CHAPTER 6
CONTRIBUTION OF ROOT RESPIRATION TO SOIL RESPIRATION IN SUGARCANE PLANTATIONS IN THAILAND

Soil respiration is an ecosystem process that is relevant to the global carbon cycle. Rising CO_2 concentrations due to soil respiration has the potential of playing a key determinant role in terms of net ecosystem carbon balance and to become one of the important drivers for climate change. Major components of soil respiration are roots and microbial respiration, with a difference in the fraction contributing to the overall carbon balance. The ability to partition soil respiration between these two components is becoming increasingly more important to gain a better understanding of ecosystem responses to global change (Hanson et al., 2000; Raich and Tufekcioglu, 2000; Wange et al., 2005; Jia et al., 2006; Wei et al., 2009; Sayer et al., 2010; Zhao et al., 2011). However, the understanding on the component of soil respiration is still very limited, especially for sugarcane ecosystem. This study proposes to investigate this aspect for sugarcane plantation system in Thailand. The measurements were performed for the whole growing period of 344 days to quantify the contribution of root respiration to total soil respiration. The data obtained from the experiment was used for calculating the microbial respiration from sugarcane soils. This data is necessary to clarify for understanding on GHG balance for this crop. This chapter focused on the changes in sugarcane root respiration over a one-year cycle of planting.

6.1 Methodology

6.1.1 Site description

The experimental site covered an area of 535 m^2 was located in a permanent sugarcane field in Nakhon Sawan province situated in the lower northern region of Thailand, as shown in Figure 6.1. The climate at the experimental site is a tropical monsoon with a mean annual rainfall of 1,118.7 mm and an average annual temperature of 28.8 °C for the year 2012 (TMD, 2013). The soil type is clay dominant with low organic carbon content and moderately alkaline in the top 30 cm layer, as shown in Table 6.1.

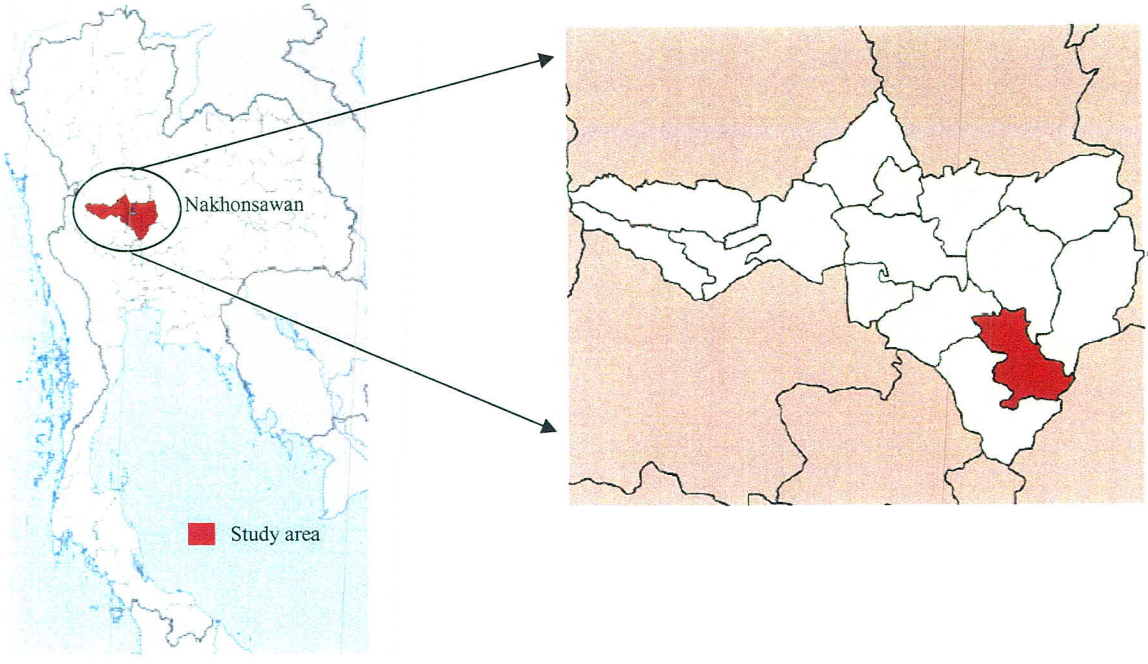


Figure 6.1 Study area located in Nakhon Sawan province

Table 6.1 Soil Properties of the sugarcane plantation at the experimental site

	Soil depths	
Soil characteristics	0-10 cm	10-30 cm
Texture and colour	Very dark grayish brown clay	
Textural analysis (%)		
Sand	29.24	31.24
Silt	24.88	24.88
Clay	45.88	43.88
pH	7.87	7.93
Organic carbon (g kg^{-1})	10.17	7.54
Total nitrogen (g kg^{-1})	2.07	1.87
Phosphorus (mg kg^{-1})	4.00	1.00
Exchangeable K (mg kg^{-1})	174.67	163.67
Bulk density (g cm^{-3})	1.23	1.42

The experimental site where measurements were made is part of a sugarcane plantation where open burning before harvesting has been continuously practiced by farmers over the last 20 years. Sugarcane at this site was planted in January 2012 and harvested in January of the following year. Three types of plowing were done at this site:

namely subsoiler, moldboard plow and disk harrow, respectively. Chemical fertilizers were applied four times during the year as a composite of fertilizer and urea. In addition, water was supplied only three times during the planting time for plant emergency.

6.1.2 Experimental design and measurements

In this study, root respiration was measured by a direct measurement method during the growing period between February and December 2012. Trenched plots, areas without roots, were established to assess sugarcane root respiration and its contribution to total soil respiration (Fig. 6.2).

Figure 6.2 Conducting trenching experiment for monitoring soil respiration in sugarcane crop

Three trenched plots of 0.8 m (depth) x 1.0 m (length) x 1.0 m (width) in size were randomly constructed between the row-spacing of sugarcane. Three control plots, areas with roots, were established based on a location relative to the trenched plots. Polyvinyl chloride (PVC) collars (20.0 cm inside diameter and 11.0 cm height) were inserted to a depth of 4 cm in the soil. Four collars were installed in each plot that is 24 collars in total (Fig. 6.2). Living plants inside the soil collars were removed one day before the measurement of soil CO_2 respiration, which done with a Li-840A CO_2/H_2O gas analyser equipped with a Li-COR 8100A chamber (Li-Cor Inc., Lincon, NE, USA). Measurements were made every 2 months during the growing season between February

and December 2012. All measurements at each time were conducted between 8.00 and 11.00 am. One measurement cycle of 2 min was repeated two times for each collar. During measurements, soil volumetric moisture content at the top 5 cm soil layer was assessed with a soil moisture meter (ThetaProbe-HH2, Delta-T Devices Ltd., UK), and soil temperature with a soil temperature probe. Soil respiration was determined based on Equation (6.1) (Li-COR, 2006).

$$R = \frac{10VP_o\left(1-\frac{W_o}{1000}\right)\partial C'}{RS(T_0+273{\cdot}15)\,\partial t} \qquad (6.1)$$

where R is the soil respiration (μmol. m^{-2}. s^{-1}), V is the volume of chamber (cm^3), P_0 is the initial pressure (kPa), W_0 is the initial water vapor mole fraction (mmol. mol^{-1}), S is the soil surface area (cm^2), T_0 is the initial air temperature (°C), $\frac{\partial C'}{\partial t}$ is the initial rate of change in water-corrected CO_2 mole fraction (μmol^{-1} mol s^{-1}), and R is gas constant (K^{-1} mol^{-1})

Next, root respiration was estimated calculating the difference between soil respiration from a trenched plot (R_m) and a control plot (R_t) as shown in Equation (6.2).

$$R_r = R_t - R_m \qquad (6.2)$$

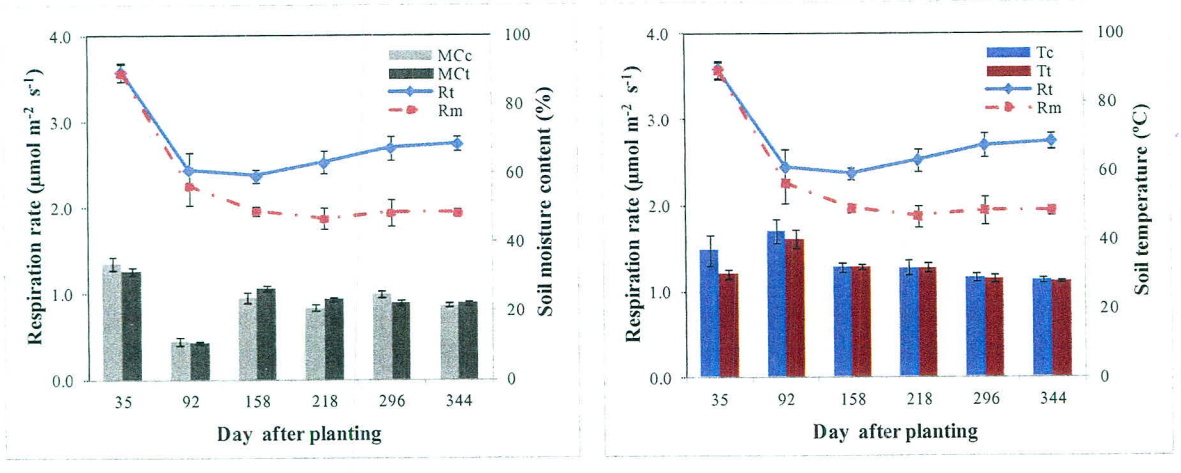
where: R_r is root respiration (μmol. m^{-2}. s^{-1}), R_t is soil respiration (μmol. m^{-2}. s^{-1}), and R_m is microbial respiration (μmol. m^{-2}. s^{-1})

6.2 Results and discussion

6.2.1 Seasonal variation of soil respiration rate in sugarcane plantation in Thailand

Figure 6.3 shows the variability observed among the 24 chambers and indicate that the data is normally distributed. Soil respiration rates from trenched plots were used to determine microbial respiration rates (R_m), while total soil respiration rates (R_t) were obtained via soil CO_2 respiration measurements performed in control plots, as shown in Figure 1. At the initial stage of growing over 92 days after planting (DAP), soil CO_2 respiration rates between the two plots are found to be not significantly different. In contrast, during 158 to 344 DAP, the total soil respiration rates in the control plots are observed to be higher than the microbial respiration rates from the trenched plots.

The difference could mainly be the result of an increasing root respiration rate as plants age under the control treatments. However, it should be noted that the high rate of soil respiration observed during the first period of planting may be due to the farm machineries employed for site preparation as well as fertilizer application. These soil disturbances may contribute to enhancing the soil CO_2 respiration rate. Another additional influencing component leading to an augmentation of CO_2 emission rate could be the high decomposition rate of sugarcane residues left after harvesting, which took place during the first stage of the growing season, as reported by Yuttitham (2009).



(a) (b)

Figure 6.3 Soil CO_2 respiration rates in the control plots (R_t) and in the trenched plots (R_m) as affected by (a) soil volumetric moisture content in the control area (MC_c) and the trenched area (MC_t), and (b) soil temperature in the control area (T_c) and the trenched area (T_t). Values are means and vertical bars indicate standard errors.

Figure 6.3 shows also that soil moisture content and soil temperature were not significantly different between the trenched plots and the control plots. This indicates that trenching has no consistent effect on the moisture content and temperature in the experimental soil. Furthermore, soil respiration is positively correlated with soil moisture content at 5 cm depth from the soil surface. Soil respiration rate decreases with soil moisture content.

6.2.2 Contribution of root respiration to total soil respiration under sugarcane plantation in Thailand

Based on total soil respiration (R_t) and microbial respiration rates (R_m), root respiration rates (R_r) from a sugarcane burnt field in Thailand were estimated, as shown in Table 6.2 and Figure 6.4, and the mean root respiration rate during the measurement period was found to amount to 0.44 μmol m^{-2} s^{-1}. This obviously indicates that root respiration rate of sugarcane plants is positively correlated with plant age. Similarly, Lee et al. (2005) stated that high physiological activity associated with root growth results in high root respiration rate, which contribution to total soil respiration is observed to rapidly increase overtime with canopy leaf expansion in a forest ecosystem.

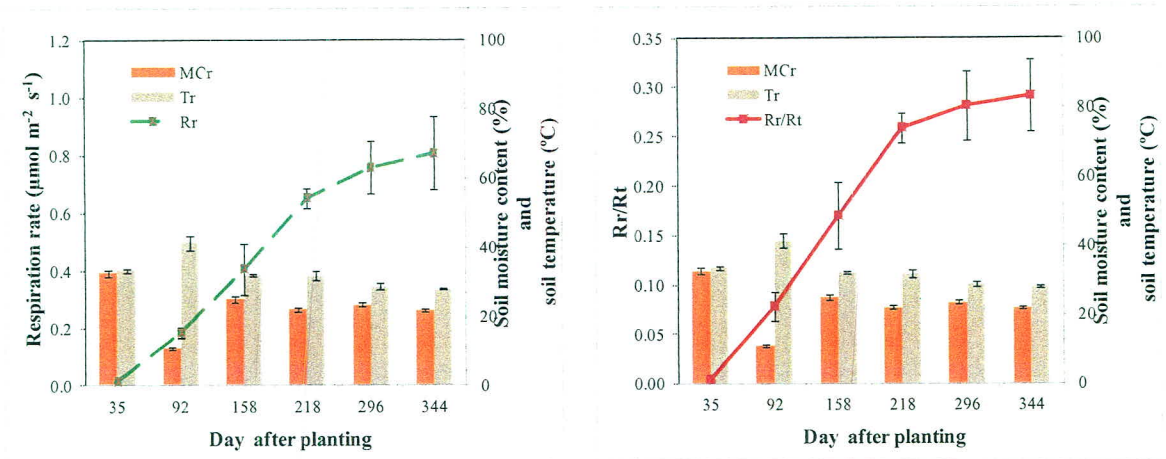
Table 6.2 Root contribution to total soil respiration from sugarcane plantations in Thailand

Day after planting	R_t (μmol m^{-2} s^{-1})	R_m (μmol m^{-2} s^{-1})	R_r (μmol m^{-2} s^{-1})	Proportion= R_r/R_t
35	3.58	3.57	0.01	0.00
92	2.44	2.25	0.19	0.08
158	2.37	1.96	0.41	0.17
218	2.52	1.87	0.65	0.26
296	2.70	1.94	0.76	0.28
344	2.74	1.94	0.81	0.29

In Table 6.2, the ratio between sugarcane root respiration and total soil respiration is generally quite site-specific and varies between 0.00 to 0.29, with the mean value of 0.18. These values are in the range found for crops (0.12 to 0.38) as reported by Raich and Tufekcioglu (2000). From previous research works, it has been found that for croplands, root respiration contributes a low proportion of total soil respiration as compared to other lands, i.e. ranging from 0.06 to 0.76 for grassland and 0.13 to 0.94 for forest. The main reason is the short duration of live roots in the crop cycle and the relatively low root biomass during the early stage of growing season. The large contribution of root respiration to soil respiration after158 DAP may results from the high respiratory activity associated with the increase in the root biomass. (Hanson et al., 2000; Raich and Tufekcioglu , 2000, Wange et al., 2005, Jia et al., 2006, Wei et al., 2009, Sayer et al., 2010; Zhao et al., 2011).

The seasonal variation was observed in sugarcane root respiration, soil volumetric moisture content and soil temperature over 344 days during the growing season (Fig. 6.4). The changing of the R_r/R_t ratio is similar trend with the seasonal change of sugarcane root respiration rate. Also, the proportions of R_r/R_t increased from 35 to 218 DAP, and then

remained unchanged after 218 DAP. It should be noted that sugarcane root respiration is mainly dependent on the developmental stages of sugarcane plant growth, increasing highly in young seedling between the vegetation stages, then declining rapidly and tending to be constant with growth during yield formation and ripening stages.



(a) (b)

Figure 6.4 Seasonal changes of (a) root respiration rate (R_r) and (b) the contribution of root respiration to total soil respiration (R_r/R_t) compared with soil moisture content (MC_r), and soil temperature (T_r). Values are means and vertical bars indicate standard errors.

In this study, the contribution of root respiration to total soil respiration (R_r/R_t) was modeled as a function of the age of plants. According to the results, the model was developed with two basic assumptions: (1) the R_r/R_t ratio increasing distinctly high in the first stage over 35 to 218 DAP, and (2) the R_r/R_t ratio tending to be constant in the second stage (after 218 DAP). The relationship between the R_r/R_t ratio and DAP is summarized as in Equation (6.3).

$$R_r/R_t \begin{cases} = 0.00138DAP - 0.04077 & \text{if } DAP < 218 \\ = 0.25853 & \text{if } DAP \geq 218 \end{cases} \quad (6.3)$$

where R_r/R_t is the contribution of root respiration to total soil respiration (dimensionless), DAP is the day after planting (day)

Figure 6.5 presents the Rr/Rt ratio calculated using Equation (6.3). The model was fitted as a function of the day after planting (DAP) ($R^2 = 0.8621$). As mentioned previously, the contribution of root respiration to total soil respiration started to increase during 0 to 218

DAP, then was stabilized after 218 DAP. In addition, the correlation of the R_r/R_t ratio between measured data in the experimental site and values was calculated using the model, as shown in Figure 6.6.

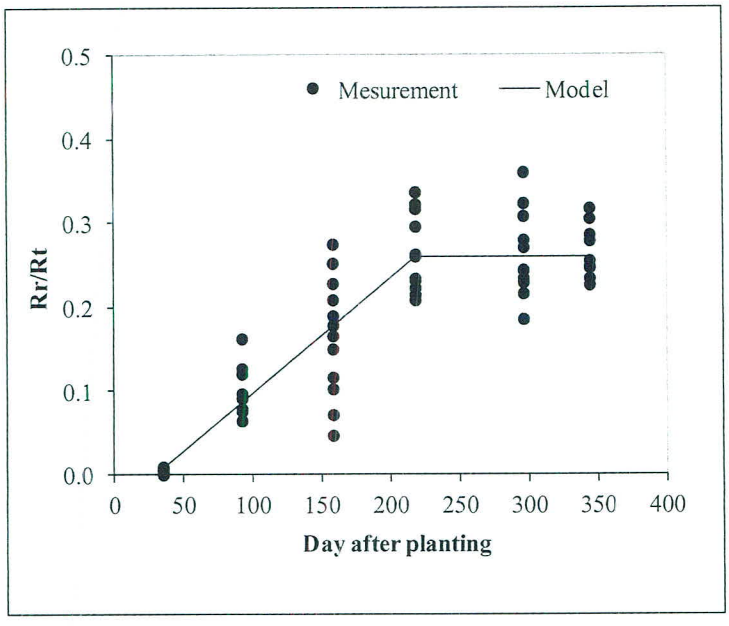


Figure 6.5 Contribution of root respiration to total soil respiration (R_r/R_t) under sugarcane area. The black line was fitted for the model.

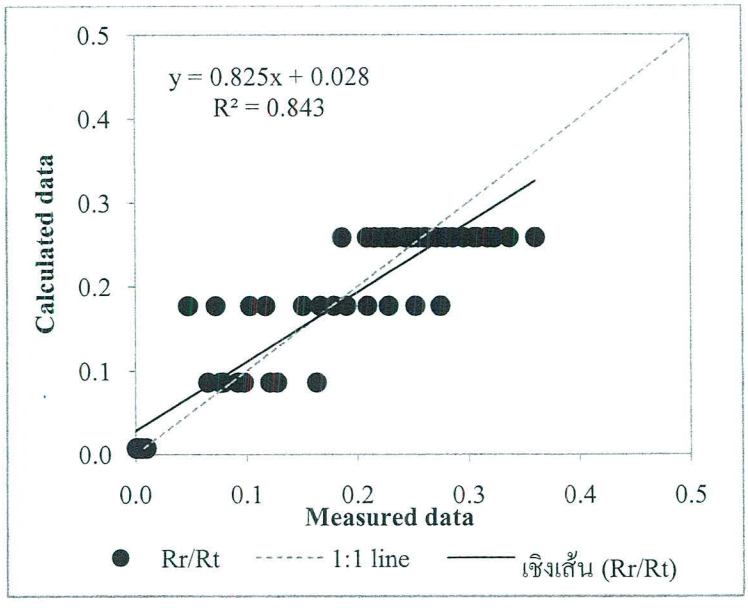


Figure 6.6 Correlation between the contributions of root respiration to total soil respiration (R_r/R_t), measured in the experiment and calculated using Eq. (6.3).

6.3 Summary of findings

The root exclusion method was used for estimating the contribution of root respiration to total soil respiration by measuring soil respiration with and without the sugarcane root in the untrenched and trenched areas, respectively. The results indicated that the contribution of roots to total soil respiration in sugarcane plantations is low comparatively lower than in forests, i.e. up to 29% vs. up to 94%, respectively. However the root contribution in this research is comparable to that reported for croplands from a previous study. Root respiration is positively correlated with the development stages of sugarcane plants. Also, it has been found that soil moisture content is one of the important factors controlling soil respiration in this study. However, the results obtained from this experiment are site-specific and may not be applicable to other areas. To confirm further the findings of this research, muti-seasonal studies of at least three years at different locations would be necessary.