Soil Respiration of Natural Forest, Forest Plantation and Agricutural Incubated Soils

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Abstract

Recently, scientists have focused attention on soil as a major source and sink for atmospheric CO_2. Three replications of two-depth soils from eleven different ecosystem types from Sakaerat Environmental Research Station (SERS), Sakaerat Silvicultural Research Station (SSRS) and Suranaree University of Technology (SUT), Nakhon Ratchasima were collected during the first week of March, 2010. The soils were then incubated at 25˚C for three days and measured their respiration rates. The highest soil respiration rate was found in sunflower with 0.823 µmol CO_2 g^{-1} h^{-1} while the lowest was found in eucalyptus plantation in SUT with 0.005 µmol CO_2 g^{-1} h^{-1}. Additionally between two natural forests at SERS, the respiration rate of dry evergreen forest was higher than in dry dipterocarp forest with the value of 0.037 and 0.016 µmol CO_2 g^{-1} h^{-1} respectively. Whereas the soil respiration rate at SSRS forests was highest in the eucalyptus plantation (0.048 µmol CO_2 g^{-1} h^{-1}) and lowest in acacia plantation (0.027 µmol CO_2 g^{-1} h^{-1}). The overall respiration rate was higher for soils from 0-5 cm than 5-15 cm, but not statistically significant difference. Soil water content and pH were positively significant related with soil respiration ($p<0.01$). Soil carbon, however, was also positively significant related with soil respiration but in lesser degree ($p<0.05$). Therefore soil water content and pH should be major driving forces for soil respiration.

Key words: soil respiration, CO_2 emission, Sakaerat Environmental Research Station

1. Introduction

CO_2 is the most important anthropogenic greenhouse gases (GHG) and its atmospheric concentration has increased from 280 to 379 ppm since the pre-industrial times to 2005 [1]. The main carbon reservoirs are the oceans, soils, the atmosphere, and land plants containing about 38,000, 1,500, 750 and 560 Pg C, respectively [2].

Recently, scientists have focused attention on soil as a major source and sink for atmospheric CO_2. On a global scale, soil respiration produces 80.4 Pg C y^{-1} with a range of 79.3–81.8 Pg C y^{-1}, accounting for 60–90 percent of total respiration of global terrestrial ecosystems and it is eleven times of current fossil fuel combustion [3]. The soils hold twice as much carbon as the atmosphere. Carbon stored in agricultural soil is 170 Gt, while the entire vegetation contains 550 Gt C [4]. Thus, a small change in soil respiration rates may have a significant effect on the global C balance and therefore on climate change.

Soil respiration includes three biological processes, namely microbial respiration, root respiration and faunal respiration. Soil microflora contributes 99% of the CO_2 efflux through decomposition of organic matter, while the contribution of soil fauna is much less [4]. Several studies have shown that factors such as soil texture, temperature, moisture, pH, available C and N content of the soil influence soil CO_2 production and emission. Soil respiration determine whether a specific land-use or management practice causes a system to be C source or a sink and fluctuation in soil CO_2 flux can result in significant changes in global C cycle [3].

Therefore, detailed information on soil respiration and its controlling factors is critical for constraining the ecosystem C budget and for understanding the response of soils to changing land use and global climate change [5], which is still not yet sufficiently understood to incorporate them into global-scale C cycling models [6].

Changes in land use almost always lead to a change in vegetation, density of above and belowground biomass, the amount of resources available for soil microbes, the physical and chemical characteristics of the soil. Thus it is of primary importance to know the mean respiration rates in each ecosystem and their responses to environmental factors when considering the C cycle.

This study aims to compare soil respiration of different land use types from natural forests, forest plantations to agriculture.

2. Materials and Methods

2.1 Sites

Eleven land use types were selected for this study. They are cornfield (C), sunflower (S), grassland (G), 20 years old *Eucalyptus* sp. (Eu1) and rubber (R) plantations from Suranaree University of Technology (SUT), dry evergreen forest (DEF) and dry dipterocarp forest (DDF) from Sakaerat Environmental Research Station (SERS), and 25 years old *Acacia auriculiformis* Cunn. (Aa), *Acacia mangium* Willd (Am), *Dalbergia cochinchinensis* Pierre (Dc) and *Eucalyptus camaldulensis* Dehnh (Eu2) from Sakaerat Silvicultural Research Station (SSRS).

2.2 Experimental Design

During the first week of March, 2010, a line transect of 40m long was laded in each ecosystem site at SUT, SERS and SSRS, along which three soil samples were collected using soil cores at an interval of 20m apart. The soils were collected from two different depths of 0-5cm and 5-15cm, packed in the plastic zip bags and transported to the SUT laboratory. The soils were then put into 500ml conical flasks, covered with parafilm paper to prevent water loss but allow diffusion of gases and then incubated under 25˚C for ten days. Soil respiration was measured at the 4th and 10th day of incubation period using LI-820 CO_2 analyzer (LI-COR, USA). Soil moisture was measured by reweighing known weighed soil after oven drying at 105˚C for 24 hrs. Other factors like soil pH (1:1 soil: water suspensions), soil organic carbon (Walkley-Black method) and total nitrogen (Kjeldahl method) were also analyzed [7].

One-way ANOVA followed by post hoc Duncan test was used to find the differences in soil respiration rates and other parameters among the ecosystems. Pearson Correlation Coefficient was calculated to find the relationship between soil respiration rate and its controlling factors. SPSS version 16 program was used for all of these analyses.

3. Results

3.1 Soil respiration rate

The mean soil respiration rates were found highest in sunflower field, followed by cornfield and lowest in the *Eculyptus* tree plantation in SUT with 0.8217, 0.4013 and 0.0052 µmol CO_2 g^{-1} h^{-1}, respectively (Table 1 and Figure 1). The mean respiration rates of sunflower were significantly higher than cornfield ($p<0.05$) and both were significantly higher than the rest. In general, the respiration rates of 0-5cm soil layers of most ecosystems were higher than those of 5-15cm soil, except sunflower and dry dipterocarp forest.

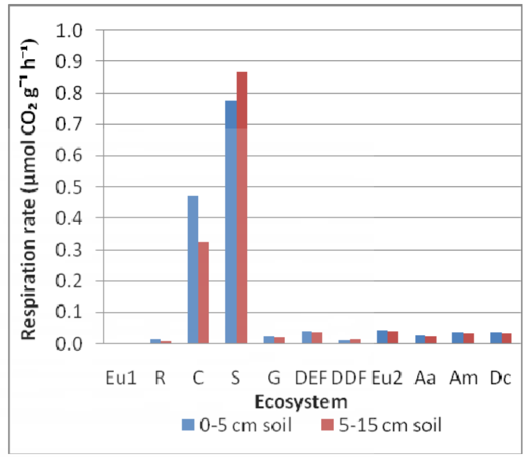

Fig. 1 Mean soil respiration rates of 0-5 and 5-15 cm soil depth in different ecosystems.

3.2 Soil physical and chemical factors

The mean soil water content was highest in S and C but lowest in Eu1. Soil pH of sunflower and cornfield were neutral while the rest were acid, especially in forest plantation.

Mean soil organic carbon (OC) was highest in DEF followed by Aa but lowest in R with 2.9148, 1.9814 and 0.4063%, respectively (Table 1).

Mean soil total nitrogen (N) was highest in DEF (0.3239%) followed by Am (0.1509%) but lowest in R (0.0365%).

In general, only soil pH and water content had significant positive correlation with soil respiration (Fig. 2 and Table 2)

Table 2 Pearson correlation coefficient of soil respiration rates and its controlling factors.

	water content	pH	C	N
respiration	.660**	.752**	-.273*	-0.18

* Correlation is significant at $p<0.05$
**Correlation is significant at $p<0.01$

Table 1 Mean soil respiration rates and soil characteristics of two soil depths.

Site	Respiration rate (μmol CO_2 g^{-1} h^{-1})		Water content (%)		Organic C (%)		Total N (%)		Soil pH	
	0-5	5-15	0-5	5-15	0-5	5-15	0-5	5-15	0-5	5-15
Eu1	0.005	0.005	0.67	1.24	0.679	0.391	0.064	0.048	5.27	5.18
R	0.015	0.009	2.17	4.06	0.488	0.325	0.030	0.043	5.64	5.63
C	0.475	0.327	12.36	16.91	1.288	0.672	0.088	0.075	7.08	7.09
S	0.775	0.868	17.59	16.23	0.862	0.625	0.070	0.087	7.47	7.68
G	0.025	0.024	1.35	3.25	1.543	0.921	0.105	0.076	6.48	6.13
DEF	0.039	0.036	10.27	13.96	3.208	2.622	0.445	0.202	4.26	5.22
DDF	0.015	0.017	2.67	4.28	1.742	1.167	0.161	0.088	5.23	4.16
Eu2	0.043	0.039	7.19	10.87	1.888	1.297	0.078	0.112	4.48	4.59
Aa	0.028	0.027	6.97	9.85	2.139	1.823	0.154	0.130	4.43	4.41
Am	0.036	0.032	6.49	9.66	1.921	1.361	0.172	0.130	4.43	4.55
Dc	0.037	0.033	6.26	10.03	2.174	1.481	0.156	0.142	4.53	4.58

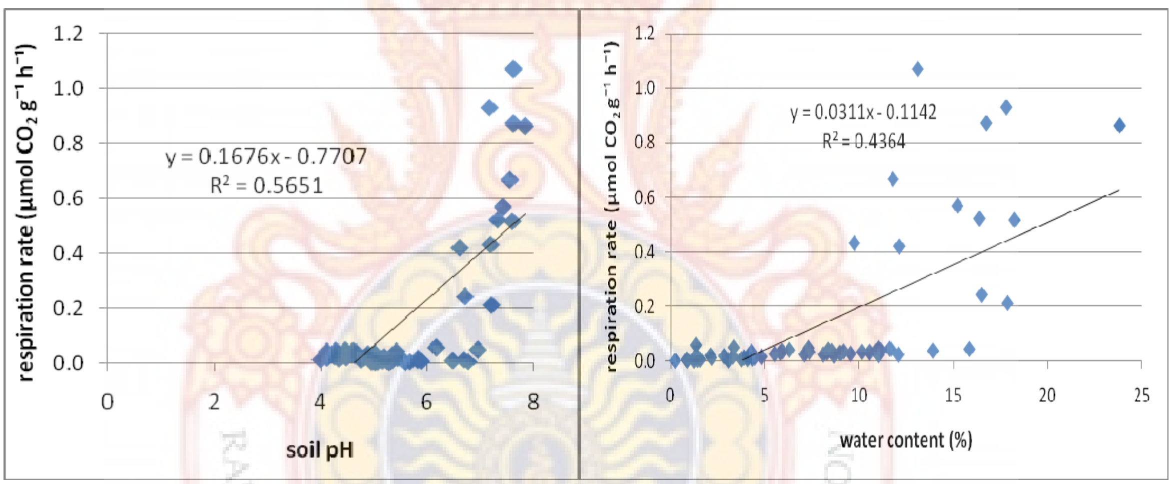

Fig. 2 Relationships between soil respiration rates with soil pH and water content.

4. Discussion

Soil respirations differ significantly among land use types in our study. The rates were significantly higher in the agricultural crop lands (cornfield and sunflower) the same as in [8] and [9].

In tropical primary, secondary forests and palm plantation, the main factors effecting soil respiration are soil water content, organic C, and root biomass [9]. However, our study showed that soil respiration was highly correlated with soil water contents which agreed with previous studies [10, 11, 12, 13].

There were no significant differences in water content of DEF and cornfield but the mean respiration rates were significantly higher in cornfield ($p<0.05$), which suggest that croplands may release far more CO_2 than natural forest.

Soil CO_2 production and emission ware influenced by the presence of crop plants and that production ranged approximately 2 to 3-fold greater in cropped soil compared to bare soil [4]. There was also decreased in soil respiration rates with addition of nitrogen in different ecosystems [13] and increased nitrogen in soil acidify soil and reduce microbial activities [4].

The soil pH of crop fields was neutral (6.5-7.8) but natural and plantation forest soils were acid (4.2-5.6). The soil pH showed significant positive correlation with soil respiration in different ecosystems ($p<0.01$) which agrees with other study [14].

There were significantly lower soil OC and TN in croplands compared to other ecosystems and highest was found in the natural forest (DEF) ($p<0.05$). Soil OC decreased significantly ($p=0.007$) from natural forest to mixed crop systems and attributed that the increase may depend on differences in the vegetation cover or soil type [15].

5. Conclusion

The study showed that agricultural croplands had significantly higher mean soil respiration than those of forest plantations and natural forests. The agricultural croplands had negative impact on soil organic carbon and total nitrogen contents. The factors that influenced soil respirations were soil water content and pH. Water content more than 10% in neutral soil significantly enhances soil respiration rates.

6. Acknowledgement

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