INTERACTION OF CARBON DIOXIDE AND METHANE IN CARBON EXCHANGE BETWEEN FLOODED RICE PADDY ECOSYSTEM AND THE ATMOSPHERE

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ABSTRACT
A combined study of micrometeorological flux measurement of carbon dioxide (CO_2) and methane (CH_4) and measurement of their stable carbon isotopes at a paddy field indicated that CH_4 production can affect not only greenhouse gas budget of wetland ecosystem but also isotopic signature of respired CO_2.

INTRODUCTION
Freshwater wetlands like rice paddies are unique ecosystems that have two main pathways, through carbon dioxide (CO_2) and through methane (CH_4), in gaseous carbon exchange with the atmosphere. Although numerous studies on gaseous carbon exchange between the freshwater wetlands and atmosphere have been conducted from the 1980s, most of those studies place their focus on either of the two pathways. Studies on quantitative relationship or interaction between the two processes are rare [*Kim et al*., 2000]. In order to understand these two pathways in the carbon exchange and their interaction, we made a combined study of micrometeorological flux measurement of the two gases and measurement of their stable carbon isotopes in soil, plant and the atmosphere at a paddy field in central Japan.

METHODS
The study was conducted at Mase paddy flux site (36° 03'N, 140° 02'E, 15 m asl) in Central Japan. At the study site, rice (*Oriza sativa* L.) is cultivated following customary practices: rice is transplanted at the beginning of May and harvested in mid-September. The paddy is flooded to a depth of 3 cm from late April to mid-August with temporary interruption by mid-season drainage. At the study site, CO_2 and CH_4 exchange between the paddy field and the atmosphere have been monitored since the summer of 1999. CO_2 flux density was measured by the standard eddy covariance method with an open-path infrared gas analyzer, while CH_4 flux density was determined by the modified aerodynamic method from the vertical gradient of concentration (Miyata *et al*., 2000). In addition to the flux measurement, profiles of CO_2 and CH_4 concentrations and their carbon isotope composition have been measured from the 2002 growing season. CO_2 and CH_4 concentrations were measured *in situ* at 5 heights, 3 within and 2 above rice canopy, using an infrared gas analyzer and a FID (flame ionization detector)-type hydrocarbon analyzer, respectively. Air samples for isotope analysis were collected at the same height as the concentration measurement on selected days in the growing season, and analyzed in laboratory to determine carbon isotope composition of CO_2 and CH_4 [*Han et al*., 2005b]. We also analyzed soil and plant samples to determine source isotopic composition of CO_2 and CH_4 released to the atmosphere.

RESULTS AND DISCUSSION
CO_2 and CH_4 fluxes exhibited seasonal variations influenced by rice growth and filed management. The total net ecosystem CO_2 exchange (NEE) of a growing season showed year-to-year variations of >100 g C m^{-2} $season^{-1}$, which were principally caused by inter-annual variation in meteorological conditions and resultant plant growth, and to a lesser extent by cultivation practices such as timing of drainage prior to harvest and post-harvest plowing of the field. The total CH_4 emission of a growing season also showed inter-annual variability, but it was influenced more by the water management of the paddy (drainage practices) than by meteorological conditions. Seasonal CH_4 emission to the atmosphere is approximately

3% of the annual NEE, and therefore negligible in the annual carbon budget of the paddy. However, CH_4 emission has important contribution to the greenhouse gas budget of the paddy if the global warming potential of CH_4 (8.4 times as much as that of CO_2 on molar basis for 100 years of time horizon) is taken into account.

In order to determine $\delta^{13}C$ of respired CO_2, Keeling plot was applied to nighttime profiles of CO_2 concentration and its carbon isotope. Both $\delta^{13}C$ of respired CO_2 and that of foliage showed increasing trends with days after flooding, but the former was always less negative than the latter by 3-4‰. In addition, respired CO_2 was enriched when the paddy was drained [*Han et al*., 2004]. These results indicate that below-ground (root and microbial) respiration has significant contribution (~30%) to ecosystem respiration even under flooded conditions, although the below-ground respiration is often neglected when CO_2 exchange of flooded ecosystem is discussed. This finding is supported by the result of partitioning nighttime ecosystem respiration into plant and soil components by using empirically determined relationship between soil temperature and soil respiration [*Mano et al*., 2004].

Oxidized fraction of CH_4 in soil was determined from difference in $\delta^{13}C$ between soil-entrapped CH_4 and CH_4 released from foliage (Han *et al*., 2005a). The oxidized fraction of CH_4 showed an increasing trend with the development of plant roots, from about 20% at the beginning of the growing season to >60% in late growing season. In the total of a growing season, a third of produce CH_4 was oxidized into CO_2 before being released to the atmosphere. $\delta^{13}C$ of CO_2 and CH_4 stored in soil exhibited contrasting seasonal trends: CH_4 was depleted with days after flooding, while CO_2 was enriched. This implies that carbon isotope ratio of soil-stored CO_2, which was finally respired into the atmosphere, was influenced by isotopic fractionation in methanogenesis through CO_2 reduction. Unlike non-flooded ecosystem, CH_4 production in fresh wetland ecosystem such as rice paddies can affect not only greenhouse gas budget of the ecosystem but also isotopic signature of respired CO_2.

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