B-5 The impacts of land-use/cover change in terrestrial ecosystems of tropical Asia on greenhouse gas emissions (Abstract of the final report)

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Total Budget for FY1999-FY2001 90,655,000Yen (**FY2001**; 31,051,000Yen)

Key Words Humid tropical forests, Peat wetlands, Indonesia, Land-use/cover change, Greenhouse gases, Carbon budget, Soil microorganisms, Controlling factors, Scaling-up, Remote sensing, GIS, Eddy correlation method, Net ecosystem productivity, Intermolecular stable isotope ratios

1. Introduction

Land-use/cover change in the Asia-Pacific region has been rapidly progressing since the 1970s, and a part of tropical forests has been converted to agricultural fields, rubber and oil-palm plantations. The impacts of land-use/cover change on the emission of greenhouse gases (GHGs), however, have not been studied in the Asia-Pacific region, although a report by IPCC (Intergovernmental Panel on Climate Change, 1994) pointed out the possible impacts of the deforestation in tropical regions on global warming. The emission estimate of GHGs by IPCC has a large uncertainty due to luck of field data in the Asia-Pacific region. We started to measure the fluxes of GHGs in some terrestrial ecosystems in Sumatra and Kalimantan, Indonesia, to evaluate the GHG emissions in tropical Asia, under the strong collaboration with many researchers in Indonesia, from 1996 for six years.

2. Research Objectives

The purpose of this study is, to measure the flux of GHGs from humid tropical forests and peat wetlands in succession of land-use/cover change in Indonesia, to clarify the emission rate of GHGs in tropical Asia, to develop a methodology of scaling-up for the regional estimate of GHG emissions, using the local flux data-set and GIS and remote-sensing database of land-use/cover change, and to evaluate the impacts of land-use cover/change in tropical Asia on GHG emissions. This program was successfully conducted by collaborating with many researchers in BIOTROP-GCTE-IC-SEA, Bogor Agricultural University, Lambung Mangklat University, Jambi University, Murawarman University in Indonesia, and National University of Singapore.

3. Research Method

It has the following five sub-programs:

(1) Field measurements of greenhouse gas emission from soils under different land-use in humid tropical forests in Jambi province, Sumatra, and in peatlands in southern Kalimantan, and Jambi, Sumatra;

(2) Meteorological and biological influences on the carbon dioxide concentration and fluxes in the tropical secondary forests in Samalinda, east Kalimantan;

(3) Studies on controlling factors of greenhouse gas emissions from soils in humid tropical forests in Jambi, Sumatra;

(4) Development of database for ecosystem changes and of methodology for scaling-up the estimate of greenhouse gas emission on a regional scale;
(5) Development of mitigation options for nitrogen oxides emission from agro-ecosystems in Asia.

Finally, we had an International Workshop on "Land-use Change and Greenhouse Gases, Soil C and Nutrient Cycles in the Tropics", during 19-21 February 2002, at Tsukuba, Japan

4. Results and Discussion

(1) Field measurements of greenhouse gas emission from soils under different land-use in humid tropical forests in Jambi, Sumatra, Indonesia

The GHG fluxes were measured at 6 sites from soils under different land-use pattern in humid tropical forests and its surrounding area at PasirMayang in Jambi, Sumatra from September 1997 to March 2002. An analysis by Landsat image clearly showed that the forests in this observational site were rapidly converted to agriculture and plantations, as shown in Fig. 1. Four different land-use sites of primary (P1, P2) and logged-over (L1, L2) forests, a site (O) clear-cut and burned in 1996, and a site (R) of young rubber plantation from 1995/1996 was set up to measure the flux of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from the soil surface to the atmosphere every month. At all the sites, CO_2 and N_2O were emitted from the soil to the atmosphere, while CH_4 was absorbed by the surface soil at all but one site (P2) where the positive CH_4 flux was observed possibly due to termites. At L1, N_2O emission was greatly enhanced after the forest was cut and burned, while it decreased to the same level as that before deforestation within two and half years, as shown in Fig. 2. On the contrary, the uptake of CH_4 was very low after cut and burned, and was gradually increased to the same level as that before deforestation. This result was significantly different from a field study in Central America where the enhancement of N_2O emission after deforestation to pasture continued for ten years. The N_2O emission rate from humid tropical forests in Jambi was in a range of 0.13-0.39 kgN ha^{-1} y^{-1} and was much lower than that in the previous studies in Central and South America. It strongly indicates that N_2O emission rate from tropical forest soils estimated by IPCC was overestimated.

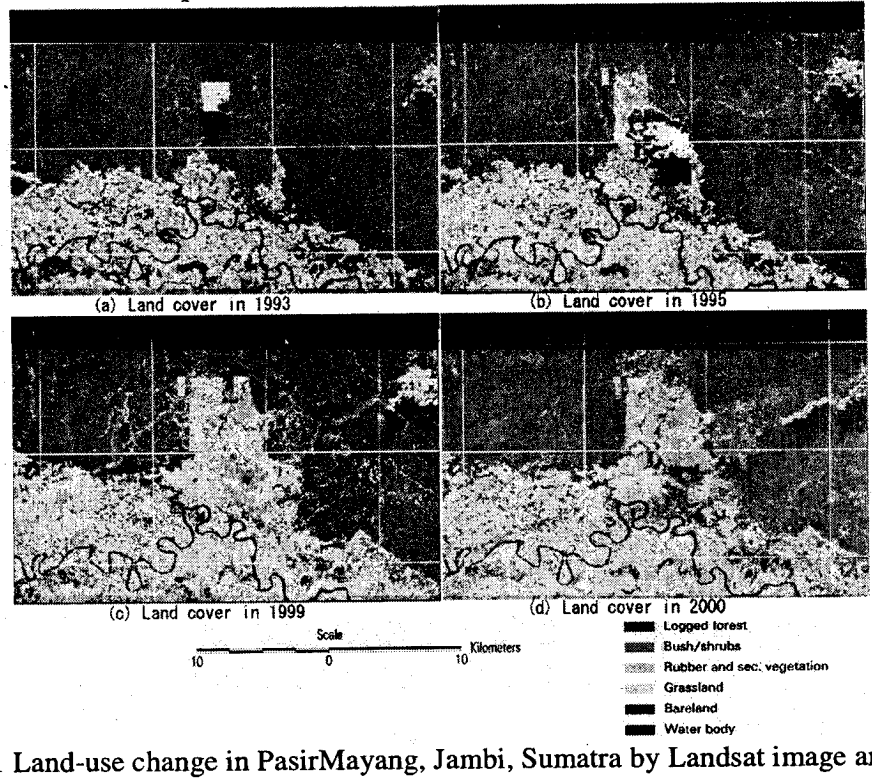

Fig. 1 Land-use change in PasirMayang, Jambi, Sumatra by Landsat image analysis (1993, 1995, 1999 and 2000)

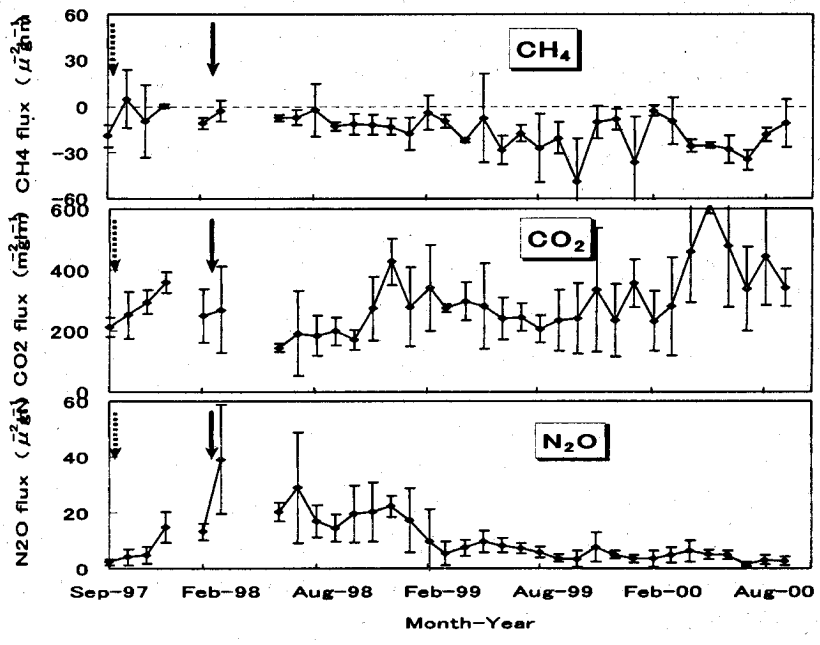

Fig. 2 Time series of flux of CH_4, CO_2 and N_2O measured at L1 site in PasirMayang, Jambi during Sep 1997-Sep. 2000. Dot and solid arrows mean the start period of cutting, and the period of burning, respectively.

An intensive field study was performed on a regional scale(250km x 130km) in Jambi province in September 2001 to evaluate the representativeness of these flux data at PasirMayang in Jambi. N_2O flux was highest in primary and logged-over forests, and lowest in grasslands with Alang-alang. The long-term trend of N_2O flux in rubber plantation seemed to be gradually increased, while it showed no increase in oil-palm plantation where the CO2 flux was lowest among the different land-use sites.

These field measurements revealed that the deforestation by clear-cut and burn, and land-use management had significant impacts on GHG emissions, especially on N_2O flux.

(2) Studies on Controlling Factors on Greenhouse Gas Emissions from the soils in Jambi, Sumatra

To confirm the controlling factors regulating the GHG emission from the soils in humid tropical forests in tropical Asia, we took soil samples at five land-use types in Sumatra, Indonesia. The number of ammonium oxidizer, nitrite oxidizer, denitrifier and methane oxidizer were counted by the MPN method. Also the content of soil sugars was measured. To validate the result obtained from the fixed PasirMayang Research Site, we made a field mission for sampling of soils and gases around Jambi Province in Sumatra for 18 days in September 2001. At 27 sites we measured gas fluxes and took soil samples, and analyzed the relationship between the fluxes and the various soil properties.

Ammonium oxidizer and nitrite oxidizer were detected at a clear-cut site in PasirMayang. This result is consistent with the assumption that the N_2O at the site is mainly produced from the process of nitrification. The number of denitrifier was less than 10 thousands cells, suggesting that N_2O emission on the process of denitrification was negligible. A good correlation was found between the nitrification rate and N_2O fluxes, and the relationship is adaptable globally. The ratio of N_2O emission to nitrification rate in the soil type of Andisols was smaller than that in other soils.

The CO_2 and CH_4 fluxes were affected by the water regime, controlled by the rainy and dry seasons in this area. The CH_4 uptake rate was correlated with the pore space of the topsoil in PasirMayang. The CH_4 uptake rate was possibly affected by termites in some experimental sites. The soil sugar content, extracted by hot water, showed a good correlation with CO_2 emission rate. A strong correlation was found between the amount of litter layer and the CO_2 emission rate at the

PasirMayang sites, while no apparent correlation was found between them at 27 sites in Jambi area.

In conclusion, the values of CO_2 and CH_4 fluxes in this area are comparable with those reported in the other tropical regions, but the N_2O fluxes were lower than those in the other tropical regions.

(3) Dynamics of methane (CH_4) and nitrous oxide (N_2O) in the tropical peat wetland

Tropical peatland has approximately 29 million ha in the world wide, among which 22.4 million ha is located in southeast Asia, mainly Indonesia and Malaysia. Present study was designed to investigate the dynamics of CH_4 and N_2O from tropical peatland and the factors affecting the process of their emissions. This study was conducted from December 1998 until December 2001, using 11 peatland sites in South Kalimantan and 6 in Jambi, Indonesia. Permanent plot was established to measure the seasonal changes of gas emission. Gas samples were collected by chamber method. A composite soil sample from each site and soil depth was taken and analyzed for various chemical and microbiological properties.

Most of the peat soils considered in this study are classified as shallow peat soils in South Kalimantan because the soil depths were <100 cm. The peat soils were strongly acidic having a pH value less than 5. The organic carbon contents varied with locations and soil depths and ranged from about 100 to 620 g C kg^{-1} soil.

The results showed that land use management, changing water table and locations had a significant impact on the dynamics of CH_4 and N_2O. Cultivated upland resulted generally in the higher amounts of N_2O emission compared to other land-uses and also reported values in temperate and boreal regions. The emission rate of CH_4, however, was generally low compared to that reported from other wetlands. The emission of both gases exhibited seasonal changes regulated by rainfall, groundwater table and soil Eh (redox potential).

(4) Meteorological and biological influences on the carbon dioxide concentration and fluxes in the tropical secondary forest

There are few data in the tropical area where absorption of carbon dioxide by forests seems to be large. Especially, there is no long-term data in the South Asia. This makes difficult to estimate CO_2 balance in the global scale. East Kalimantan had been damaged by the drought-linked fire in 1997. This drought was related with a particularly pronounced El Ñino Southern Oscillation (ENSO) event. Generally speaking, CO_2 concentration increases in ENSO period. Reasons of this seem to be large CO_2 emission by fire, decrease in CO_2 absorption by dry climate, and decomposition of died trees in the tropical forests. Thus, the yearly change in CO_2 balance (absorption and emission) in the secondary forest is very important in the CO_2 balance on the global scale.

A relationship between daily NEP (Net Ecosystem Production) and APAR (absorved photosynthetic active radiation) was expressed by a parabolic curve throughout the year, because there was no seasonal change in 2000 and 2001. Nighttime NEP was assumed as the same value at sunset, because

Table 1 NEE, R, and GPP measured in the forest ecosystems in the world

Forest type	Location	NEE	R	GPP	authors
Tropical Rainforest	Brazil	1.0	23.4	24.4	Grace et al.(1995)
Tropical Rain Forest	Brazil	5.9	24.5	30.4	Malhi et al.(1997)
Tropical secondary forest	Bukit Soeharto	3.4	12.9	16.3	This study, 2000
Tropical secondary forest	Bukit Soeharto	4.6	12.9	17.5	This study, 2001
Cool temperate deciduous forest	Japan	1.8	6.2	8.0	Yamamoto et al.(1999)
Cool temperate deciduous forest	USA	3.7	7.4	11.1	Wofsy et al. (1991)
Warm temperate deciduous forest	Italy	4.7	5.4	10.1	Valentini et al. (1996)

Boreal forest 1.	Canada	3 8	.91	0.2	Black et al.(1996)

the temperature difference from sunset to sunrise was small (2~3℃). A yearly NEP was 3.4 and 4.6 ton C/ ha / year in 2000 and 2001, respectively. The growing rate of biomass above the ground (B_a) also increased from 3.1 (in 2000) to 4.6 (in 2001) ton C / ha / year.

Comparing ecological parameters of Bukit Soeharto with those in other forests in Table 1, Net ecosystem exchange (NEE) is almost equal to that in mature tropical forest. Total Respiration (R) and Gross photosynthetic production (GPP) in Bukit Soeharto is smaller than ones in mature tropical rain forest, and larger than ones in the forests in mid-latitude.

(5) Methodology Development for Data Base of Eco-System Changes and Scale up to regional area from Local Observation Data

Land cover changes of Pasirmayang Area, Center of Jambi Province in Indonesia were investigated using ground survey and LANDSAT/TM data on 9 April 1999, 17 June 1995 and 11 June 1993 (Fig. 1). We determined forest cut down 3-5% every year and agricultural fields were increased constantly. We estimate total greenhouse gas emission volume each year as the total of gases fluxes times each land cover. Land cover changes of Muarasabak Area, east lowland of Jambi Province, were also investigated land cover at 1989, 1992 and total above carbon stocks were calculated in the each year. To establish scale up method, we performed the case study works to make the distribution map of net primal production (NPP) using meteorology data 1992 −1993, and summed up NPP values of arable land, grassland, forest and others. We used the CRU Global Climate Dataset for meteorology data, land cover map of IGBP-DIS for land-use, and Chikugo Model for the NPP calculation. In this project, large area surveys of GHG measurement were performed in Jambi Province, Sumatra Island, in Indonesia and a lot of photos were acquired. We developed photo image database linked with map information and the database can use very easy.

(6) Development of mitigation options for nitrogen oxides emission from agro-ecosystems in Asia.

A field experiment was conducted to develop the mitigation options for N_2O and NO emissions from fertilized upland fields at Tsukuba, Japan in 1999-2000. The application method of fertilisers (25 kgN $m^{-2}h^{-1}$) was broadcasting mode (BC) where the fertilizers were incorporated uniformly down to the depth of 15cm below the soil surface, and band mode(B) where the fertilizers were put into the trench at the depth of about 10cm. Two types of fertilizers were used in both application methods. The one was easily decomposable urea (U) and the other was coated urea (CU). Chinese cabbage was transplanted from September in 1999 and 2000 for several months, and the flux of N_2O and NO was measured by closed chamber method. Compared with U-BC plot, total emission rate of N_2O was lower by 20 % only in the plot where coated urea with the application amount of 20 % less than that of usual application rate among several plots, with no decrease in the yield. These results strongly suggest that the mitigation option alternative to broad casting application method is the band mode application with coated fertilizer, and the total N2O emission could be reduced by 20% if the application amount would be reduced by 20% compared with that in local practice.

Twelve types of agricultural soils in both upland and paddy fields were collected from Chinese uplands and paddy fields, to compare their nitrification and denitrification activities under the same laboratory conditions. The results showed the nitrification rate was strongly influenced by soil pH. Added ammonia was nitrified in the first week in alkaline soils (pH≈or>8) and had fresh emissions of N_2O and NO simultaneously, except Loessial soils sample with high C/N ratio. The nitrification rate was slow in acid soils (pH<5.0). The denitrified activities were low in all soil samples compared with their nitrification, except acid paddy of Red earths. The fresh emissions of N_2O in nitrification assay were significantly correlated with the fresh emissions of NO and CO_2 (P<0.05), but without non-fresh emissions. The N_2O emissions from denitrification assay also were significantly correlated with the

CO_2 emissions ($P<0.01$).