Greenhouse gas budget of Japanese rice field as an AsiaFlux Network site under recent field management

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1. IIntroduction*

Agricultural fields have important roles on greenhouse gas budget; the plants uptake atmospheric CO_2 and the ecosystem including soil microorganism activities emit CO_2 as their respiration. Also wet low farmlands such as rice paddy are major CH_4 source and upland enriched with fertilizer emits N_2O. These sink and source strength can be changed by the management manner. Furthermore, land use changed year by year in the last several decades. Therefore, the current greenhouse gas budget of agricultural fields could be different from estimated values previously using limited scientific results (IPCC report, 1995). Thus, it becomes important to detect the current greenhouse gas budget in agricultural land. Observed data on greenhouse gases exchange between terrestrial ecosystems and the atmosphere are strongly demanded to conclude inter-governmental agreements in COP6 .

From this point of view, AmeriFlux (http:// cdiac.esd.ornl.gov/ programs/ ameriflux/) and CARBOEUROPE (http:// www.bgc-jena.mpg.de/ public/ carboeur/ carbo.html) have been launched on the flux observation project at various types of ecosystem including agricultural fields. We have established AsiaFlux Network from September, 1999 (http://www-cger.nies.go.jp /^moni /flux /asia flux/indexJ.html); in which more than 30 flux observation sites in Japan and Asian countries are involved for long-term greenhouse gas budget monitoring studies, and several agricultural fields are covered. Rice paddy is major agricultural ecosystem adapted to eastern Asia, especially in the Asian monsoon climate zone. Rice paddy is major CH_4 source and has been thought to be CO_2 sources as the annual budget, thus has been seemed to be undesirable farmland in the global change topic. To reveal the actual greenhouse gas budget at rice paddy, four rice paddy sites are involved in the AsiaFlux Network; those are at central Korea, central Thailand, and two sites at Okayama and Tsukuba in Japan.

As we had observed CO_2 and CH_4 fluxes at a rice paddy near Tsukuba (Yawara field 36°0'N, 140°01'E) during the growing seasons between 1993 and 1995, that resulted in yearly differences of flux levels (Harazono et al., 2000). In this paper we show the preliminary results of continuous greenhouse gases flux observation at Mase rice paddy site in 1999 and 2000, especially carbon budget during rice growing season and non-cultivation period are discussed. Then some problems in the flux observation are pointed out.

2. Outline of the field and the cultivation

Mase measurement site (36°03'N, 140°01'E, elevation 15 m) is at traditional rice paddy field in central part of Japan. The artificially irrigated homogeneous rice field extended about 1.5 km north to south and 1 km east to west.

Rice paddy field was managed as typical current Japanese way, where was flooded during the growing period and was left as non-cultivated dry upland condition after harvest in autumn till the next cultivation in late spring. Rice straw was left at the field after the harvest and the field was plowed in October, early January and late March. After each plow the field was bare soil condition and rice straw was mixed into the soil as organic matter. The field is filled with irrigation water at late April and rice plant is transplanted in early May. Rice plant grows faster in late June and July then the heading is appeared in early August after a week period of mid-summer drainage. Maximum plant height is 1.0m just after heading. Before harvest the irrigation is closed in late August and the harvest is in early September, but the actual harvest day is varied (delayed or advanced a couple of weeks) depend on the individual farmers management and yearly climate difference. At one time, the field had been used to produce vegetables or wheat after harvest, but is plowed in October and is left as dry upland until next April, the beginning of the growing season. Therefore non-cultivation period continues 8 months in cool-cold season, under current field management manner.

3. Methods of flux observation

Measurement tower (6.2 m in height) was set at the field and sensors of temperature, humidity, short and long wave radiation, and wind profile were mounted. Dominant wind direction at the site was south in summer, northwest in winter, respectively. The fetch for flux measurement at the tower was more than 0.7 km to the dominant wind directions.

CO_2, sensible and latent heat fluxes were determined at 2.2 m height by eddy correlation method using 3D-sonic anemometer (Kaijo, DA-600) and open path type CO_2/H_2O fluctuation meter (Advanet, E009b or DDG, OP2) (Harazono et al., 1998). The span lengths of DA600, E009b, and OP2 are 0.1m, 0.1m and 0.2m, respectively and the separation distance between the sonic anemometer and the gas sensor is 0.17m. The sampling rate was 10Hz and continued 27.4 min at 30-min intervals (16400 sequential data are collected). After removing trends each fluxes were calculated every 30-min average and demanded corrections for CO_2 and latent heat fluxes caused by air density, sensor span length, and sensor separation are applied (Miyata et al., 1998 2000).

Micrometeorology and gas concentration are measured every 10-second and 15-min averaged data are recorded by digital data logger (Campbell, CR21 & CR10X), then 30-minute averaged data after the quality control were used.

Measurement started on July 31, 1999 and continued except the maintenance days of equipment and heavy rain days. Three harvest samplings were carried out in 2000 cultivation season, those were on July 28, August 28 and October 17. July sampling was carried out under the maximum plant height (1.05m) and leaf area index (LAI=5.8), and the August sampling was just before harvest and the October sampling was special in 2000 to measure the re-growth rice plant only observed in 2000 autumn with much rain and high temperature.

4. Results and discussions

4.1 Daily variation and seasonal change of CO_2 flux

Daily variations of CO_2 exchange between the rice field and the atmosphere are shown in Fig. 1, in which downward flux is defined as negative. CO_2 flux in daytime was large negative values on August 2 that shows strong uptake of atmospheric CO_2 in rice maturing period and high level of night time efflux by the ecosystem respiration. After harvest, CO_2 flux was positive through the day when the field had plowed and the high level peak in the afternoon is caused by higher soil temperature. The nighttime respiration level is almost the same level as in mature period. During the winter season, the efflux from the field is low level that reflects the low soil temperature especially in nighttime. When the field was flooded with irrigation water, CO_2

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efflux was almost zero and then the daytime CO_2 flux changed to negative two weeks after rice transplant.

Table 1 shows CO_2 exchange levels on typical clear days during the rice growing period in 2000. We could not get flux data between July 2 and 28 because the equipment at the site had unusual lighting damages. Daytime uptake increased rapidly until late June and the maximum level was 52 $gCO_2\ m^{-2}d^{-1}$, then decreased to around 30 $gCO_2\ m^{-2}d^{-1}$ in early August and 6 $gCO_2\ m^{-2}d^{-1}$ of uptake was observed just before harvest. Nighttime efflux level increases with the growth of rice plant and slightly decreased in mature period with senescence of the plant. However nighttime CO_2 flux was high level again when the field was drained before harvest (shown with symbol * in Table 1). We can find the effects of irrigation management on the seasonal changes in CO_2 flux as well as the changes caused by weather change.

4.2 CO_2 budget in growing and non-cultivation periods

Daily CO_2 flux was separately accumulated for daytime (light condition) and nighttime (dark condition) and the seasonal trends of CO_2 uptake by rice plant and CO_2 efflux from the ecosystem are shown in Fig. 2.

In August CO_2 uptake in daytime decreased rapidly with senescence of the rice plant and the flux changed upward under drained condition before harvest. Right after the harvest, daytime CO_2 efflux was maximum level of 11.5 $gCO_2\ m^{-2}d^{-1}$ under upland field condition with rice stamp. A couple of weeks later CO_2 efflux decreased to around 5 $gCO_2\ m^{-2}d^{-1}$ and then gradually decreased to the mid winter level of 3 $gCO_2\ m^{-2}d^{-1}$.

Nighttime CO_2 flux was continuously positive throughout the season and the level was high in mid August in 1999 and in July in 2000, that reflected the high respiration levels by rice plant of its higher biomass periods. Nighttime CO_2 efflux level during non-cultivation period decreased as the same manner with those in daytime and the minimum level was occurred to winter.

In late April the field was filled with irrigation water (on April 20), the CO_2 flux levels in both daytime and nighttime decreased dramatically close to zero. The water layer acted as the resistance to CO_2 transfer from soil layer to the atmosphere in flooded period of the rice paddy field. The daily amount level was lower than 2 $gCO_2\ m^{-2}d^{-1}$ under flooded condition, then the CO_2 flux in daytime changed to negative (sink flux) several days after transplant. As the rice plant was still small in this period, so the negative CO_2 flux observed right after transplant could be contributed by the CO_2 uptake of the algae photosynthetic activity.

Sink CO_2 flux in daytime increased rapidly in June but we failed to get the maximum flux level in July owing to lightning damages that was thought to be largest sink during the growing period. After August, the daytime uptake level decreased rapidly in 2000 season and the tend was almost the same as that in 1999.

Fig.3 shows the accumulated carbon by the rice field from the beginning of the measurement on August 1, 1999. The curve showing the accumulation of the carbon exchange between the rice ecosystem and the atmosphere, returned to zero about a week after the harvest in 1999. Then it increases with the time owing to the ecosystem respired CO_2 during non-cultivation period. The increase rate was high just after harvest. The maximum value was appeared around transplant day with 396 $gC\ m^{-2}$. After the maximum the level decreased rapidly owing to the high rate of photosynthetic CO_2 uptake. The minimum value was 414 $gC\ m^{-2}$ just before harvest day. This means that the rice ecosystem accumulates 810 $gC\ m^{-2}$ of atmospheric carbon in 2000 growing season (May to August) and also releases 396 $gC\ m^{-2}$ of carbon as respired CO_2 to the atmosphere during the previous non-cultivation period (from September,1999 to April, 2000).

We measured the rice biomass increased during the 2000 growing season, that was 1851.8 $g\ m^{-2}$ of total dry matter (leaf, stem, root, and grain) . This is equivalent to around 824 $gC\ m^{-2}$ of carbon applying a common conversion factor. The harvest sampling value was very close to that determined by accumulation of eddy flux measurement. As there are additional carbon frown out from the field through the irrigation water that was not measured by harvest sampling, the accumulated value from eddy flux measurement should be greater than the harvest sampled value. Also the eddy flux evaluation could be a little over evaluation because some lacked data for rainy day or equipment damaged period were implemented using relatively clear day data. However, the evaluated value by eddy flux measurement at the rice paddy site has reasonable accuracy.

The respired CO_2 during the previous non-cultivated period was almost the half of that accumulated in the growing period, that is equivalent to the organic matter left at the field after the harvest. The grain weight taken away for foods from the field was 805 $g\ m^{-2}$ and the ratio to the total dry matter (1852 $g\ m^{-2}$) was 043. The evaluated respired carbon value from eddy flux measurement was slightly higher than that estimated from the harvest sampling.

We have some difficult problem in the evaluation of night time eddy flux determination. Respired CO_2 has strong relation with temperature and the nighttime temperature (air and soil) was lower than that in daytime. However the measured efflux level in daytime was lower than that in nighttime during winter period (Fig.2). The of nighttime efflux could be over evaluation, that was brought about the intermittent high fluctuation of CO_2 concentration during calm night with stable atmospheric stability conditions. The further analyses are needed to determine more accurate CO_2 budget at flux monitoring site.

Finally, we found much different CO_2 exchange in September and October in 2000, that the daytime CO_2 flux changed sink from mid September and continued to end October. During the period, temperature was higher than normal year and we had much rain after harvest, therefore the re-grew rice plant (sprout) from left stump grew up and the highest plant height was around 0.6 m in late October. The field looked like green rice field in June. The yearly weather change makes different CO_2 exchange at the field, especially during non-cultivation period. We have to reveal the yearly variation of carbon sequestration caused by different climate by continuing the long-term flux observation under AsiaFlux study. Which can contribute to provide the scientific data supporting discussions in the international negotiations on CO_2 emission control after COP6.

5. CONCLUSIONS

From preliminary measurements, the CO_2 emission in non-cultivation period was evaluated as 400 $gC\ m^{-2}$, while the up taken CO_2 during the growing period was 810 $gC\ m^{-2}$ in 2000 growing season. 353 $gC\ m^{-2}$ of grain was taken away from the field. Carbon budget at the rice field was almost even under the current farm management condition in 1999 and 2000. However we need to reveal the effect of climate change on the carbon sequestration at rice paddy by long term observations.

Eddy correlation flux measurements brought about reasonable results at the rice paddy field. However we need more accurate evaluation of night-time CO_2 exchange over the field.

Acknowledgements

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Reference

1) Harazono et al., 1998: Measurement of energy budget components during the International Rice Experiment (IREX) in Japan. *Hydrol. Processes*, 12, 2081-2092.
2) Harazono et al., 2000: Greenhouse gas budget at Japanese rice paddy as an AsiaFlux Network site. *Proc. Of 24*[d] *Conf. on Agric. & Forest Meteorolo*., 321-324.
3) Miyata *et al*., 1998, Micrometeorological measurement of methane emission from a Japanese rice paddy. *Proc. Of 23*[rd] *Conf. on Agric. & Forest Meteorolo*., 321-324.
4) Miyata *et al*., 2000, Carbon dioxide and methane fluxes from an intermittently flooded paddy field. *Agric. & Forest Meteorolo*., 287-303.
5) IPCC, 1995: Climat Change-The Science of Climate Change, 445-481.
6) Schmid, H. P. et al., 2000: Measurement of CO_2 and energy fluxes over a mixed hardwood forest in the mid-western United States. J*. Agric. Forest Meteorolo*. 357-374.

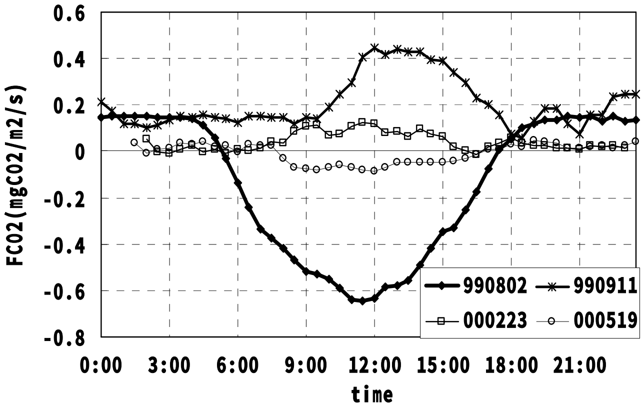

Fig.1 Daily variation of CO_2 flux at a rice paddy field in central Japan after late growing period.

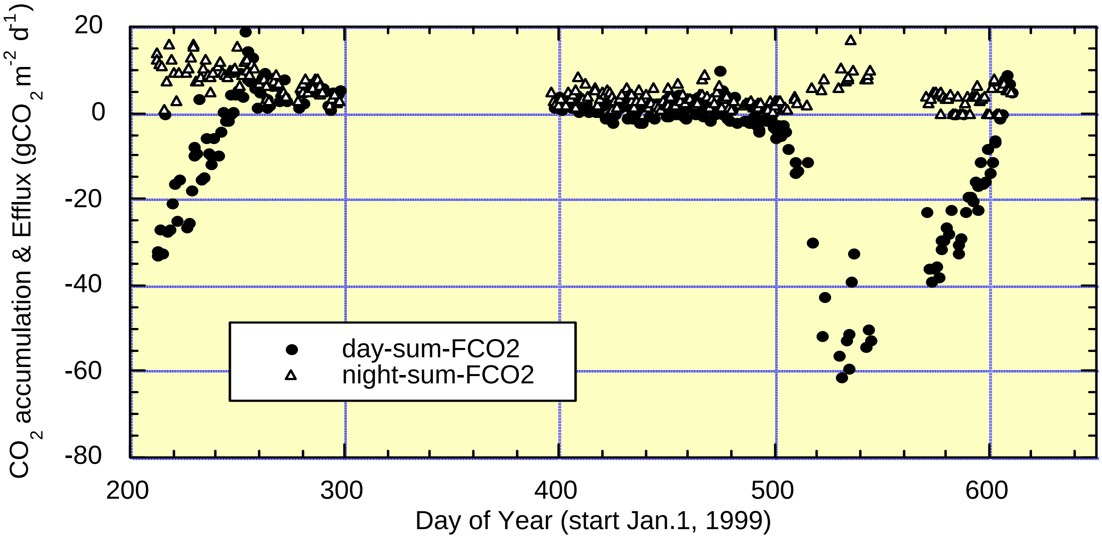

Fig.2 Seasonal trends of daily CO2 exchange at rice paddy in 1999 and 2000.

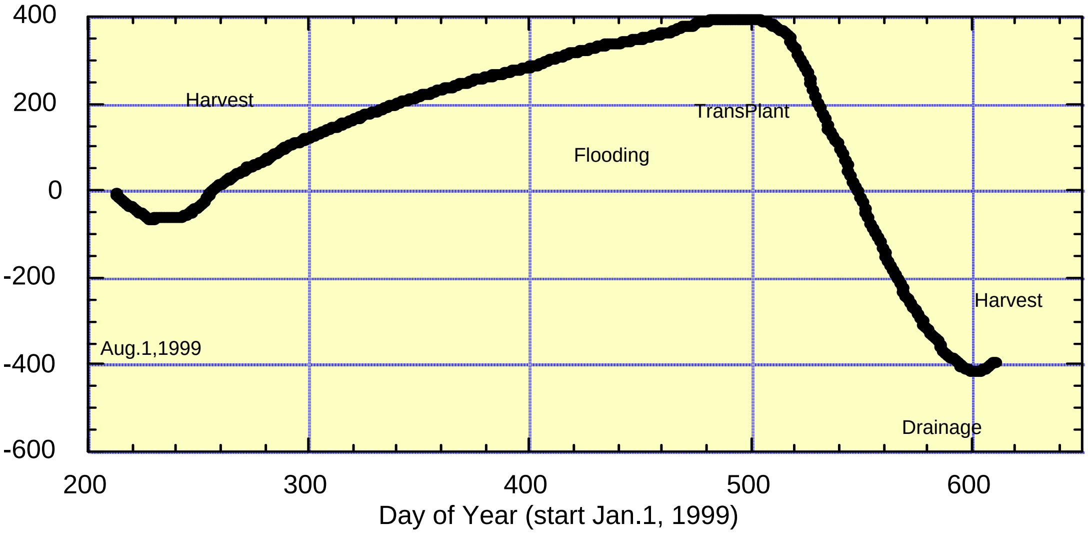

Fig. 3 Trend of accumulated carbon budget at rice field from the beginning of measurement on August 1, 1999.

Table 1 Seasonal trend of daily CO_2 exchange at the rice paddy

	Daytime Uptake	Nighttime efflux
10-May	-0.97	2.19
26-May	-13.49	2.49
2-Jun	-30.17	5.74
8-Jun	-42.91	7.74
18-Jun	-52.63	7.23
equipment trouble caused by lighting		
1-Aug	-31.41	7.75
11-Aug	-29.03	6.27
28-Aug	-5.99	7.77*