B-1.3.2 Quantitative analysis of carbon cycle system in Paddy Field

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Abstract A quantitative study of carbon cycle system was made from 1993-1995 on a well controlled paddy field in which rice was cropped yearly from May to September, at Tsukuba in central part of Japan. In paddy field system, carbon contents of solid phase(soil and rice plant), aqueous phase(flooded water, irrigation water and percolated water) and gaseous phase(carbon dioxide and methane) were analyzed. Following results were given. Carbon content of plow layer soil and rice plant produced was estimated to be 4600 and 650 kg/10a, respectively. In rice plant, carbon was distributed throughout paddy(233), straw(263), stubble(136) and tiller(16kg/10a) after harvest. Carbon content of flooded water, irrigation water and percolating water were estimated to be 1.6, 8.1 and 30kg, respectively. Yearly input of C to paddy field ecosystem per 10a was estimated to be 1200kg/10a and 10kg/10a as gaseous C(CO_2 fixation) and aqueous C (irrigation and precipitation), respectively. Yearly output of C was estimated to be 500kg and 10kg as respiration and methane formation respectively. Consequently, net CO_2 fixation was calculate to be 700kg/10a/year. In 700kg, 650kg was fixed in rice plant and 30kg was leached to underground water.

Key words Paddy field, Carbon, Soil organic matter, Irrigation water, Percolating water, Methane flux, Carbon dioxide flux

1. Introduction

Increased concentration of green house gas in atmosphere is considered to make the temperature elevate gradually of the ground surface of earth. Carbon dioxide is one of the green house gases among which it is macro-constituent. To take engineering coutermeasure to global warming, quantitative analysis of carbon cycle in various kinds of ecosystems is essential research. In present study, the carbon contents and flux were estimated on the various constituents of a paddy field ecosystem.

2. Research methods

Experimental field was of NIAES, Tsukuba, Ibaraki 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) burried 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. Carbon dioxide and methane flux were measured by the closed chamber method of Minami and Yagi (1988). A polycarbonate chamber(60x60x100cm) is placed over rice paddies for 10min and air samples are taken from the chamber for CO_2 and CH_4 analysis by gas chromatography equipped with TCD and FID. Decrease of CO_2 concentration of the field under rice plant proceeded first order equation, $\log[A]=\log[A_0] -(k/2.3)t$, where A is CO_2 concentration; A_0, initial concentration; k, rate constant and t, time. Then, we calculated k value from the equation and estimated initial velocity of CO_2 flux from the equation of $v=kC_0$ where v is initial velocity and C_0 is initial CO_2 concentration. Rice plants were sampled at the same time to those of gas sampling and estimated the increased amounts of rice C between sampling time.

3. Results

Brown rice production of this paddy field in 1993,1994 and 1995 was 500, 550 and 403 kg $10a^{-1}$, respectively. Carbon content of plow layer(0-15cm) at April and November, was estimated to be 4810 and 4310 Kg $10a^{-1}$, respectively., Carbon in rice plant after harvest was distributed throughout paddy(233), straw(263), stubble(136) and tiller(16kg/10a) after harvest(Fig.1). 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. Fig.2 shows variation of rice plant C during growth. ratio of shoot/stubble in rice plant sampled at 12/5/1995, 24/5/1995 and 27/6/1995 was estimated to be 0.37, 0.36 and 0.35, respectively.

Fig.3 shows seasonal variation of carbon content in flooded water. Average C concentration was estimated to be $15.7g/m^3$. Assuming the depth was 10cm, amount of flooded water was calculated to be $100m^3/10a$ and the carbon content was estimated to be 1.6kg/10a. Fig. 4 shows seasonal variation of carbon content in irrigation water. Average C concentration was estimated to be $17.1g/m^3$. During rice growing season(May-Sep.)in 1994, amount of irrigation water used was 471 $m^3/10a$. Total carbon input as irrigation water was calculated to be 8.1 kg 10a-1. Fig.5 shows seasonal variation of carbon content in percolation water. Average C concentration was estimated to be 66.4g/m3. As percolation rate was 3mm/day, amounts of percolation water in our experimental field was calculated to be $450m^3$ during rice growing season and amounts of C percolated was estimated to be 29.9kg/10a.

Fig.6 shows seasonal variation of CO_2 and CH_4 flux in experimental field. CO_2 was flowed into paddy field during rice growing season and flowed out during drainage season. Methane emitted only during flooded season. Although atmospheric temperatures in 1994 and 1995 were higher than that in 1993, the inflow of C to the field in both year were estimated to be lower than that in 1993(Fig.6). Fig.7 shows diurnal variation of CO_2 and CH_4 flux in experimental field during 11:00 4th -8:00 5th August 1993. At 11:00, the rate of CO2 inflow reached maximum. Fig 8 shows relationship between temperature in chamber and absolute value of CO_2 and flux. The absolute values were inversely proportional to temperature in chamber. in July and August while the values in June to September were proportional to temperature in chamber. From Fig.8 the measured values were corrected to the values based on the temperature outside chamber (Fig.9). From the data described above, annual carbon balance was calculated(Fig.10). Yearly input of C to paddy field ecosystem per 10a was estimated to be 1200kg/10a and 10kg/10a as gaseous C(CO_2 fixation) and aqueous C (irrigation and precipitation), respectively. Output of C was estimated to be 500kg and 10kg as respiration and methane formation respectively. Consequently, net CO_2 fixation was calculate to be 700kg/10a/year. In 700kg, 650kg was fixed in rice plant and 30kg was leached to underground water.

4. Discussion

Present field research showed that main pool of the carbon was soil in the paddy field ecosystem. Carbon content at November was lower than that at April, suggesting that soil organic matter was decomposed considerably during flooded period. Itou and Iimura (1989) reported that amount of CO_2-C evolved from paddy field site without rice plant were estimated to be 289kg/10a during rice growing season. From Fig.2, the amounts of C fixed by rice plant during 12/5-27/6, 27/6-27/7, 27/7-28/8 and 28/8-8/9 in 1995 were calculated to be 66,168, 328 and 10kg/10a, respectively. From Fig.6, the amounts of C fixed by the paddy field during 12/5-27/6, 27/6-27/7, 27/7-28/8 and 28/8-8/9 in 1995 were calculated to be 96, 181, 187 and 48kg/10a, respectively. Large difference was observed between the estimates of the period 27/7-28/8 obtained from Fig. 2 and 6. The difference suggests that chamber method underestimated CO_2-C inflow during high temperature condition. Bong and Murata(1977) reported that apparent photosynthesis of rice plant decreased when temperature was elevated over 35 ℃.

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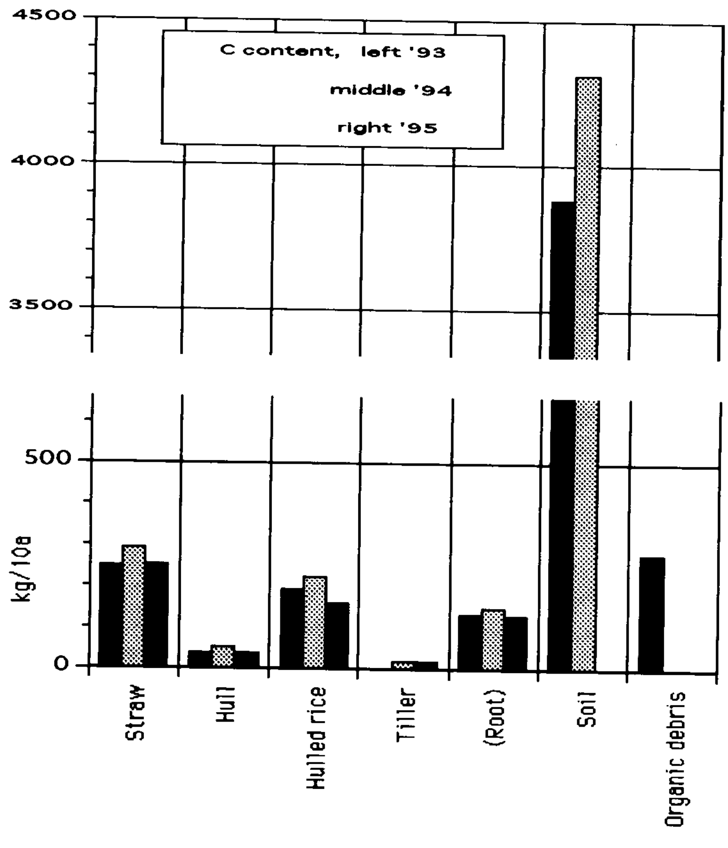

Fig.1. Carbon Content of soil and plant

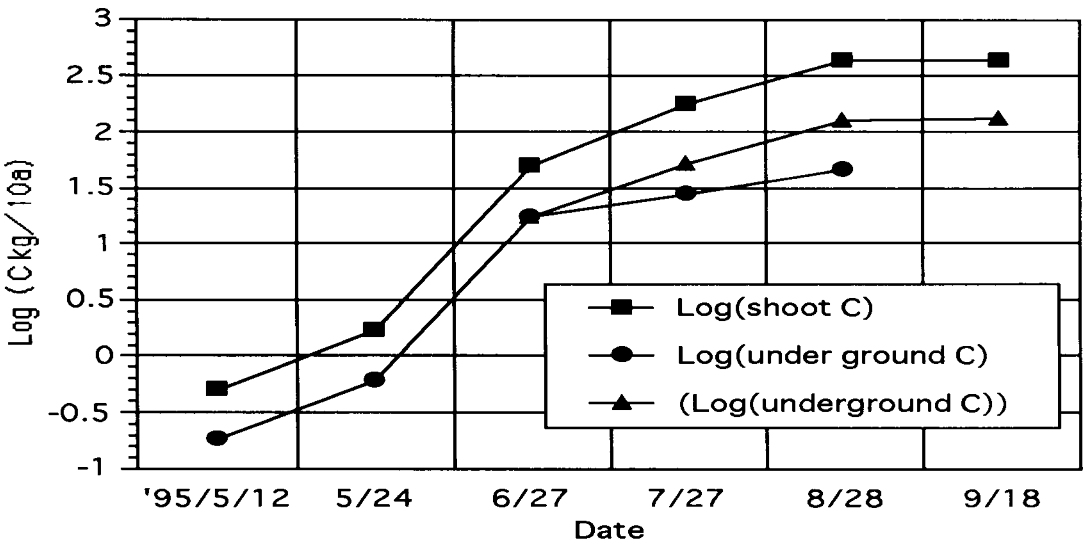

Fig.2. Variation of rice plant C during growth

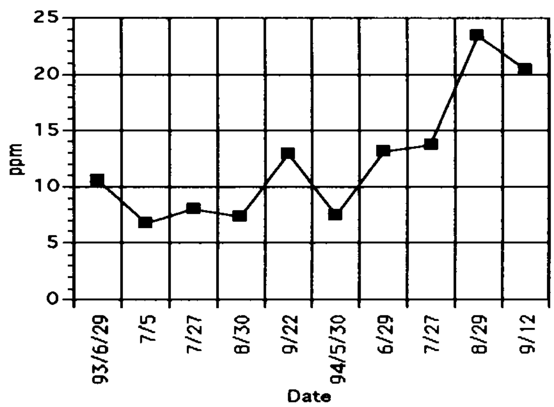

Fig. 3. Seasonal variation of carbon content in flooded water

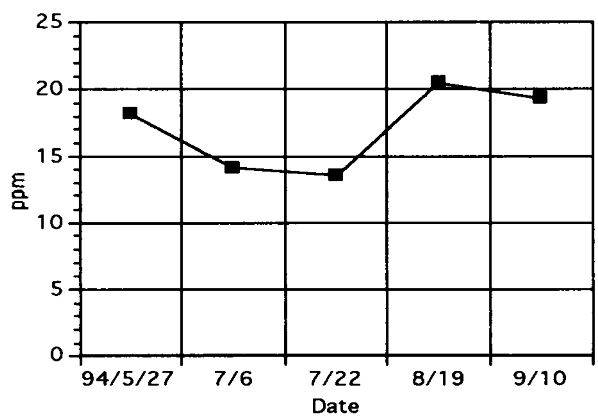

Fig.4 Seasonal variation of carbon content in irrigation water

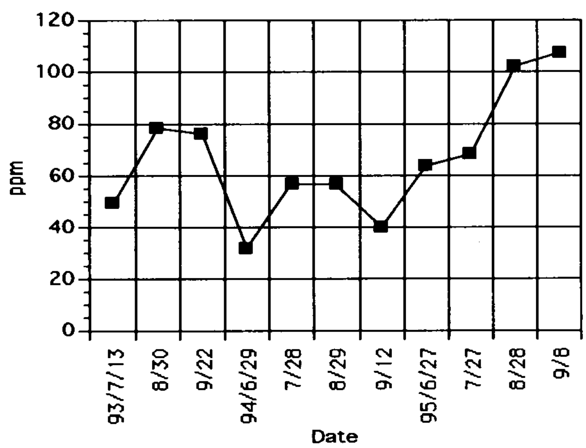

Fig.5. Seasonal variation of carbon content in percoration water

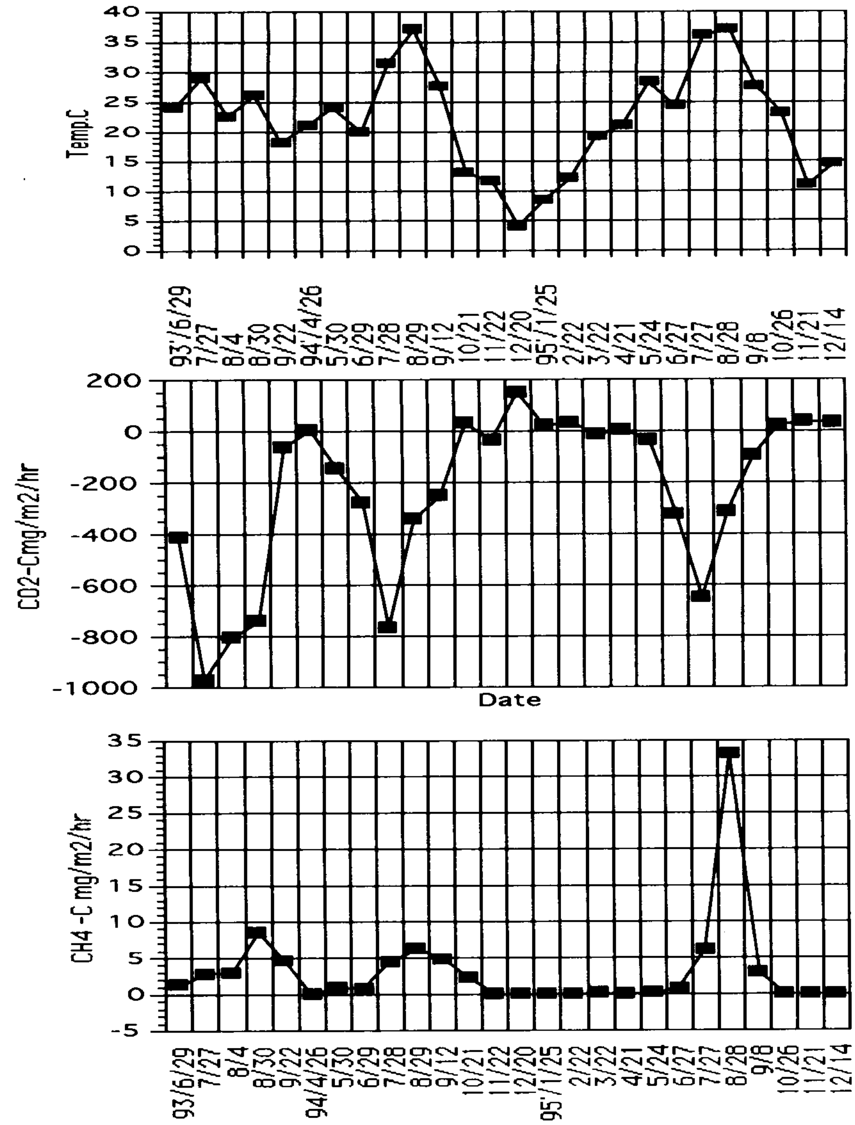

Fig.6. Seasonal variation of carbon dioxide and methane flux in experimental field

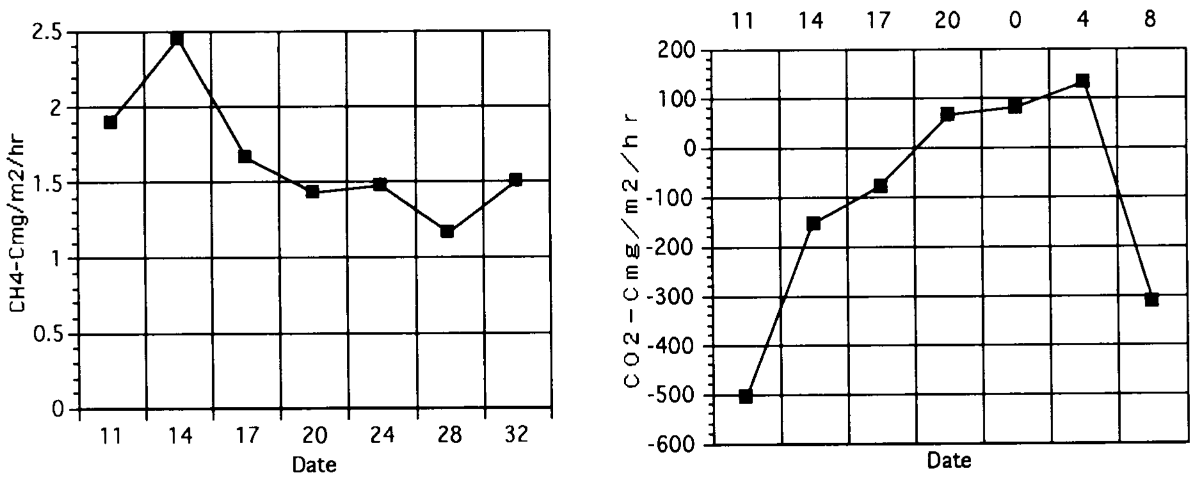

Fig.7. Diunal variation of carbon dioxide and methane in experimental paddy field during 11 : 00 4th - 8 : 00 5th August 1993 ; Left : methane ; Right : carbon dioxide

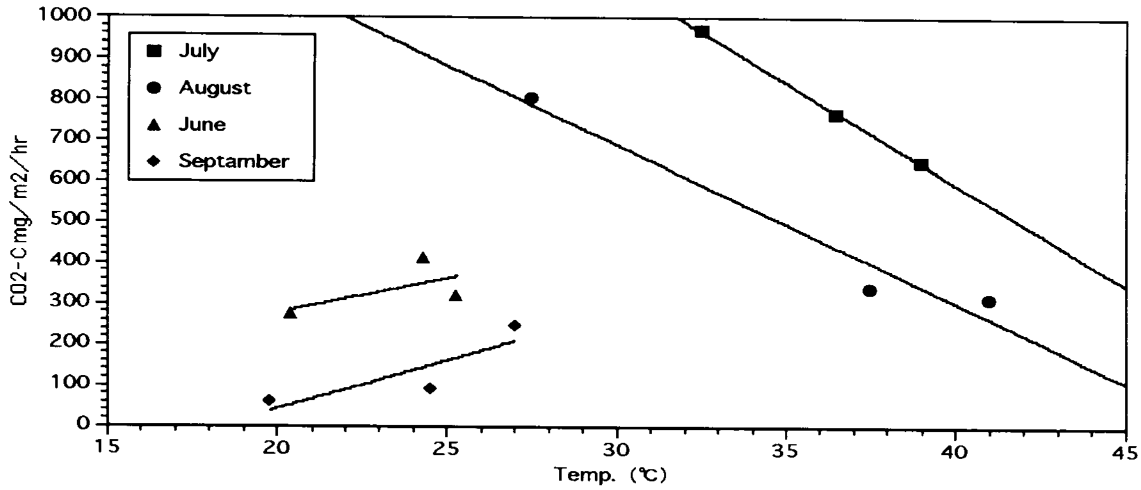

Fig.8. Relationship between temperature in chamber and absolute value of carbon dioxide flux

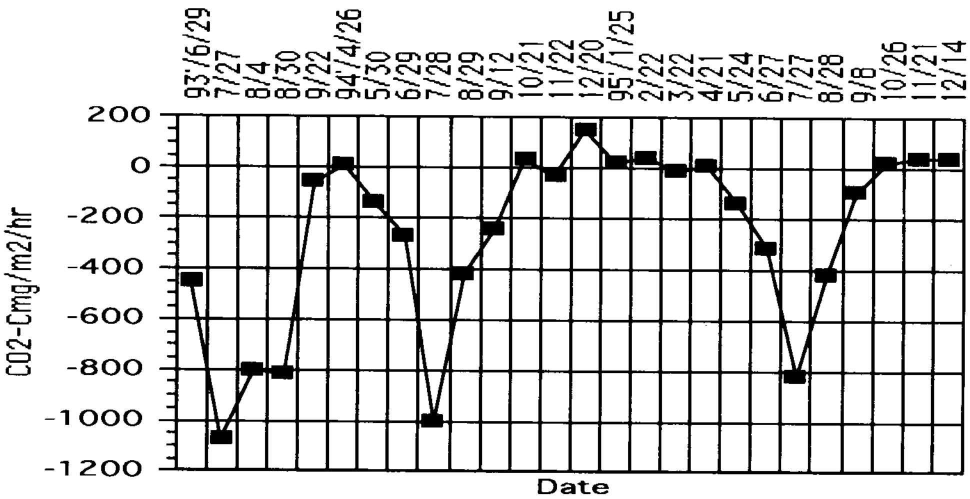

Fig.9. Corrected seasonal variation of carbon dioxide flux

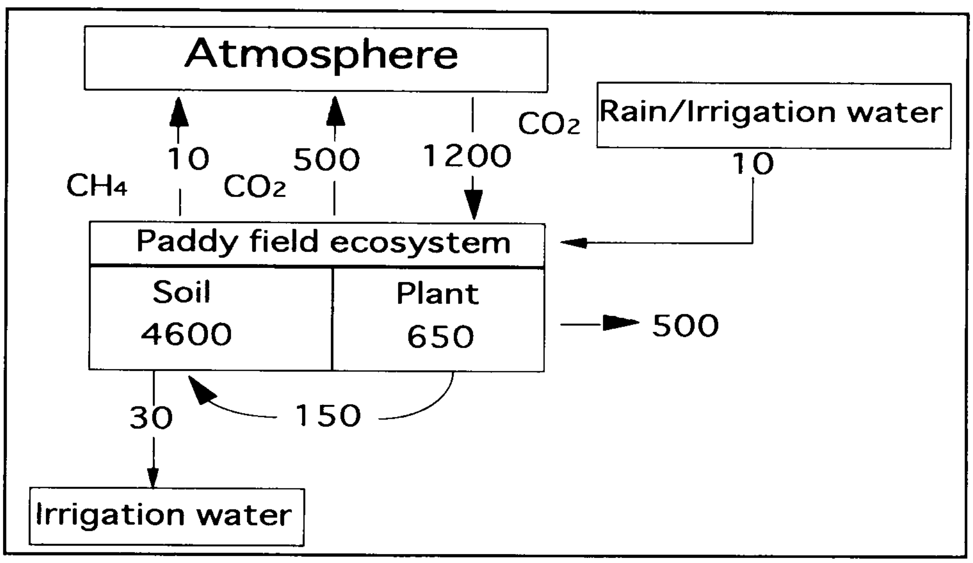

Fig. 10. Annual carbone balance in paddy field soil (kg/10a)