Microbial biomass and activities in a Japanese paddy soil with differences in atmospheric CO_2 enrichment, soil/water warming and rice cultivars

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Abstract
Paddy surface and subsurface soil samples were collected from former Rice-FACE (free-air CO_2 enrichment) sites with elevated soil/water temperature treatment in successive rice crop season to investigate effect of CO_2 and temperature on microbial biomass, enzyme activities, and methanogenic and methanotrophic activities in a paddy soil. The FACE experiment was conducted in the field, with two CO_2 levels, ambient and ambient + 200 µL/L (FACE), located in Shizukuishi, Iwate, Japan until 2004. A warming treatment of soil/water temperature of 2 degree from transplanting until harvest (May-September 2006) was set up with water-proof heater in flooded water in the field. Soil microbial biomass C were significantly larger in surface layer than those in subsurface soil, but effect of previous CO_2 treatment and warming treatment on microbial biomass were both not significant. Dehydrogenase activity and dissolved organic carbon (DOC) had no significant difference between elevated and ambient temperature, though significantly higher in surface soil than sub-surface soil. Methane (CH_4) production (methanogenic) activity was increased by elevated temperature, but no effect on CH_4 oxidation (methanotrophic) activity. These results indicated that elevated temperature may affect soil microbial processes in different ways.

Key Words
Paddy soil, methane production and oxidation, dissolved organic carbon, temperature.

Introduction
Microbial biomass is important nutrient pool especially for nitrogen (N) in paddy soil (Inubushi *et al.* 1991; Shibahara and Inubushi 1995; Inubushi *et al.* 2002a). Microbial biomass can be also more sensitive early-warning indicator than total soil organic matter to see environmental impacts such as increasing concentrations of greenhouse gases on soil ecosystems, warming temperature, farmers' practices and so on such as in upland soil (Powlson *et al.* 1987) and in paddy soil (Hoque *et al.* 2001). Atmospheric concentrations of CO_2 and methane (CH_4) have been annually increasing at a rate of 0.5% and 0.8%, respectively. The increasing CO_2 is mainly attributed to fossil fuel combustion and land use changes, and its concentration is expected to double by the middle of this century compared with preindustrial values (Lal and Kimble 1995; IPPC 2001). Methane, another important greenhouse gas, accounts for about 20% of the current increase in global warming, which is caused by an imbalance between CH_4 sources and sinks (IPPC 2001). Paddy fields have been regarded as major anthropogenic sources of global CH_4 emission, with annual estimates ranging from 47 to 60 $TgCH_4$ (Houghton *et al.* 1995; IPPC 2001).

Effect of elevated CO_2 in the atmosphere on soil microbial biomass in paddy field has been examined in rice-FACE (Free-air CO_2 Enrichment) experimental site in Shizukuishi, northern part of Japan (Inubushi *et al.* 2001; Hoque *et al.* 2002). Under standard N application level, elevated CO_2 (ambient + 200µL/L) significantly increased biomass N in the upper soil layer at harvest by 25–42% compared to ambient CO_2, regardless of N application rate. In low N soil, these significant increases were also observed at the ripening stage (Hoque *et al.* 2002). However the effect of elevated CO_2 on microbial biomass was not examined for long-term, except Lou *et al.* (2006) who measured CH_4 production potential of soils, taken 2 months after rice harvest, by incubation method and found that CH_4 production potential was approximately 2–4-fold higher in FACE soil than ambient soil and approximately 500–1,000-fold greater in surface soil than sub-surface soil. In general, the FACE soil contained more DOC than ambient soil, particularly in the surface soil layer. In previous reports, we also showed effect of elevated CO_2 on CH_4 emission from paddy field in the FACE sites to find more CH_4 emitted under elevated CO_2 conditions, indicating positive feedback of greenhouse gas increase (Inubushi *et al.* 2003). Methane is end product of anaerobic decomposition of organic matter in paddy field as well as natural wetlands. Microbial biomass and its debris can be substrate for methane production. Dissolved organic carbon in soil under elevated CO_2 conditions was more than ambient soil in the FACE site (Lou *et al.* 2006). Part of CH_4 produced in soil is oxidized by methanotrophic bacteria (Inubushi *et al.* 2002b). However we do not know yet how microbial biomass related to CH_4 emission and oxidation, and dissolved organic carbon in paddy soils planted with various rice varieties under elevated CO_2 condition. Effect of soil/water warming in paddy field is not investigated especially in relation to soil microbial biomass and their activity, such as methane production potentials.

Objectives of this study are to investigate microbial biomass dynamics in paddy soil as affected by CO_2 and temperature elevation to find effect of CO_2 and temperature conditions in relation to microbial biomass CH_4 production and oxidation.

Methods

Experimental sites

The FACE experiment was conducted in the filed, with two CO_2 levels, ambient and ambient + 200 μL/L (FACE), with 4 replicate rings, located in Shizukuishi, Iwate, Japan until autumn 2004 (Inubushi *et al.* 2003; Lou *et al.* 2006). Warming treatment of soil/water temperature in 2 degree from transplanting until harvest (May-September 2006) was set up in each FACE and ambient rings with water-proof heater in flooded water in the field, monitored and recorded (Borjigidai *et al.* 2006).

Soil sampling

Paddy surface (0-1cm) and subsurface (1-10cm) soil samples (Andisol paddy soil type) were collected in August 2006 from ambient-temperature (Ambient 1) and warming subplots in FACE ring and from non warming subplot in the ambient CO_2 ring (Ambient 2) to investigate effect of former CO_2 treatment and successive warming effects on microbial biomass, enzyme activities, and methanogenic and methanotrophic activities in a paddy soil.

Analysis

Soil microbial biomass was determined by chloroform-fumigation extraction method (Inubushi *et al.* 1991). Dehydrogenase activity was measured by TTC reduction method (Trevors 1984). Methane production potential was measured by incubation method (Lou *et al.* 2006) and oxidation activity was measured by propylene oxidation method (Watanabe *et al.* 1995).

Results

Soil microbial biomass C was significantly larger in surface layer than those in subsurface soil (Figure 1). Effects of previous CO_2 treatment and warming treatment on microbial biomass were both not significant. Dehydrogenase activity and dissolved organic carbon (DOC) had no significant difference between elevated and ambient temperature, though significantly higher in surface soil than sub-surface soil (Figure 2). Methane (CH_4) production (methanogenic) activity was increased by elevated temperature, but no effect on CH_4 oxidation (methanotrophic) activity (Figure 3). These results indicated that elevated temperature may affect soil microbial processes in different ways.

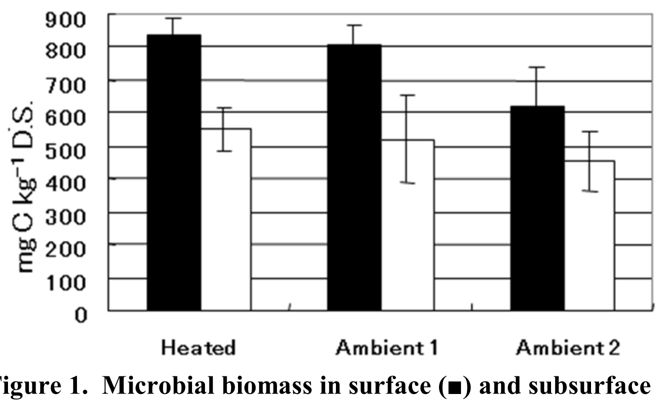

Figure 1. Microbial biomass in surface (■) and subsurface (□) soil as affected by CO_2 and temperature elevation.

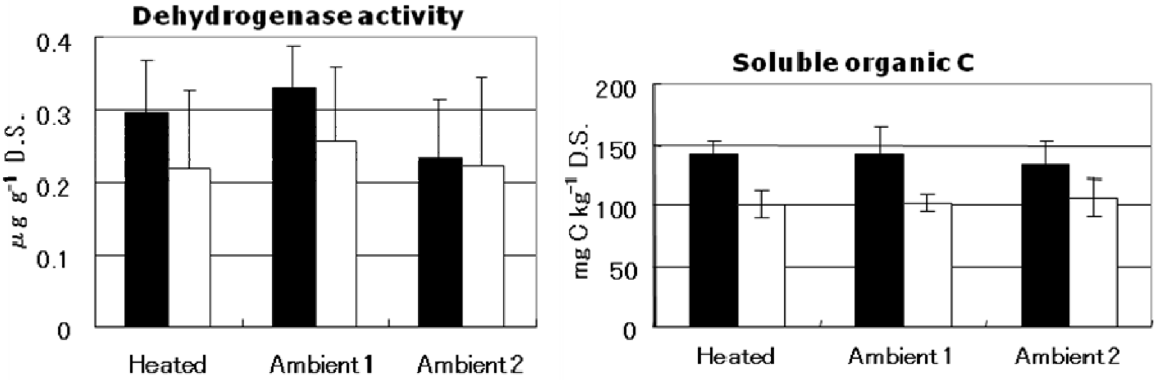

Figure 2. Dehydrogenase activity and dissolved organic carbon (DOC) in surface (■) and subsurface (□) soil as affected by CO_2 and temperature elevation.

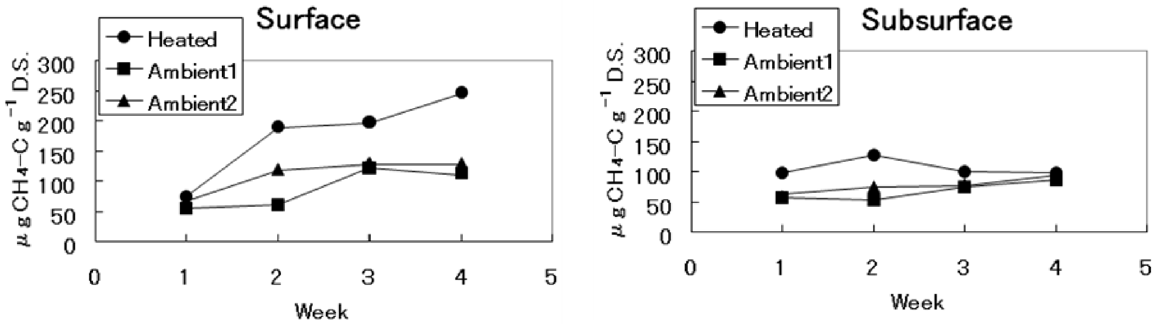

Figure 3. CH_4 production activities in surface and subsurface soil as affected by CO_2 and temperature elevation.

Conclusion

Soil microbial biomass C were significantly larger in surface layer than those in subsurface soil, but effect of previous CO_2 treatment and warming treatment on microbial biomass were both not significant. Dehydrogenase activity and dissolved organic carbon (DOC) had no significant difference between elevated and ambient temperature, though significantly higher in surface soil than sub-surface soil. Methane (CH_4) production (methanogenic) activity was increased by elevated temperature, but no effect on CH_4 oxidation (methanotrophic) activity. These results indicated that elevated temperature may affect soil microbial processes in different ways.

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Mineralogical assemblage and iron oxides of soils of the Pantanal biome, Brazil

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Abstract
The Pantanal biome is the largest wetland area of the world. Located in the centre of South American continent, it is being affected by the expansion of agricultural use. The effect of this occupation on environmental components of this complex biome such as flooding, sedimentations, vegetation and the characteristics of soils can not be evaluated due to scarce scientific information related to these factors. This study aimed to obtain information related to the forms of iron oxides features and mineralogical assemblage of the predominant soil classes found in this environment, once these characteristics reflect changes introduced by modifications in drainage conditions, flooding and sedimentation processes. The Gleysols present higher clay content than the Planosols and Plinthosols studied, probably related to deposition of clay in the lower position of the landscape, where they occur. The Plithosols, in spite of their lower clay content, showed the largest increase in Fe_d and Fe_d – Fe_o content, which must be related to the better oxidation conditions of this soil found on low ridges and mounds. The uniform mineralogical assemblage of the studied soils indicates that the origin and composition of the sediments and/or the pedogenic processes were similar in these soils.

Key Words
Pantanal biome, agricultural expansion, sedimentation processes, pedogenetic processes.

Introduction
The Pantanal biome, located in the middle of the South American continent (16° - 20°S and 58° - 50°W), predominantly in Brazil, is considered the world's largest wetland, occupying an area of about 200,000 km^2 (Por 1995). The landscape is characterized by a mosaic of landforms, such as permanent and temporary rivers and lagoons, vast extensions of floodplains and non-flooded mounds and ridges usually covered with woody vegetation (Haase 1999). The distinct areas have received different types of sediments resulting in a different behavior of water dynamics in the soil profile, which determines the occurrence of different pedogenetic process (Couto and Oliveira 2009). Hydromorphism is the predominant acting pedogenetic process where the redistribution of iron and the development of grey soil colors and reddish mottling (gleying) is the most viewable consequence. In non-flooded landforms podzolization and laterization are the main acting pedogenetic processes. At the Barão de Melgaço region, located in Northern Mato Grosso State, Brazil, three main soil classes are identified: Gleysols (exchangeable aluminum-rich) in seasonally flooded areas, Planosols (sodium-saturated with eutric character) and Plintosols (low cation exchange capacity and base saturation) in slightly more elevated landforms (Couto and Oliveira 2009).

The environmental impact of the increasing land use in this biome is not assessed yet. This is related to the existence of poor scientific environmental information about the relationship between landforms, vegetation and distribution of soils. In order to improve the understanding of the environmental responses to the anthropogenic influence, this study aimed to collect information about mineralogical assemblage and iron oxides features of the main soil classes of Pantanal biome in Northern Mato Grosso State, Brazil.

Methods
The study was developed at RPPN-SESC Pantanal at Barão de Melgaço sub region located between Cuiabá and São Lourenço Rivers, 145 km away from Cuiabá, capital of Mato Grosso State. The landscape is plain to gently sloping with elevations ranging from 80 to 150 m. Local climate is classified as Aw, with mean annual temperature ranging from 22 to 32 °C, with a well defined dry season from May to September and a rainy season from October to April. The total annual precipitation is around 1000 to 1200 mm. Data of three modal soil profiles was obtained from SBCS (2002): Umbric Gleysol (GLum), Haplic Planosol (PLha) and Haplic Plinthosol (PTha).