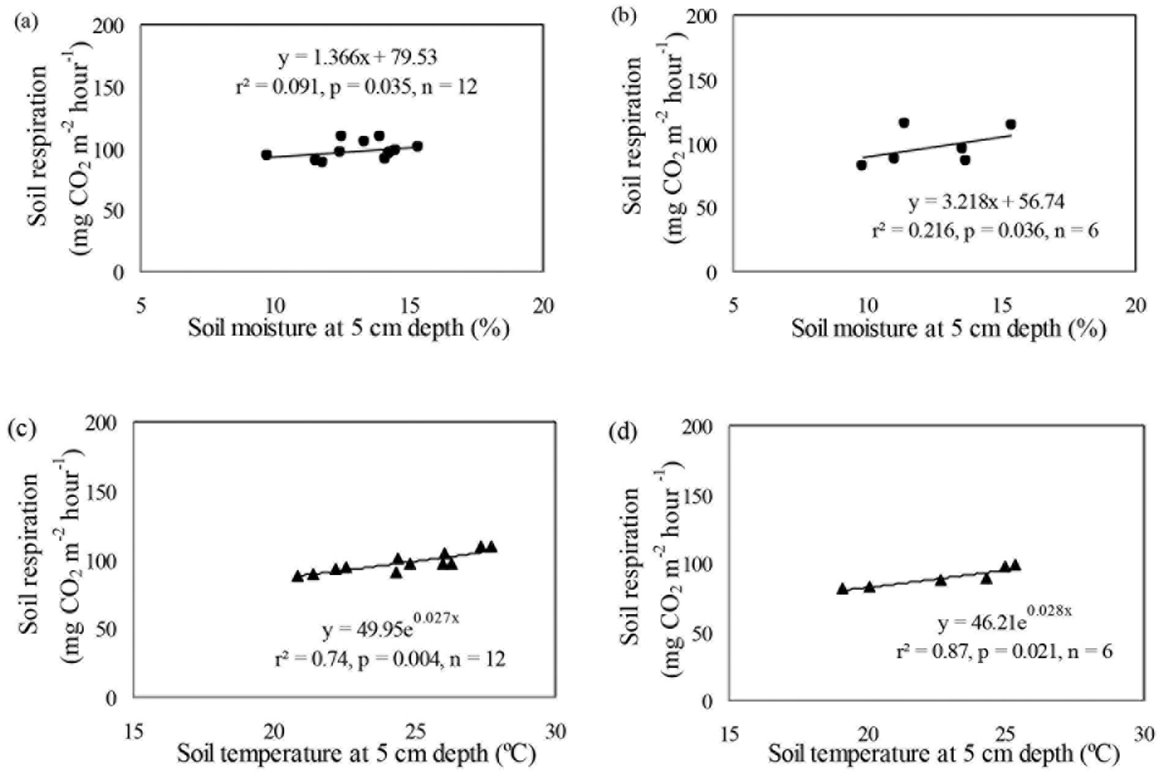

Figure 3 Relationships between diurnal variation of soil respiration and hourly average soil moisture for (a) teak plantation and (b) mixed deciduous forest and between diurnal variation of soil respiration and hourly average soil temperature for (c) teak plantation and (d) mixed deciduous forest; 28 February 2011 and 28 January 2011 are examples of diurnal variation of soil respiration in teak plantation and mixed deciduous forest respectively

teak plantation and mixed deciduous forest respectively. This result indicates that optimum soil moisture affects biomass decomposition, producing higher microorganism population and biotic activity (Panda et al. 2010, Mohanty & Panda 2011). High soil moisture also influences ion uptake by roots, which in turn increased root activity and root growth and, thus, root respiration.

Role of soil moisture and soil temperature on soil respiration

Generally, soil moisture and soil temperature are considered to be the most influential environmental factors controlling the rate of soil respiration. These factors interact to affect the productivity of terrestrial ecosystems and decomposition rate of soil organic matter, thereby

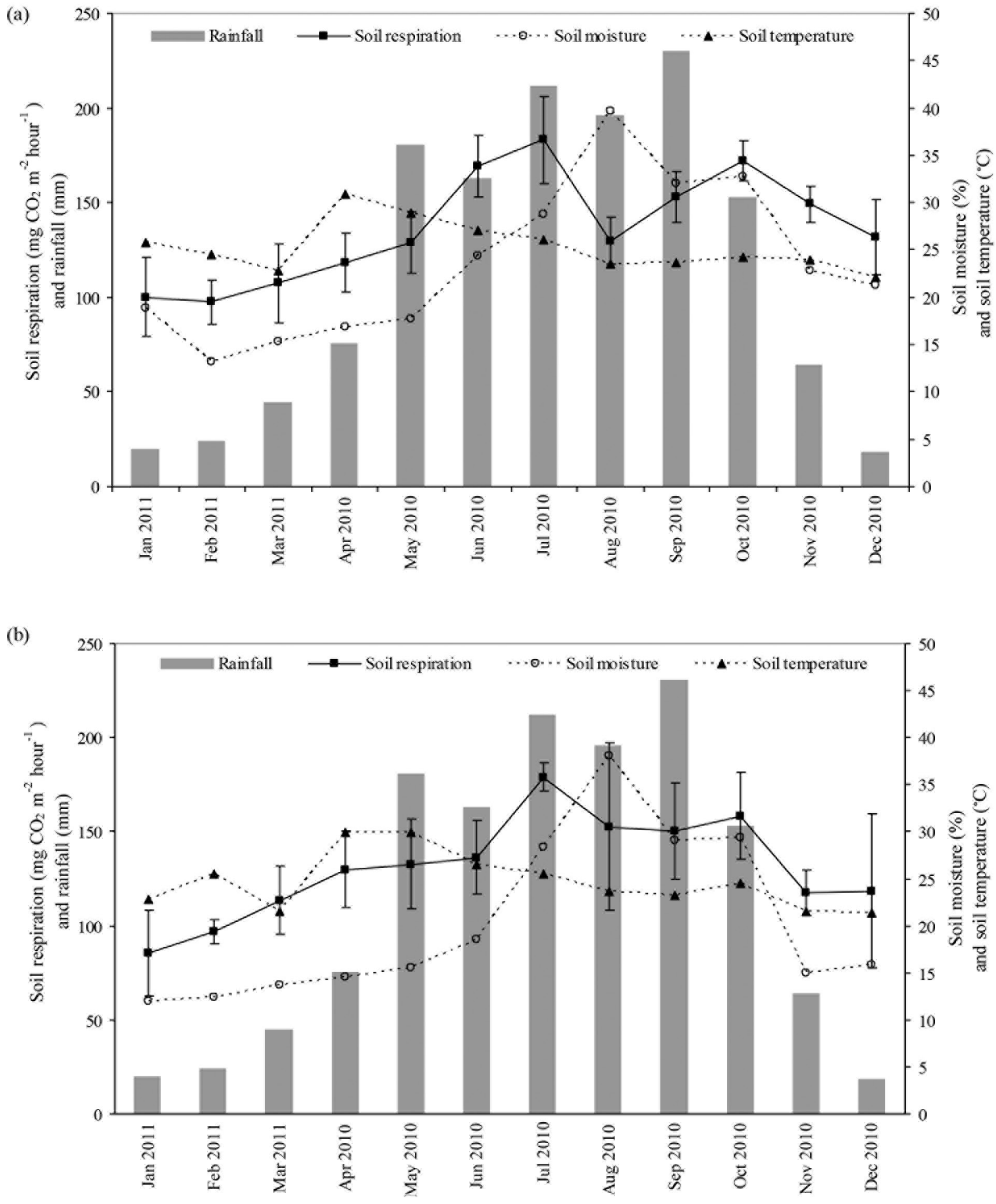

Figure 4 Monthly variation of soil respiration, rainfall, soil moisture and soil temperature in (a) teak plantation and (b) mixed deciduous forest; error bars represent standard deviations of three replicates within months

driving the temporal variation of soil respiration in tropical regions (Wiseman & Seiler 2004, Han et al. 2007). The current study showed the correlation of soil moisture and soil temperature at a soil depth of 5 cm with soil respiration and high coefficients of determination (r^2) (Figure 6).

Diurnal variation of soil respiration was attributed to soil temperature (Figures 3c and d). There was an exponential regression and positive correlation with soil temperature at 22.1–30.9 °C and 21.3–30.0 °C in teak plantation and mixed deciduous forest respectively. The temperature

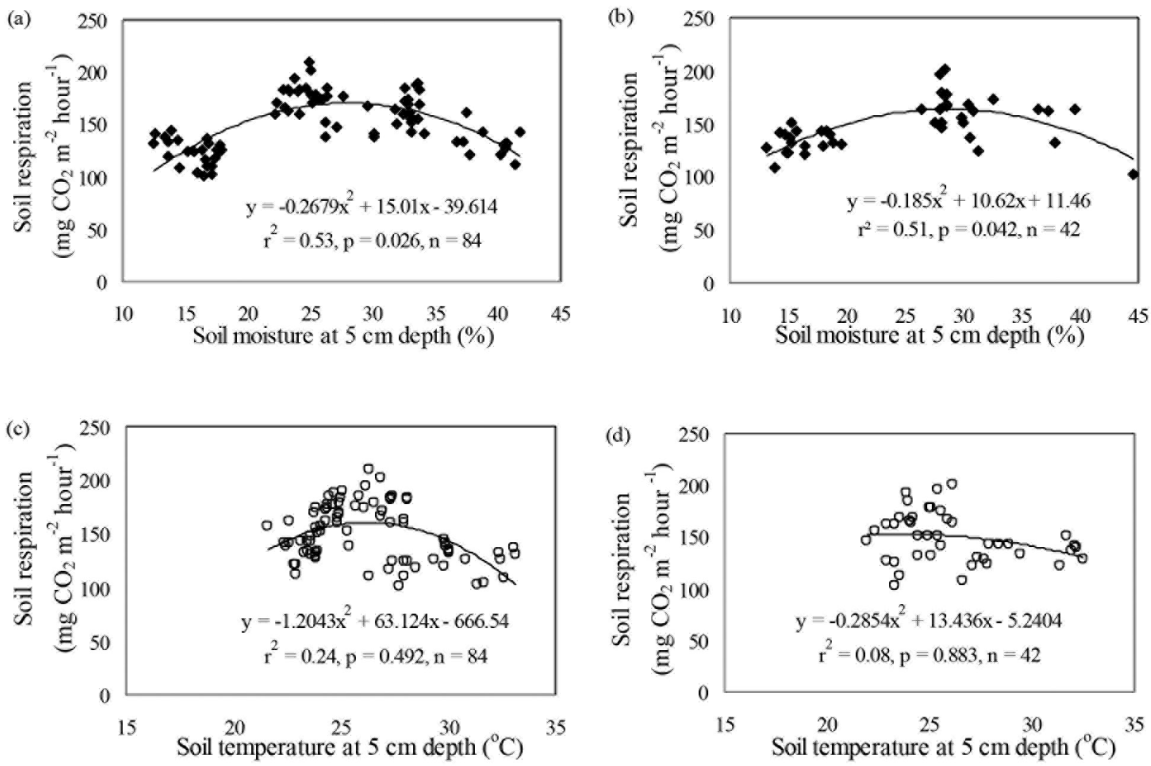

Figure 5 Relationships between soil respiration and hourly average soil moisture in wet season at (a) teak plantation and (b) mixed deciduous forest and between soil respiration and hourly average soil temperature in wet season at (c) teak plantation and (d) mixed deciduous forest

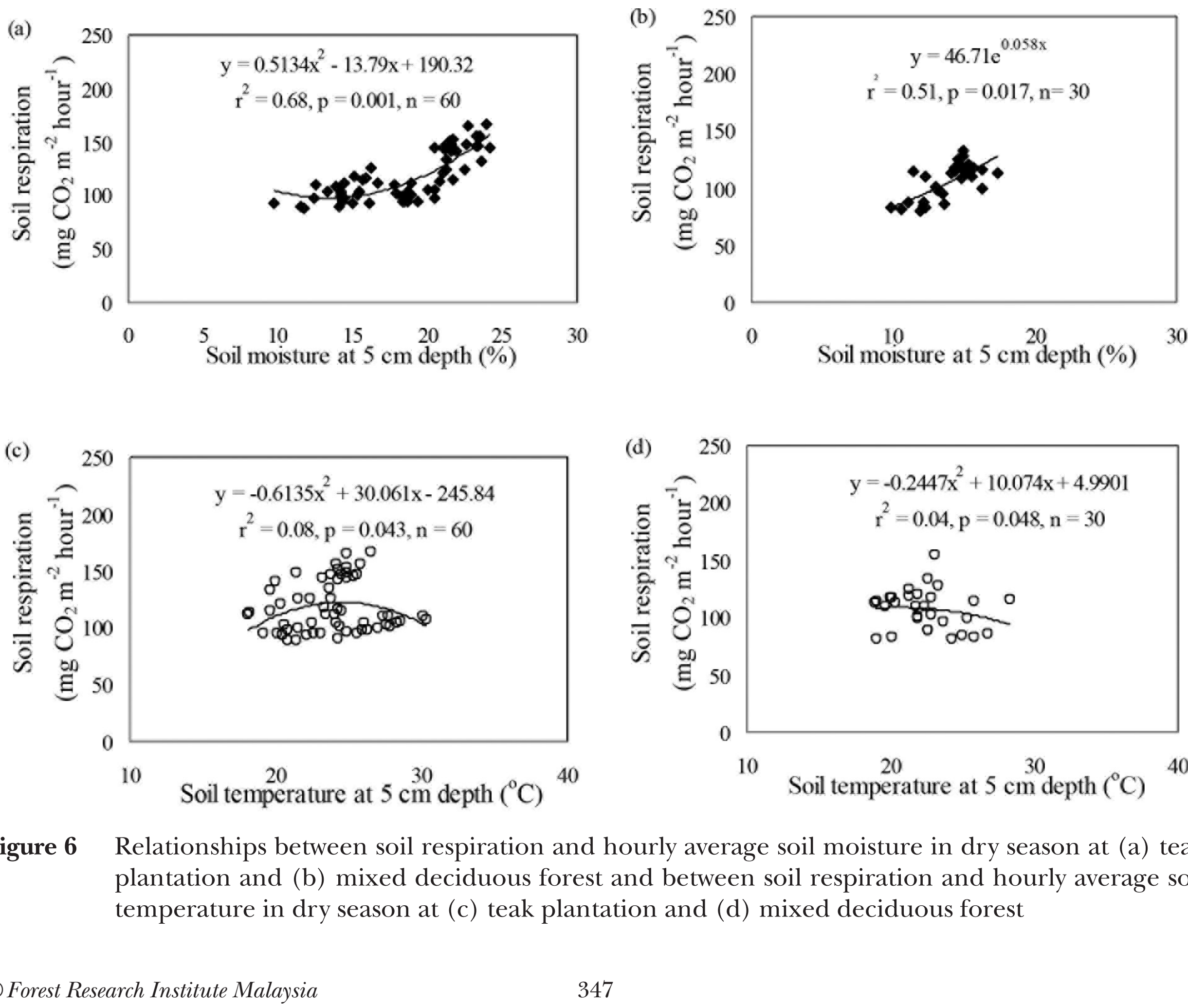

Figure 6 Relationships between soil respiration and hourly average soil moisture in dry season at (a) teak plantation and (b) mixed deciduous forest and between soil respiration and hourly average soil temperature in dry season at (c) teak plantation and (d) mixed deciduous forest

sensitivity of soil respiration was described by Q_{10} value. Average Q_{10} value was 1.63 and ranged from 1.12–2.77 when soil temperature was 18.08–33.17 °C in the teak plantation. For mixed deciduous forest, the average Q_{10} was 2.02 and ranged from 1.15–7.77 at soil temperature 18.97–32.50 °C. These results indicated that soil respiration in mixed deciduous forest was more sensitive to change in temperature than that in teak plantation due to large soil respiration variation in mixed deciduous forest observed during the early wet season. Q_{10} values obtained from tropical soil in this study were lower than those found in temperate soil (Luan et al. 2012). Unlike diurnal variation in soil respiration which was influenced by soil temperature, seasonal variation in soil respiration was rather determined by soil moisture, which was controlled by rainfall events. Amounts of soil moisture and rainfall were correlated with r^2 values of 0.56 and 0.74 for teak plantation and mixed deciduous forest respectively. In the wet season, the amount of rainfall was 1211 mm and soil moisture ranged from 14.7–39.7% and 14.5–38.1% in teak plantation and mixed deciduous forest respectively. Soil respiration in the wet season could be explained with a polynomial regression that was significant at both sites (Figures 5a and b). On the other hand, in the dry season, the amount of rainfall was 117.6 mm and soil moisture ranged from 13.1–22.8% and 12.0–15.8% in teak plantation and mixed deciduous forest respectively. The dry season could be explained as a significant polynomial regression in teak plantation (Figure 6a) while in the mixed deciduous forest, as a significant exponential regression (Figure 6b). There was a rather poor correlation between soil respiration and soil temperature in the wet (Figure 5c and d) and dry (Figure 6c and d) seasons. Results of this study concurred with observations by Ohashi et al. (2008) and Takahashi et al. (2009, 2011) who worked on tropical soil. Conversely, seasonal variations of soil respiration in temperate soil were correlated with soil temperature (Atarashi-Andoh et al. 2012, Luan et al. 2012).

CONCLUSIONS

Our study showed that land cover change had no effect on soil respiration behaviour in terms of diurnal and seasonal variations while soil temperature and moisture were major factors influencing diurnal and seasonal variations of soil respiration. Diurnal variation in soil respiration was largely fluctuated in teak plantation than in mixed deciduous forest. The values fluctuated with diurnal patterns of soil temperature on a daily basis for both sites, with maximum value of soil respiration occurring between 12 and 2 p.m. Soil respiration in mixed deciduous forest was more sensitive to change in soil temperature (Q_{10} = 2.02) than that in teak plantation (Q_{10} = 1.63) due to large soil respiration variation in the former during the early wet season. Seasonally, soil respiration values were 326.8 and 313.2 g C m^{-2} $year^{-1}$ (136.7 and 131.0 mg CO_2 m^{-2} $hour^{-1}$) in the teak plantation and mixed deciduous forest respectively. There were seasonal variations in soil respiration at both sites. Soil respiration in the wet season was significantly higher than that in the dry season. On the other hand, the difference in soil respiration in teak plantation and mixed deciduous forest was not significant in the wet and dry seasons. Soil moisture was a major factor influencing seasonal variation of soil respiration while soil temperature played a key role in controlling diurnal variation of soil respiration.

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