B-6.1.1 Quantitative Analysis of Carbon Cycle in Agro-ecosystems

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Abstract

The objectives of the study were to clarify quantitative carbon cycle in such agro-ecosystems as vegetable field, paddy field and agro-forest.(1) Carbon budgets of a sweet potato (*Ipomoea batatas*) - chinese cabbage (*Brasica rapa*) double-cropping field and an abandoned field were -168 and -187 $gC/m^2/yr$, respectively. The carbon budgets suggest that croplands act as a source of carbon dioxide. (2) Carbon cycle through solid phase or liquid phase was measured in a paddy field. About $90gC/m^2/yr$ was assumed to be accumulated in the system. Carbon dioxide flux measured in paddy fields by the alkaline absorption method was appeared to be overestimated compared with IR analysis and chamber methods. (3) Net carbon absorptions of forest ecosystems from atmosphere in a managed agro-forest, an abandoned agro-forest and a 50 years old deciduous natural agro-forest were 3.7, 2.2, 3.9tC/ha/year, respectively. The results show that both a agro-forest and a natural deciduous forest perform as a carbon sink.

Key Words Carbon cycle, Upland field, Paddy field, Agro-forest, Agro-Ecosystems

1. Introduction

It is important to understand quantitatively a carbon cycle in terrestrial ecosystems in reference to global warming. An agro-ecosystem contains various land uses with intensive human intervention. However, few quantitative data have been accumulated yet on effects of human intervention in such agro-ecosystems as composed of an paddy field, an upland field, an agro-forest and an uncultivated land on the greenhouse gas increase. New methods for evaluating carbon cycles in such ecosystems should be also developed.

2. Research Objective

In studies in unit agro-ecosystems, carbon cycles in cultivated fields, uncultivated lands and agro-forests are clarified: carbon cycle in (1) vegetable field, and abandoned or uncultivated upland field, (2) paddy field, where methane as well as carbon dioxide emits and carbon flows in and out of the field, (3) agro-forest where understory vegetation is artificially managed.

3. Research Method

(1) Vegetable field and abandoned upland field

To clarify carbon budgets in croplands, we made a sweet potato (*Ipomoea batatas*) - chinese cabbage (*Brasica rapa*) double-cropping field and a 1yr-old abandoned field at the National Institute of Agro-Environmental Sciences (NIAES) and measured their carbon cycle. We measured net production and dark respiration of plant and estimated the carbon amounts fixed through photosynthesis. We also monitored stubble, harvest and soil respiration to estimate the carbon flux on soil surface.

(2) Paddy field

Experimental field was lcated in NIAES consisted of Gray Lowland Soil. Rice(Koshihikari) was cropped yearly from May to September under continuously flooded condition. Soil samples were taken from surface layer(0-15cm) at April. Shoot production was estimated by quadrate sampling (1m x 1.2m, duplicate), at harvesting time. Root and stubble production was estimated from the amount grown in container (30.5cm x 46cm x 26cm, duplicate) buried shallowly in the plow layer. A part of these materials were finely powdered. Carbon content of the powder was measured by NC-analyzer (Sumigraph NC-90). Aqueous carbon content was analyzed by TOC analyzer.

(3) Agro-forest

We set three experimental plot; managed plot (cutting undergrowth and raking litter for every year) and abandoned plot (dominated by 1.5m draft bamboo) in 15 years old *Quercus* agro-forest in Ibaraki Prefecture, and Fujinita plot in 50 years old *Castanea-Quercus* natural forest in Tochigi Prefecture. We measured tree height and diameter at breast height of individual trees in 20m x 20m quadrate in each plot, estimated tree biomass using allometric correlation equations[1] and underground/aboveground biomass ratio[2]. Undergrowth biomass was estimated by weight of undergrowth and ratio of underground/aboveground biomass of draft bamboo[3]. Litterfall was measured using 1m^2 litter traps every 1-2 months. Fallen branches was measured in 10m x 10m quadrate every year. We sampled A_0 layer every 2 months, measured the weight and the water contents of the A_0 layer. We surveyed soil profile to estimate carbon accumulation in 1m depth. We measured CO_2 emission from the forest floor using the sponge alkaline absorption method[4] at 10 points in each plots every month for 1 year. We measured air temperature and soil water contents in the forest.

4. Result and discussion

(1) Vegetable field and abandoned upland field

The annual carbon budget of the sweet potato field during summer was a black value but that of the chinese cabbage field a large red value, and consequently that of the double-cropping field was -187 gC/m^2/year (Table 1). The abandoned field had no output of carbon through harvest, but its soil respiration was larger than the double-cropping field, and its carbon budgets was -168 gC/m^2/year (Table 1). These results suggest that croplands act as a source of carbon dioxide.

Table 1. Annual carbon budgets of a double-cropping field and a 1yr-old abandoned field. (gC/m^2/year)

	Input		Output			Balance
	Photo-synthesis	Stubble	Plant resp.*	Soil resp.*	Harvest	
D.c. field*	1319	0	597	565	324	-168
A. field*	1115	22	684	640	0	-187

*) D.c.:Double cropping, A.:Abandoned, resp.:respiration

(2) Paddy field

Brown rice production of this paddy field was 552 kg/10a. Table 2 shows the carbon contents of soil, fertilizer input and rice plant produced. Carbon content of plow layer(0-10cm), manure input and rice produced was estimated to be 3760, 0.5 and 596 kg/10a, respectively. In rice plant, carbon was distributed throughout paddy(217kg/10a), straw(282kg/10a), stubble (41kg/10a) and root(56kg/10a). The carbon of paddy and straw were removed from paddy field ecosystem, while the carbon of stubble and root were reduced in the paddy field soil. During rice growing season(May-Sep.), 79,243 l/10a was used(Table 3) as irrigation water. Total carbon input as irrigation water was calculated to be 1.73 kg/10a. Carbon content of rain and percolating water was estimated to be 1.4 and 2.0kg/10a, respectively(Table 3).

Respiration rates of the soil were measured in two cylindrical chamber by IR gas analyzer. The measured values in both chamber agreed well. The respiration rate during Jan. 7th 16:00 - Jan. 8th 9:00 was constant. At noon, the rate reached maximum with value of 52.8mg CO2 m^2/hr. By the alkaline

Table 2. Carbon contents of arable soil, fertilizer and rice plant

	Dry matter kg/10a	Carbon content %	C kg/10a
Arable soil	187,440	2.00	3,760
Fertilizer input	36.5	1.39	0.5
Rice plant production	1,649	36.1	596

Table 3. Carbon contents in irrigation water and percolating water during growing period

	Water volume l/10a	Concentration ppm	C g/10a
Irrigation water	79,243	20.32	1,730
Precipitation	367,000	2.79	347
Percolating water	102,000	19.80	2,020

absorption method[4], the respiration rate was also measured at same day. The measured value was 77.3 mg CO2 m^2/hr. It was about twice as much as that measured by the air-flow chamber method.

Present field research showed that main pool of the carbon was soil in the paddy field ecosystem. Carbon input to the field was calculated to be 100.6 kg/10a/year as root, stubble, fertilizer, irrigation water and precipitation, whereas the annual flux was presumed to be 5-6 kg/10a from the estimate of percolating carbon(2 kg/10a) during rice growing season. From the difference between the input C and flux C, net carbon input was estimated to be about 90 kg/10a/year. Most of the C is decomposed and mineralized by the soil microorganisms.

(3) Agro-forest

The carbon stocks in forest ecosystems of the managed plot, the abandoned plot and the Fujinita plot were respectively 62.9, 79.7, 331.7tC/ha (Figure 1). The carbon in forest ecosystem stocked mainly in plant biomass in the managed plot and the abandoned plot, and in soil in the Fujinita plot. The plant biomass in the managed plot, the abandoned plot were about 1/3 times of that in the Fujinita plot. The soil carbon in the managed plot, the abandoned plot were respectively 1/9, 1/7 times of that in the Fujinita plot. Growth of the plant biomass in each plot was about 3-4tC/ha/year. Sum of the litterfall, the fallen branches and the fallen trees were respectively 3.0, 4.1, 4.2tC/ha/year. Accumulation of A_0 layer in the managed plot was 0.2tC/ha in growing season, increased to 2.5tC/ha in autumn, reduce to

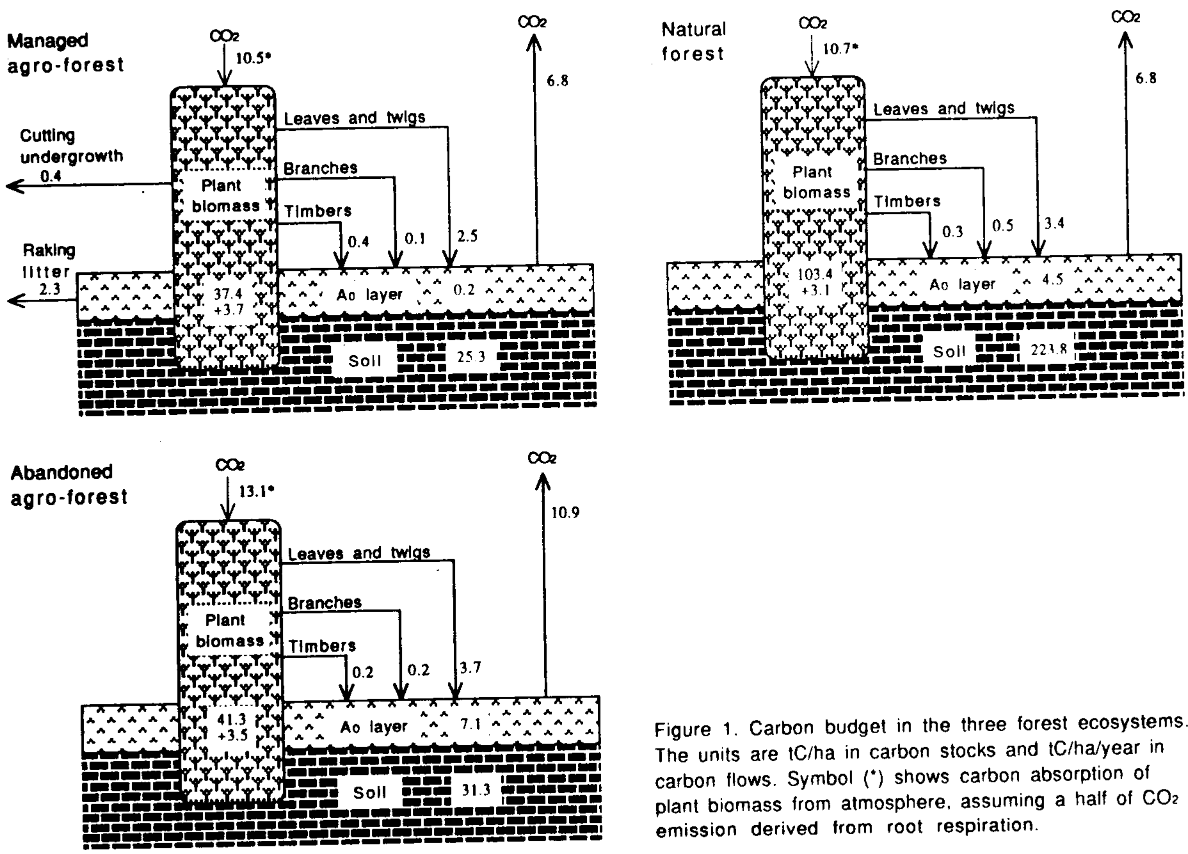

Figure 1. Carbon budget in the three forest ecosystems. The units are tC/ha in carbon stocks and tC/ha/year in carbon flows. Symbol (*) shows carbon absorption of plant biomass from atmosphere, assuming a half of CO_2 emission derived from root respiration.

0.2tC/ha again by raking. Accumulation of A_0 layer in the abandoned plot and the Fujinita plot fluctuated respectively 6-9, 4-6tC/ha in range. The CO_2 emission in the managed plot, the abandoned plot and the Fujinita plot were respectively 700, 1000, 500 $mgCO_2/m^2$ /hour in summer, and less than 100$mgCO_2/m^2$/hour in winter in all plots. The CO_2 emission were related with the air temperature in the forests using exponential equations, but were not related with the soil water contents. We estimated annual CO_2 emission based on the air temperature data and the exponential equations. Assuming that a half of CO_2 emission derived from root respiration, net carbon absorptions of forest ecosystems from atmosphere in the managed plot, the abandoned plot and the Fujinita plot were 3.7, 2.2, 3.9tC/ha/year respectively.

Carbon stocks in agro-forest had 1/3 times of carbon stocks in natural forest. Agro-forest is kept in young stage by periodical timber cutting, then carbon stocks in agro-forest have very low level than natural forest. Abandoned agro-forest have larger carbon flow, litterfall and CO_2 emission, than natural forest. Draft bamboo in undergrowth may affect carbon flows in forest ecosystems. The carbon absorption of forest ecosystem from the atmosphere was larger in the Fujinita plot than the agro-forest plots. The results show that the 50 years old natural forest performed as a carbon sink, and human disturbances may make lower level of carbon sink than natural forest. The cutting undergrowth reduced plant biomass and litterfall. The raking litter reduced accumulation of A_0 layer, supply to soil, and then CO_2 emission. The results show that cutting undergrowth and raking litter affected carbon cycle in forest ecosystems, especially CO_2 emission. The cutting undergrowth and the raking litter took away from the managed agro-forest ecosystem. Supporting that carbon taken away from agro-forest ecosystems stock as carbon sink, net carbon absorption of agro-forest ecosystem from atmosphere will increase by cutting undergrowth and raking litter.

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