B-6.1.2 Modeling and Prediction of Carbon Dioxide Change Mechanism on Tropical Forest Ecosystems

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Abstract

Carbon cycle in a tropical forest in Khon Kaen, the northeast Thailand was measured. Carbon transfer rate was estimated 5.1 tC/ha/yr on litter-fall, 4.1 tC/ha/yr from litter to soil, 0.2 tC/ha/yr from fine root to soil, and 5.5 tC/ha/yr on decomposition of soil organic matter. The soil had 41.4 tC/ha as organic matter, and was estimated to decrease 0.8 tC/ha/yr annually. Decomposition rate of organic matter was rapid than organic matter supply such as litter-fall, then soil had low amount of carbon. Under the climate change, it is expected that carbon accumulation rate in tropical forest ecosystem will not change so much.

Key Words Carbon cycle, Model, Tropical monsoon forest, Thailand

1. Introduction

Tropical forest area, which dominates about 40 % of forest area in the world, declines 0.8 % annually, then affects to CO_2 changes as one of the green house gas in the atmosphere[1]. Therefore, it is needed to analyze carbon dynamics in tropical forest ecosystems, and to estimate effects to CO_2 changes in the atmosphere.

In forest ecosystem, carbon accumulates to tree, litter and soil organic matter, and emits as CO_2 by burning of tree and decomposition of litter and soil organic matter. Carbon transfers on plant – soil system, then carbon cycle model of tropical forest ecosystems can be constructed based on the plant – soil system. And, dynamics of the carbon cycle can be analyzed based on quantitative measurement data of stock such as litter biomass and transfer rate such as CO_2 emission.

2. Research Objective

For construction of carbon cycle, litter fall, amount of litter layer, fine root biomass, amount of soil organic matter, CO_2 emission on decomposition of litter and CO_2 emission from forest floor were measured. As environmental factors on carbon cycle, soil temperature and soil water content were measured. Based on these data, carbon cycle of tropical forest ecosystem was constructed, and carbon balance in the tropical forest ecosystems was analyzed. And, based on the carbon cycle, change of carbon cycle under the global climate change was estimated.

3. Research Methods

Study plot was set in tropical monsoon forest at Khon Kaen, Thailand, where was located on 103 E, 16 N. Annual mean temperature was 27 C, and annual precipitation was 1,197 mm mostly from May to October.

Height and DBH of tree that was higher than 2 m were measured in 10 m x 50 m quadrate. Litter fall was measured by 12 litter traps of 50 cm x 50 cm at about every month. Amount of litter layer was measured by litter weight in 6 plots of 32 cm x 41.5 cm at about every month. CO_2 emission from forest floor was measured by sponge alkaline absorption method[2)] using 10 chambers at twice a month. As environmental factors, soil temperature at 10 cm depth and soil water content at 0 – 15 cm depth were measured at the same time of CO_2 emission measurement. Fine root biomass was measured by weight of fine root in 5 plots of 25 cm x 25 cm and 30 cm depth. Amount of soil carbon was estimated from carbon content and bulk density of surface layer and 10 cm, 20 cm, 40 cm, 60 cm and 100 cm depth on 5 points. CO_2 emission on decomposition of litter was measured at chamber with about 20 g litter on forest floor at every week in rainy season. The litter was used 2 types, large leaves in 5 chambers and crush leaves in 5 chambers, because it was expected decomposition rate of leaves might be different on large and crush leaves. Measurement of CO_2 emission was conducted until disappearance of the leaves.

4. Results

The tropical forest of this study had about 25 m height and 3,860 trees/ha. Canopy tree was 440 trees/ha and DBH was less than 35 cm.

Litter fall was 30 kgC/ha/day from February to March and 10 kgC/ha/yr on other period (Figure 1). Measurement of litter fall was conducted in 1998 supplementary, and shows same litter fall rate.

Amount of litter layer was 2 tC/ha at Aplil, and increased to 9 tC/ha at June. It decreased from July, then was 4 tC/ha at October. Increasing rate of litter layer amount from April to June was higher than amount of litter fall, because a lot of seed fell on the measurement plots. The seed fall varied on spatial. Water content of litter layer was usually less than 50 wt%, except for the end of March, 250 wt%.

CO_2 emission showed higher than 1000 $mgCO_2/ha/m^2/hr$ at the early April and the middle of October, 600 – 800 $mgCO_2/ha/m^2/hr$ at rainy season from May to October, and about 500 $mgCO_2/ha/m^2/hr$ at dry season from November to April. Soil temperature did not change so much, 24 – 27 C. Soil water content was less than 5 vol% at the end of dry season, and showed 10 – 20 vol% at rainy season (Figure 2).

CO_2 emission on decomposition of litter showed, about large leaves, 4.3 $gC/m^2/day$ at the day of setting litter in chambers, and increased 8.0 $gC/m^2/day$ at 1 week later to 4 weeks later. CO_2 emission decreased from 5 weeks later, and showed 4.6 $gC/m^2/day$ at 7 weeks later when litter in chambers disappeared. About crush leaves, CO_2 emission showed 6 $gC/m^2/day$ at the day of setting litter, and increased to 9.4 $gC/m^2/day$ at 1 week later. CO_2 emission decreased from 2 weeks later depend on decreasing of litter in chambers, and showed 5 $gC/m^2/day$ at 5 weeks later when litter in chambers disappeared (Figure 3).

Under condition of no litter in chambers, CO_2 emission showed 4.6 $gC/m^2/day$. Assuming that surplus amount of CO_2 emission higher than 4.6 $gC/m^2/day$ derived from CO_2 from decomposition of litter, it was estimated that large leaves emitted CO_2 119 gC/m^2 on 7 weeks, and crush leaves emitted CO_2 105 gC/m^2 on 5 weeks. Amount of setting litter in chambers was 899 gC/m^2 of large leaves and 992 gC/m^2 of crush leaves. Therefore, ratio of CO_2 emission from litter / setting litter in chamber was 13 % on large leaves and 11 % on crush leaves.

Fine root biomass was 1.17 tC/ha. But, it varied on spatial diversity, 8 – 32 gDW in 25 cm x 25 cm and 30 cm depth. Few amount of fine root was seen deeper than 30 cm in soil.

Amount of soil carbon was 41.4 tC/ha at 0 – 100 cm depth. Carbon content of soil was higher than 0.5 % at 0 – 15 cm depth, 0.3 % at 20 cm depth, and 0.2 % at deeper than 40 cm

(Table 1).

Based on measurement data and some assumption, carbon cycle in tropical forest was constructed (Figure 4). Litter fall, amount of litter layer, soil carbon, fine root and CO_2 emission from forest floor were measurement data. CO_2 emission from litter was 12 % of litter fall 5.1 tC/ha/yr based on measurement data. About CO_2 emission from fine root, assuming that soil microorganisms was not active under very dry condition, CO_2 emission 500 $mgCO_2/m^2/hr$ under very dry condition was considered to be fine root respiration, then 11.9 tC/ha/yr of fine root respiration was estimated. Turnover rate from fine root to soil was supposed 20 % of fine root biomass. As results of carbon balance, it was estimated soil carbon declined 0.8 tC/ha/yr annually.

5. Discussion

CO_2 emission derived mostly from root respiration. In temperate forest, CO_2 emission on forest floor derives 1/2 from root respiration, 1/4 from decomposition of soil organic matter, and 1/4 from decomposition of litter[3]. Tropical climate is adequate condition for tree growth, then root respiration is higher rate than temperate forest. But, litter fall is not so higher than temperate forest. Then, it seems that CO_2 from root respiration dominates most of CO_2 emission from forest floor.

CO_2 emission from forest floor did not related with soil temperature and soil water content. High rate of CO_2 emission at April might derived from decomposition of litter due to decomposer activity increasing by rain after dry season. Litter accumulated in February and March, but decomposed in April, then litter in May was only fresh litter by observation. From June to October, even though rain came, CO_2 emission was not high rate, because litter fall was low rate. But, high rate of CO_2 emission in October, which appeared also on supplementary measurements, was unknown origin.

On plant – soil system of tropical forest, carbon transferred mainly through litter to soil, and transferred to CO_2 by decomposition of soil organic matter. On decomposition of litter, 10 – 15 % of carbon of litter emitted to CO_2. This ratio is lower than temperate forest[3]. It seems that microfauna in soil decomposed litter, then litter disappeared rapidly. In fact, rapid decomposition of detritus by termite in tropical zone was observed. It seems that microfauna such as termite affects on carbon cycle in tropical forest ecosystems.

Carbon supply by litter fall was not so high rate. But, decomposition rate of organic matter was very rapid. Therefore, even though amount of litter fall increases, it is expected that soil carbon will not increase. Carbon transfer rate through litter to soil was restricted by litter fall rate. Then, even though temperature and rain fall increase, soil organic matter is quite low amount already, it is expected that soil carbon will not decrease so much. Therefore, it is expected that, when climate change, although tropical forest area will change, carbon release rate will not change.

References

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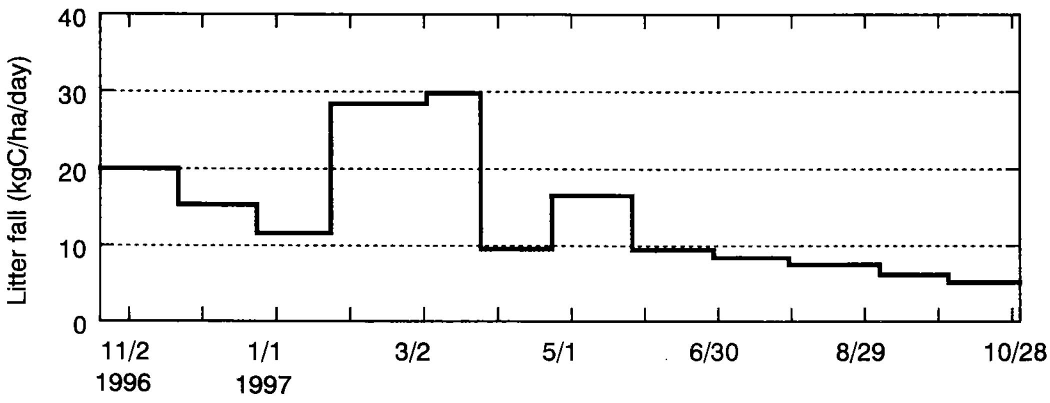

Figure 1 Litter fall at tropical monsoon forest in Khon Kaen, Thailand.

Table 1 Amount of carbon in soil at tropical monsoon forest in Khon Kaen, Thailand.

Depth	Thickness	C content	Bulk density	Soil weight	C stock
cm	cm	mg/gDW	g/100cc	t/ha	tC/ha
0-5	5	6.1	148.7	744	4.535
5-15	10	5.0	148.7	1,487	7.376
15-30	15	3.0	158.6	2,379	7.137
30-50	20	1.9	165.8	3,315	6.299
50-80	30	1.7	163.8	4,914	8.452
80-100	20	2.1	178.6	3,571	7.642
				0-100cm	41.440

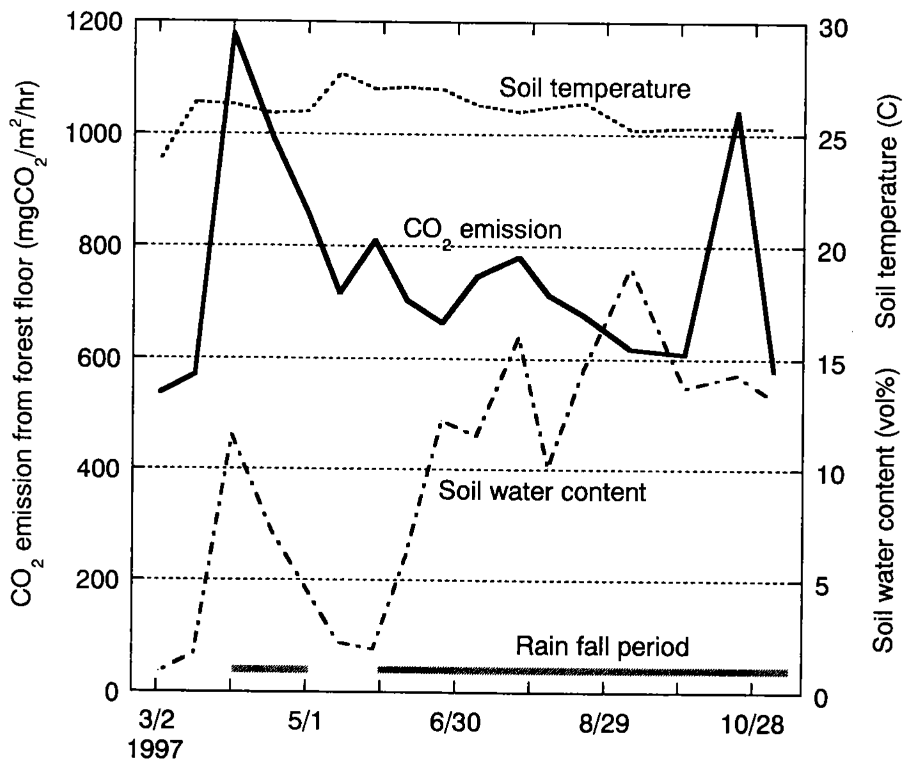

Figure 2 CO2 emission from forest floor, soil temperature and soil water content at forest floor in tropical monsoon forest in Khon Kaen, Thailand.

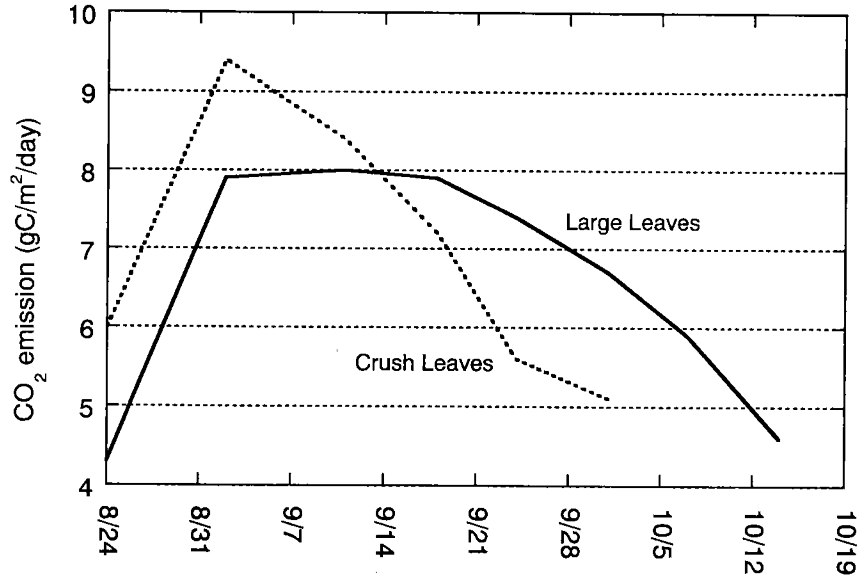

Figure 3 CO_2 emission on decomposition of litter in tropical monsoon forest at Khon Kaen, Thailand. Large leaves and crush leaves were set 20 g in each chamber. Leaves disappeared at 1 month later on crush leaves and 1 month half later on large leaves.

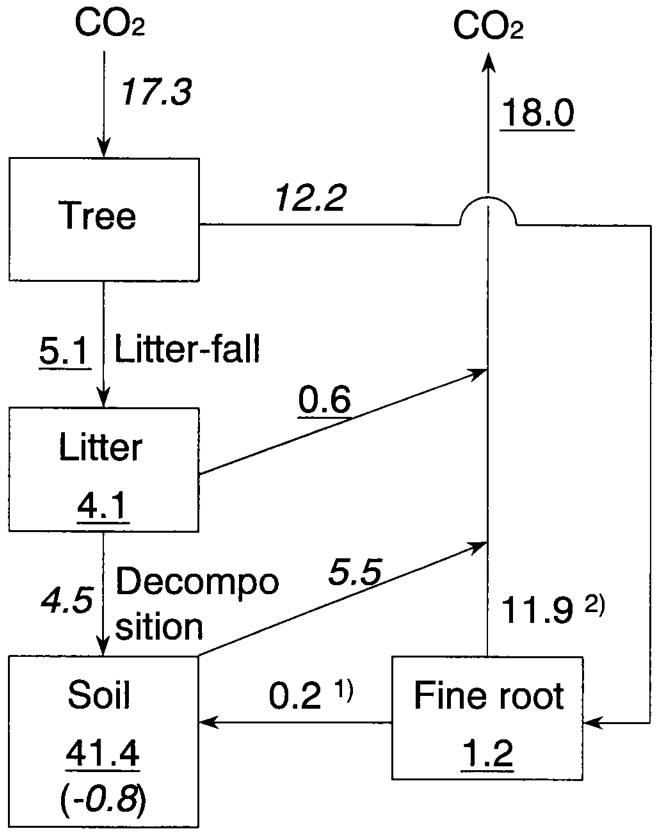

Figure 4 Carbon cycle on tropical monsoon forest in Khon Kaen, Thailand (Stock: tC/ha, Transfer: tC/ha/yr). Underline: measurement data. *Italic*: addition or subtraction.
1) 20 % of fine root biomass. 2) Assuming that root activated but microorganisms did not activate under very dry condition, then CO_2 emission rate at very dry condition and without litter was estimated as root respiration.