The Impact of Land-Use/Cover Change on Greenhouse Gas Emissions in Terrestrial Ecosystems of Tropical Asia (Collaborative study between Indonesia-Japan)

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1. Effects of land-use change on GHG emissions and major factors controlling GHG emissions and soil dynamics

1.1 Humid tropical forests in Jambi, central Sumatra

1.1.1. Long-term flux measurements of GHG from soils under 5 land-use patterns

1.1.2. Regional study on GHG fluxes from soils under different land-use patterns

1.2 GHG fluxes from Peatlands in Banjarmasin, south Kalimantan

2. Carbon budgets in a young secondary forest ecosystem suffered with the 1998 forest fires

2.1 CO_2 flux over the canopy in Samarinda

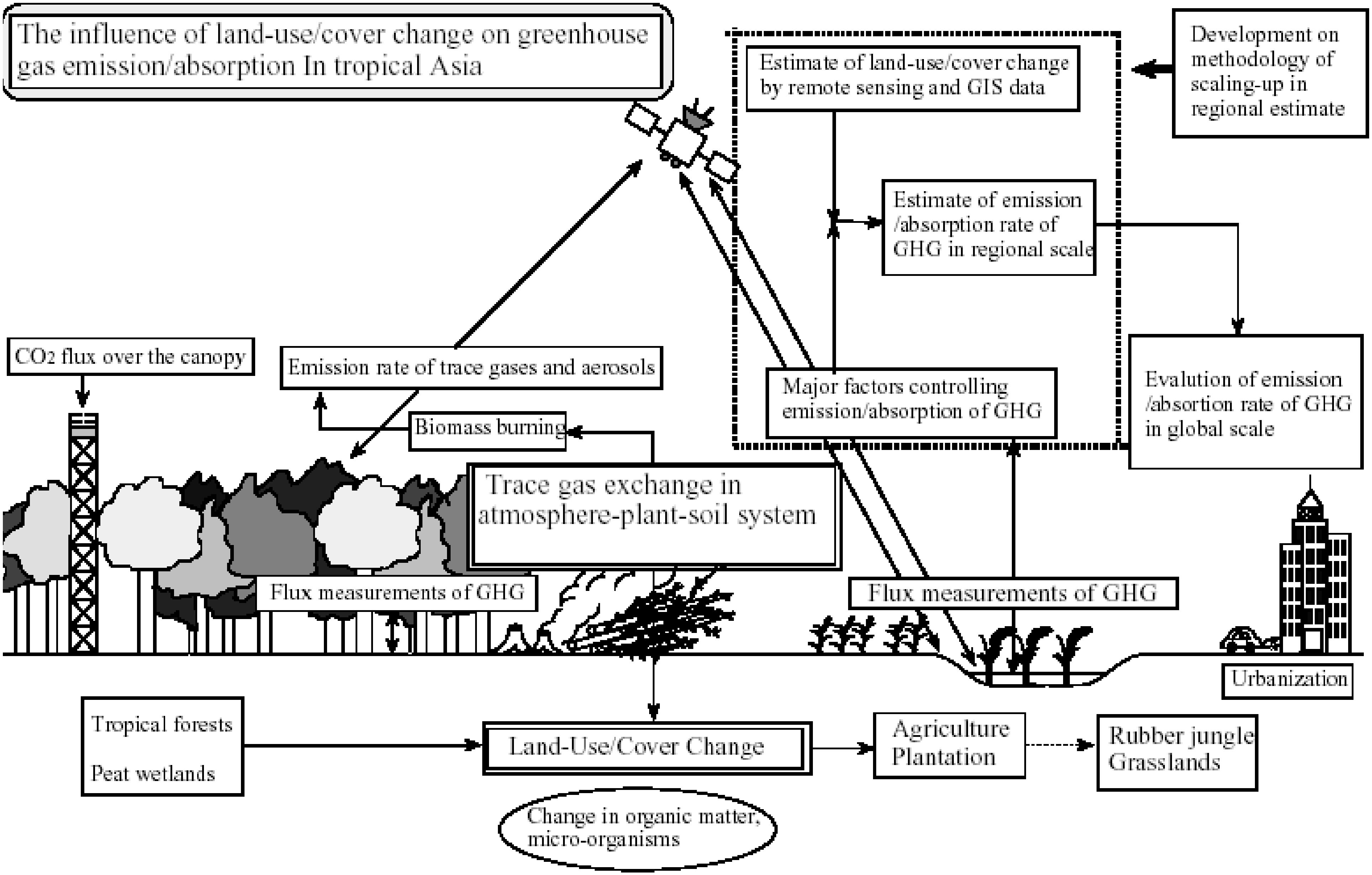
2.2 Long-term study on above-ground biomass in secondary forests

3. Monitoring of background CO_2 concentrations at a GAW station

4. Development of land-use database and of methodology of scaling up for regional estimate of GHG emissions

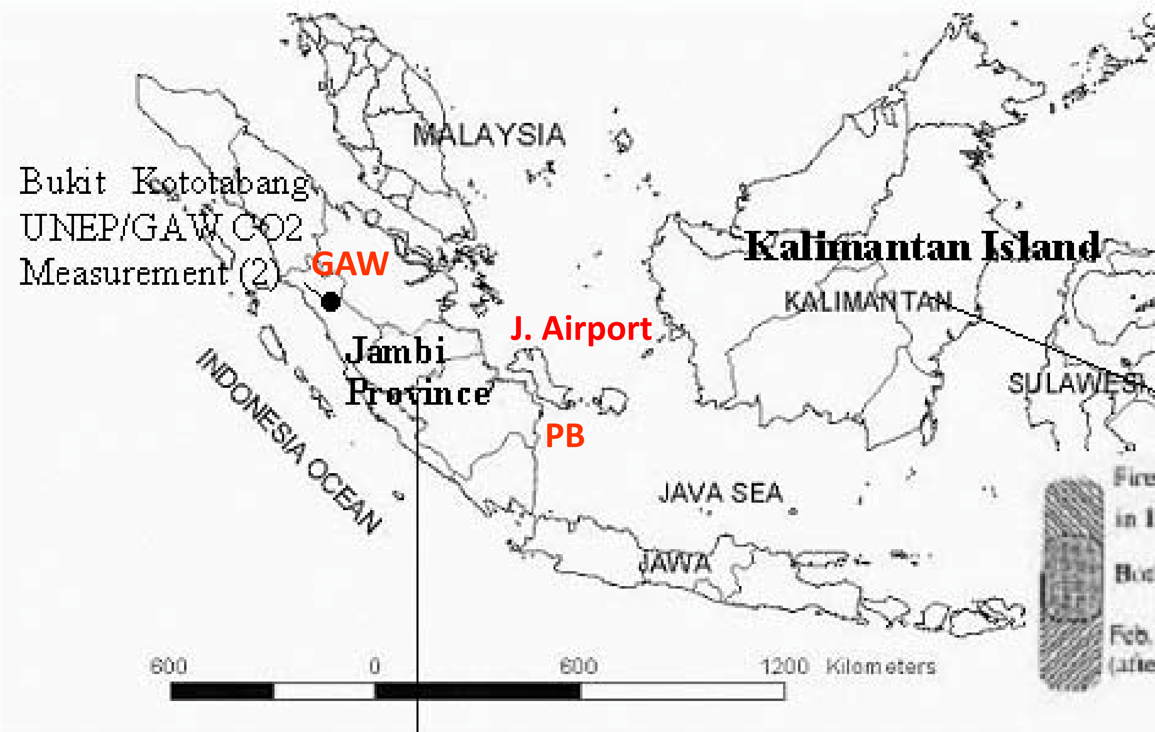
5. Trace gas and aerosol measurements emitted from biomass burning of forests and peatlands in tropical Asia

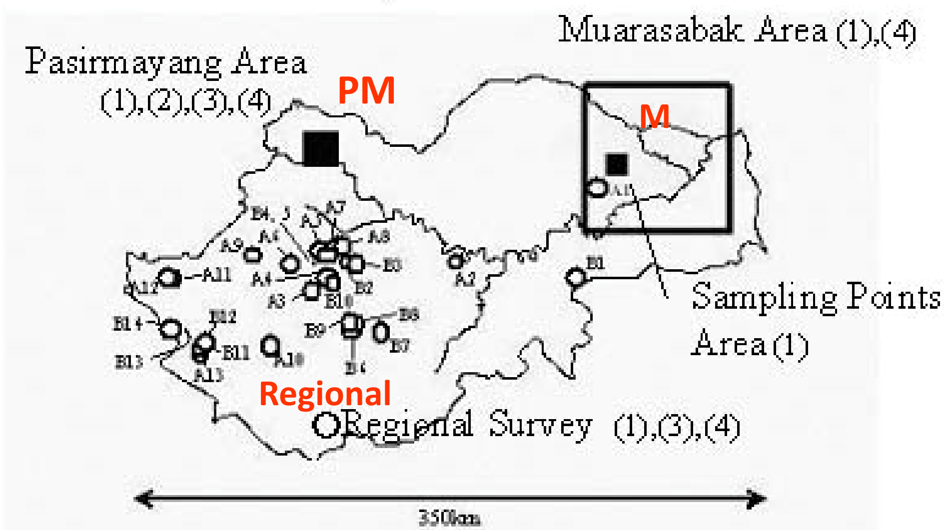
B-5


The influence of land-use/cover change on greenhouse gas emission/absorption In tropical Asia
Estimate of land-use/cover change by remote sensing and GIS data
Development on methodology of scaling-up in regional estimate
Estimate of emission /absorption rate of GHG in regional scale
CO2 flux over the canopy
Emission rate of trace gases and aerosols
Major factors controlling emission/absorption of GHG
Evalution of emission /absortion rate of GHG in global scale
Biomass burning
Trace gas exchange in atmosphere-plant-soil system
Flux measurements of GHG
Flux measurements of GHG
Urbanization
Tropical forests
Peat wetlands
Land-Use/Cover Change
Agriculture
Plantation
Rubber jungle
Grasslands
Change in organic matter, micro-organisms

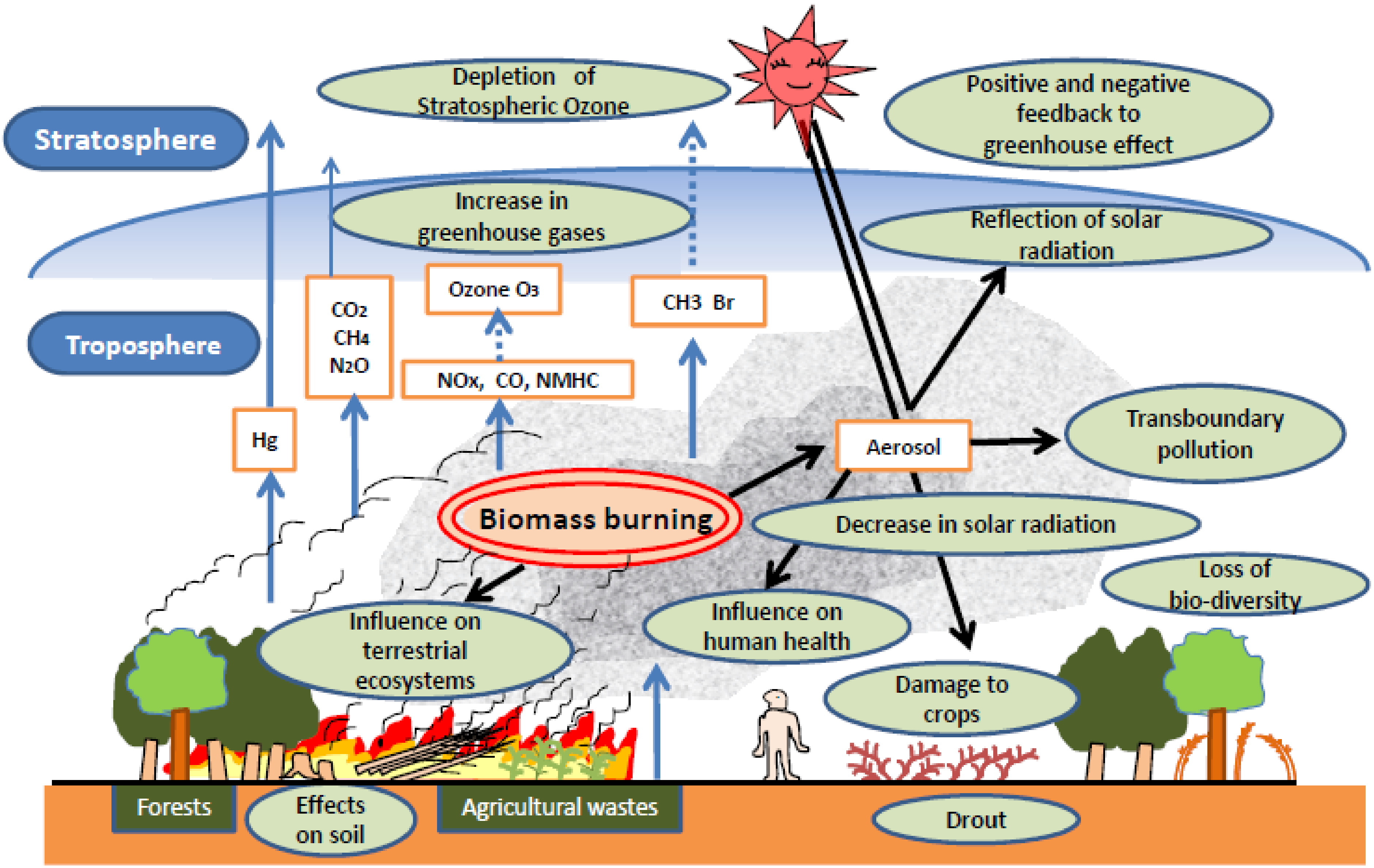
Location of field sites.

GHG emissions from Humid tropical forests:
Pasirmayang in Jambi
GHG emissions from Peatlands:
Muarasabak in Jambi, Banjarmasin in South K
Biomass burning experiment:
Palembang, Sumatra; Parang karaya, central K
Carbon budgets: Bukit Soeharto, Samalinda, i
Atmospheric CO_2 measurement:
GAW station in Bukit Kototabang, Sumatra

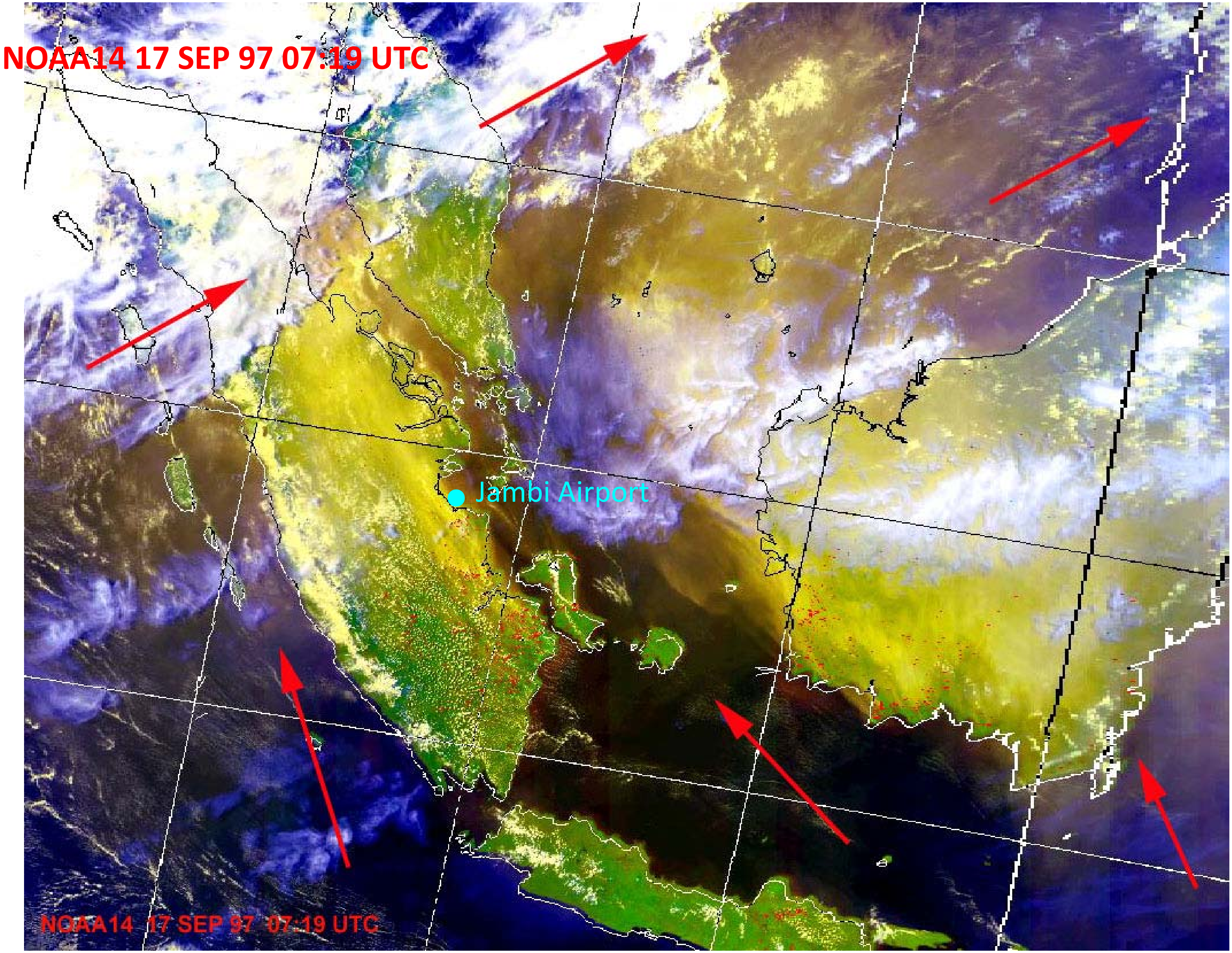




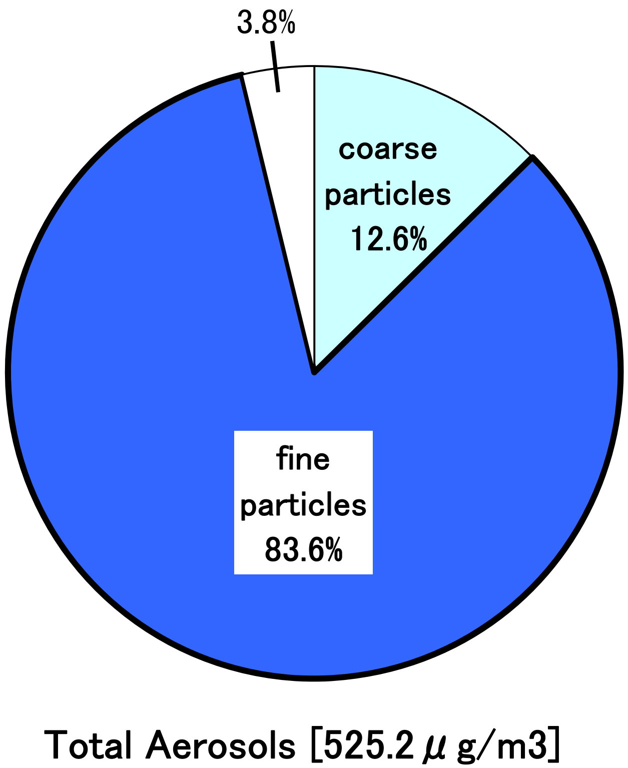
■ South Kalimantan
Peat Area Survey (1)

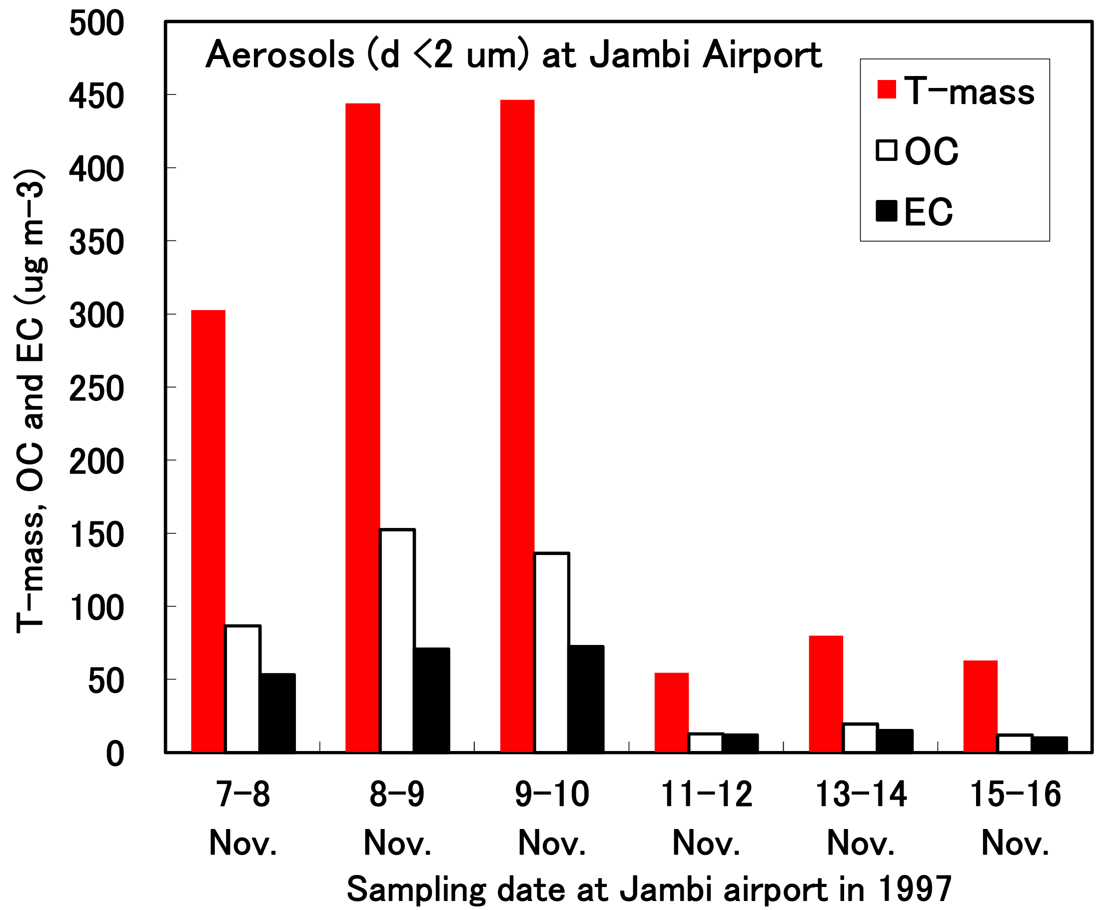


Impacts of biomass burning on local/regional/global environment

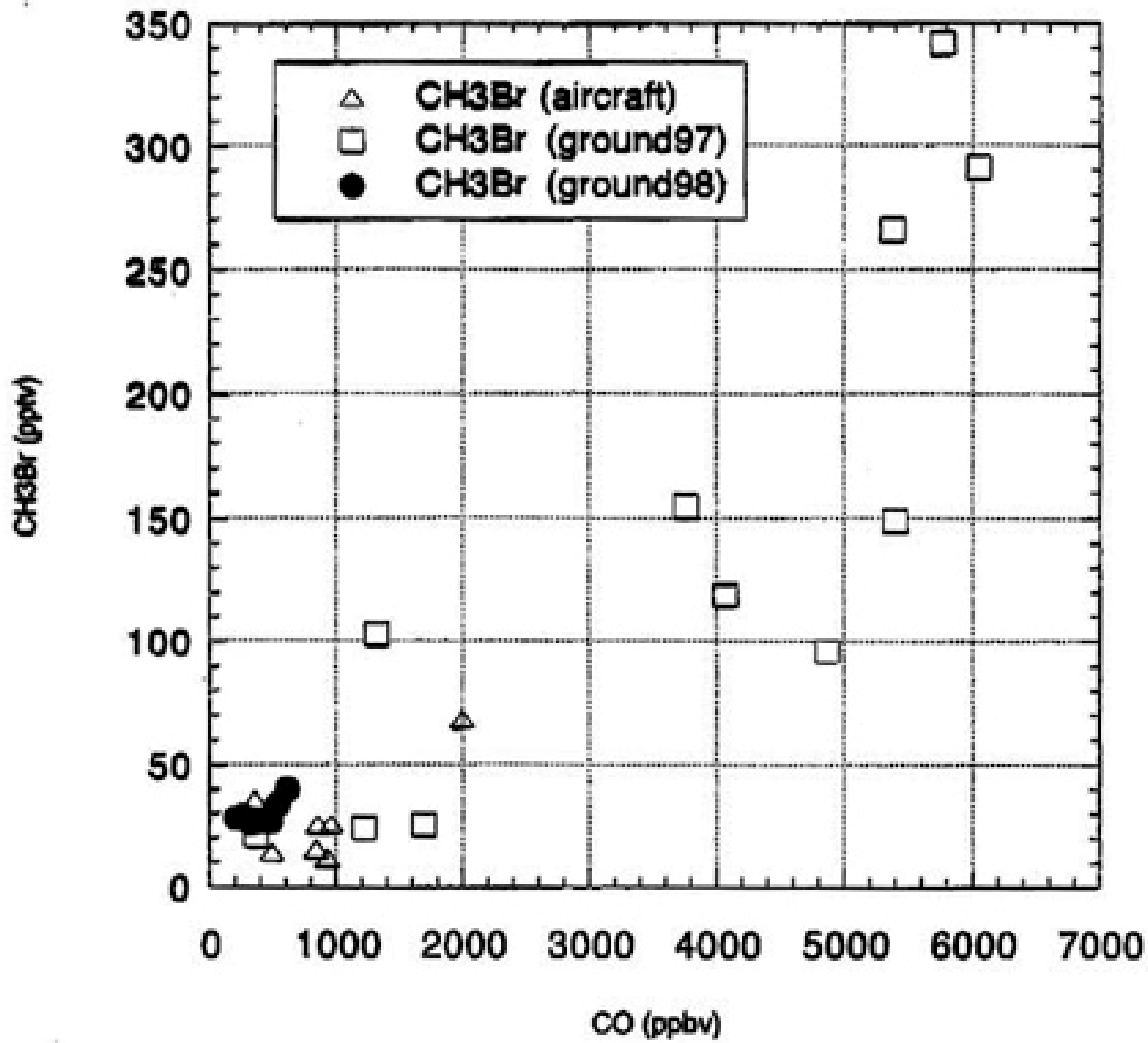


NOAA14 17 SEP 97 07:19 UTC
Jambi Airport
NOAA14 17 SEP 97 07:19 UTC





Aerosol Measurements at Jambi Airport, Sumatra, during the last period of Forest Fires (November 7-16, 1997)



Methyl bromide (CH3Br) and carbon monoxide (CO) concentrations by ground (and aircraft) measurements in the period of the forest fires (Oct.-Nov.1997) and of the non-forest fire period (Sep.1998)

Intensive field experiments on GHG emissions from soils in humid tropical forests In Jambi, Sumatra

1. Long-term measurements of GHG flux from 6 sites in Pasirmayang (Sep.1997-Mar.2002)

Period: Sep. 1997~Mar. 2002

Sites: primary forests (P1, P2)

logged-over forest (L2)

logged-over forests → clear-cut and burned → rubber plantation (L1)

(clear-cut and burned →) Gmelina Arborea → rubber plantation (O)

(bush → rubber agro-forest) 4-year plantation(R)

Measurements:

Gas flux: CO_2, CH_4, and N_2O fluxes from soils into the atmosphere

(3 replicates, every month, closed chamber method)

Soil gas : CO_2, CH_4, N_2O

Soil temperature, Soil moisture

Collection of soil samples:

analysis of physico-chemical properties of soils

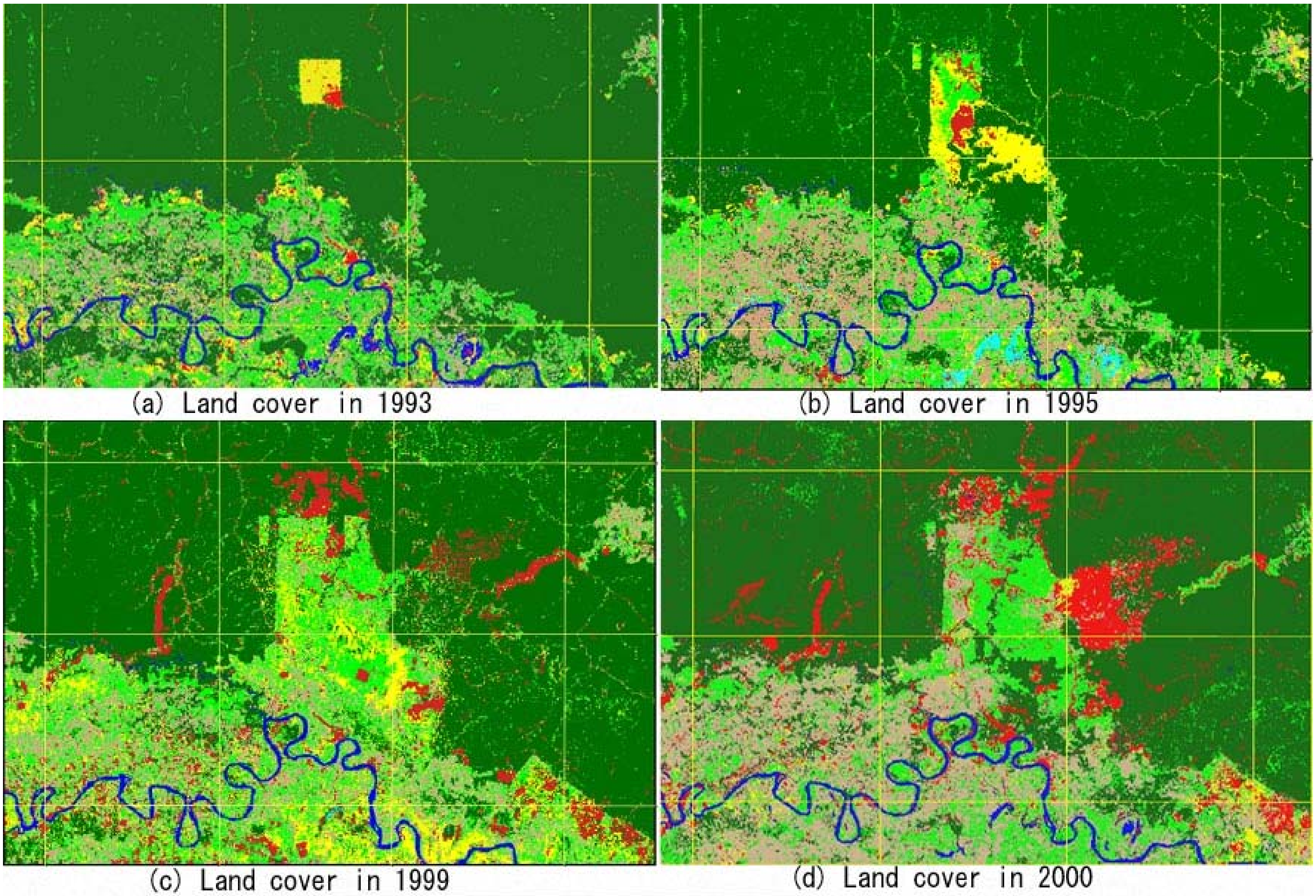
incubation experiments:

Gas production potential of soils

Nitrification and denitrification rates

Microbial analysis Isotopic analysis

2. Regional study on GHG fluxes from different ecosystems in Jambi, Sumatra

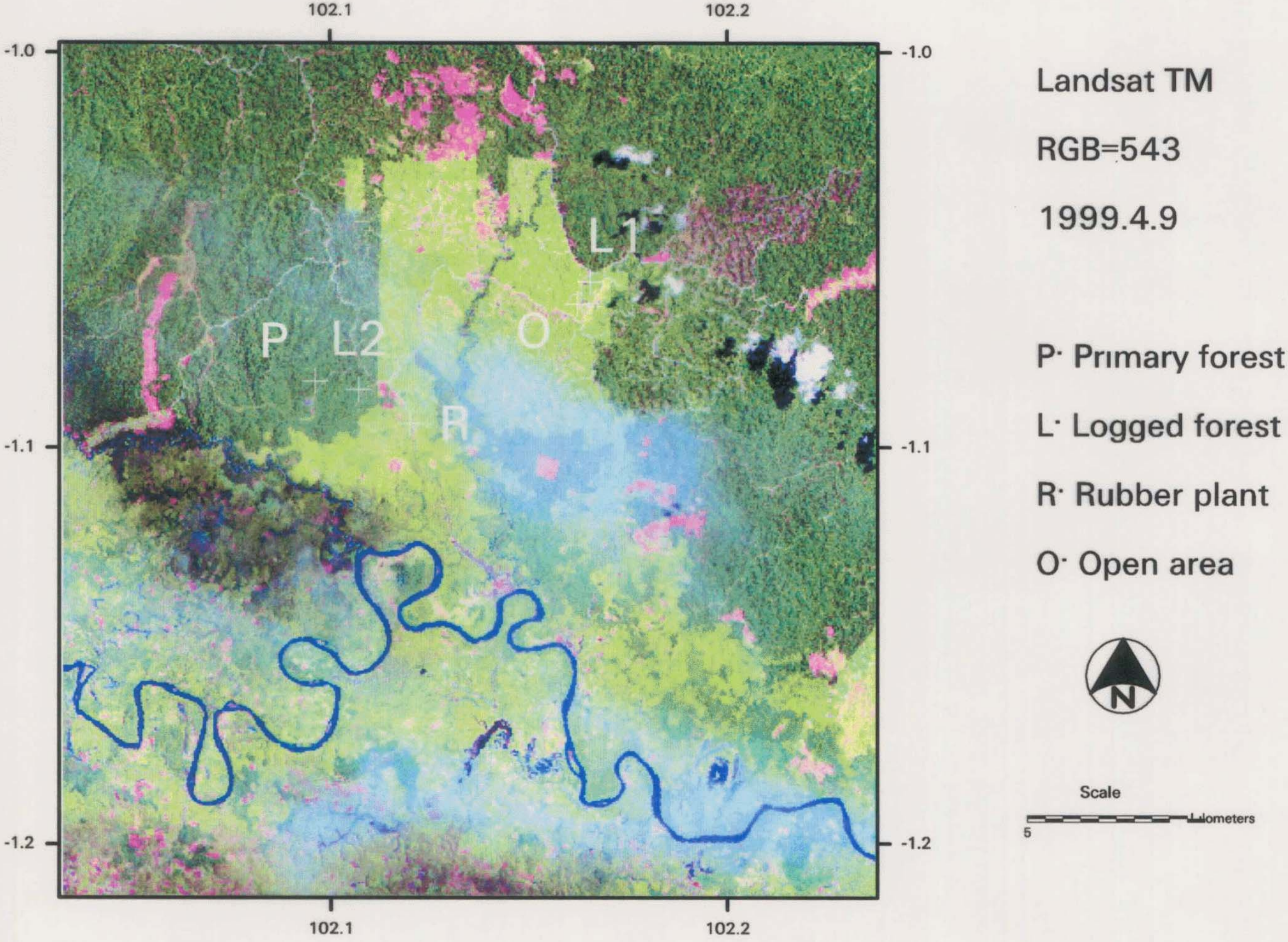


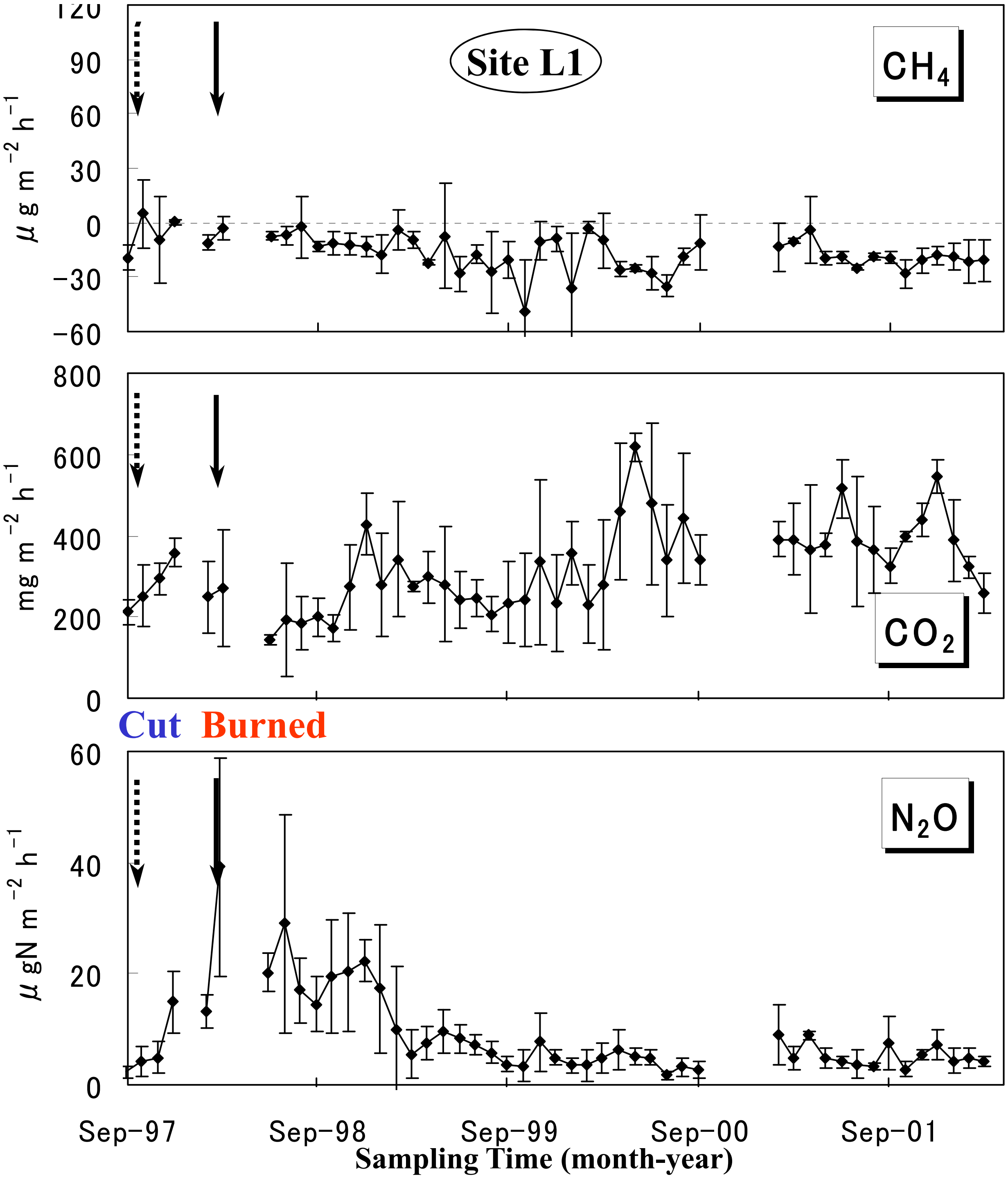
Land-use change in northern Jambi, including Pasirmayang Research Site by Landsat

The environmental conditions of 6 sites in Pasirmayang Research Site (PMRS) in Jambi, Sumatra

	Sampling site					
Conditions	P1	P2	L2	L1	O*	R**
Land-use (1997)	primary forest	primary forest	logged-over forest	logged-over forest	rubber plantation	rubber plantation
Location	1°05.16'S 102°05.70'E		1°5.24'S 102°6.59'E	1°3.81'S 102°9.75'E	1°3.66'S 102°9.68'E	1°5.65'S 102°7.21'E
Deforestation				clear-cut	clear-cut	clear-cut
period	(protected)	(protected)		(Sep.97-Feb. 98)	and	and
Burning				burned (Mar.'98)	(Aug.'96)	(Jul.'94)
(Re-)plantation				rubber	rubber	rubber
Vegetation	(note1)	(note2)				
Topography	gentle middle slope	gentle middle slope	gentle flat	gentle upper slope	flat top of hill	flat flat
Setting period	Jan.'97	Sep.'97	Sep.'97	Jan.'97	Jan.'97	Sep.'97

(note1): Vegetation of P1, P2 is a mixture of Shorea macrophylla, Dipterocarpus crimtus, etc.
(note2): Vegetation of L2 is a mixture of Shorea macrophylla, Scaphium macropodum,etc.
*O : A fast-growing tree species of Gmelina Arborea was planted but died soon. The young rubber was planted in 1998.
**R : The land was bush in 1994, clear cut in June 1994, burned in July 1994. Undergrowth was Alng-alang(*Imperata cylindrica*).

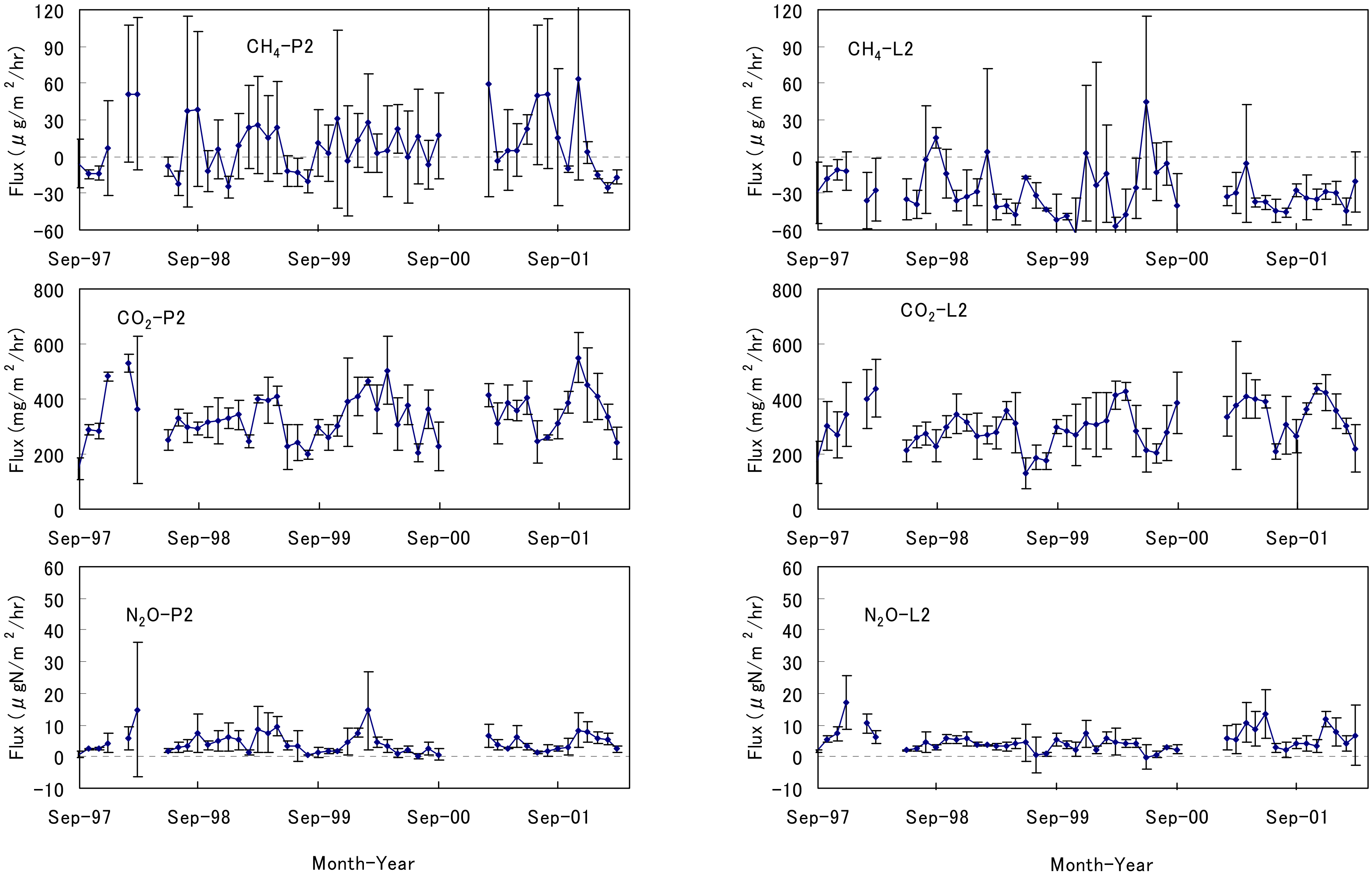

102.1
102.2
-1.0
-1.1
-1.2
P
L2
R
O
L1
Landsat TM
RGB=543
1999.4.9
P· Primary forest
L· Logged forest
R· Rubber plant
O· Open area
N
Scale
Kilometers
5



Just after clear-cut and burning, N_2O flux drastically increased, while CH_4 uptake gradually decreased.

Two years after cut and burning, N_2O and CH_4 fluxes were recovered to the same level as that before cut and burning.

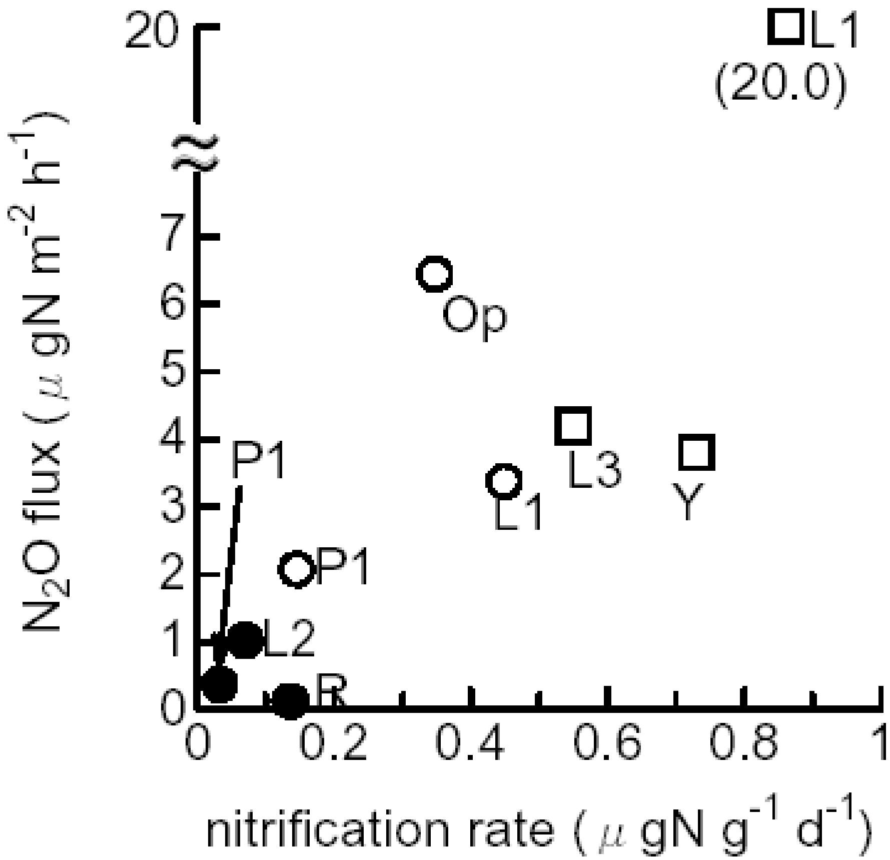
This study showed the very quick recovery of GHG fluxes, compared to that in pasture in central America where N_2O enhancement lasted for ten years.

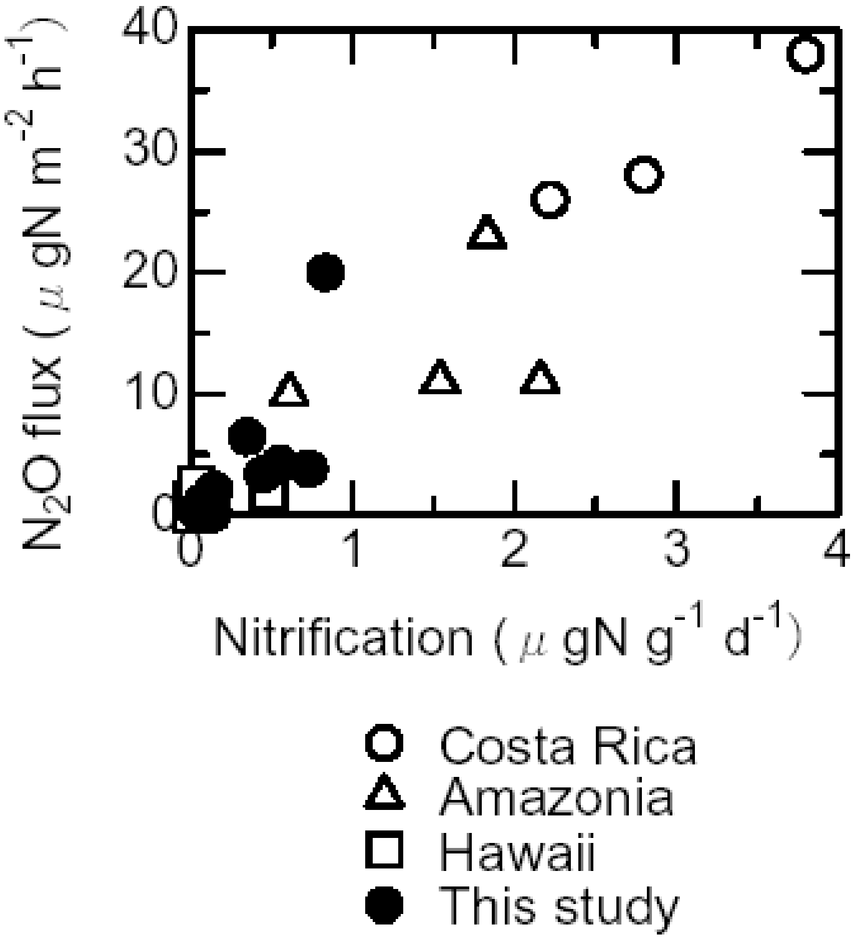


Long-term trends of CH4, CO2, and N2O fluxes at P2 (primary forest) and L2 (logged-over forest)

Note 1: CH4 flux was positive at P2

Note 2: Seasonal variation in CO2 and N2O fluxes





Relationship between N_2O fluxes in the field Experiment and nitrification rates of soils at 0-10cm depth in incubation experiments at PMRS.

Comparison of the ratio of nitrification rate to N_2O flux in this study with that in other ecosystems in the tropics (Ishizuka et al., 2002).

Nitrification is the major process of N_2O emission.

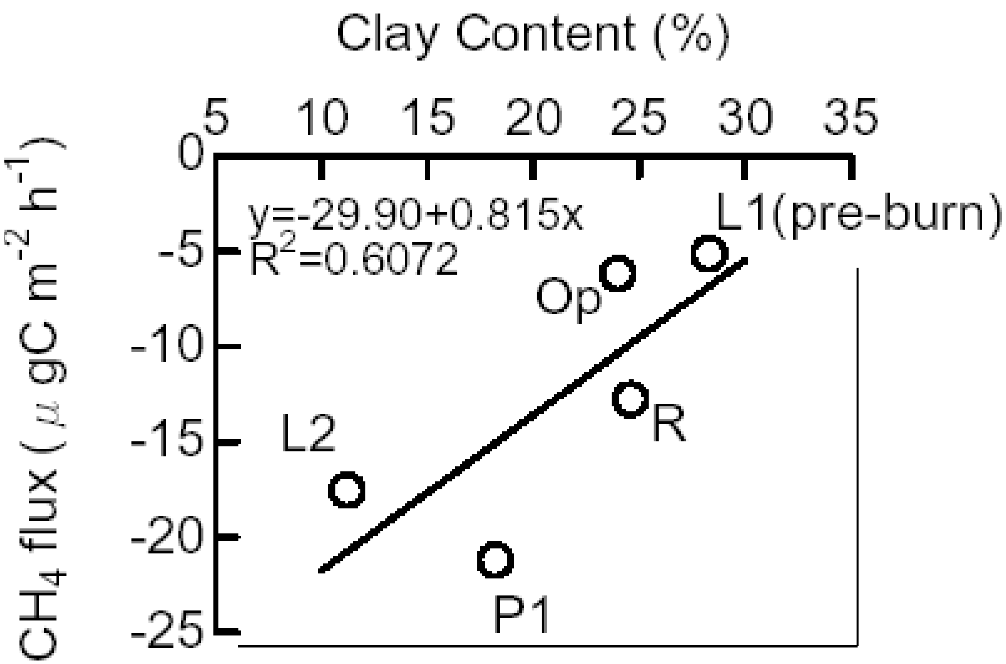
$F(N_2O)=0.176 + 9.55*N$ (F: $\mu gN\ m^{-2}\ h^{-1}$, N: $\mu gN\ g^{-1}\ d^{-1}$)

Global estimate of N_2O from tropical soils by IPCC were overestimated

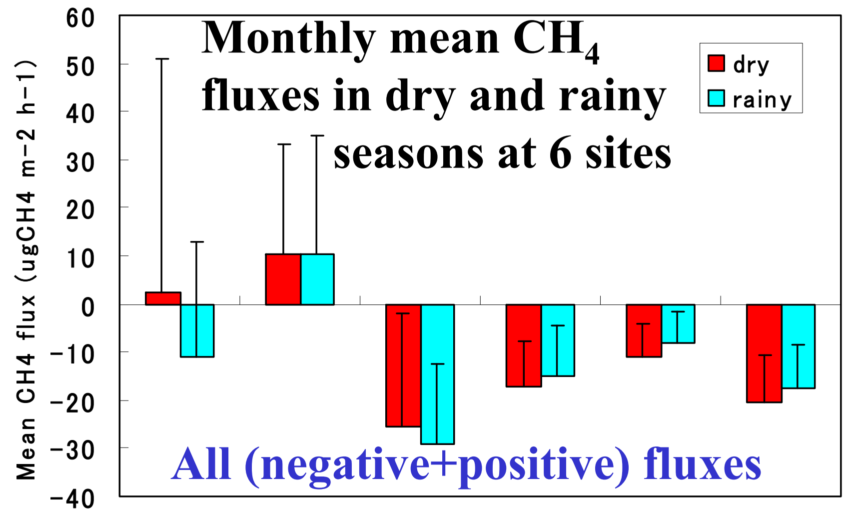
Annual N_2O emission rate: 0.228, 0.380, 0.427 kgN $ha^{-1}\ y^{-1}$ at P1, P2, L2 (this study)

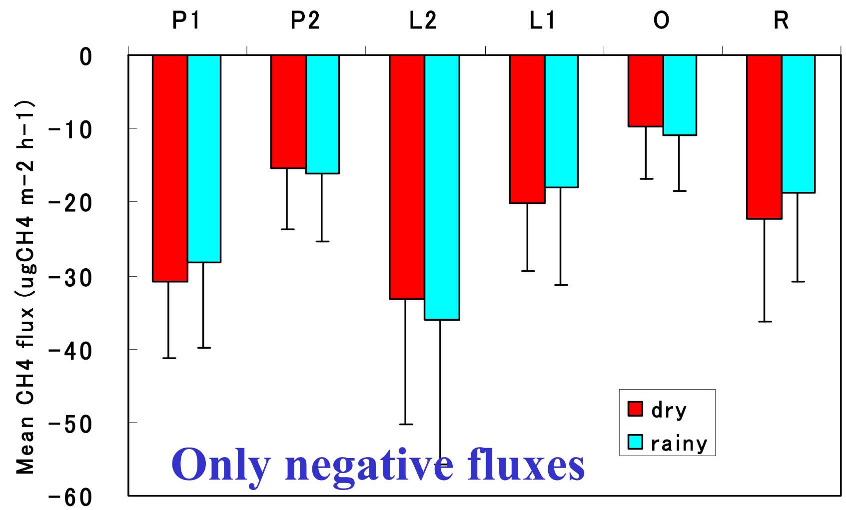
Range of N_2O emission in tropical rain forests: 0.01-7.68 kgN $ha^{-1}\ y^{-1}$ (Breuer et al., 2000)

Annual average N_2O emission from tropical rain forests:1.364 kgN $ha^{-1}\ y^{-1}$ (Potter et al., 1996)

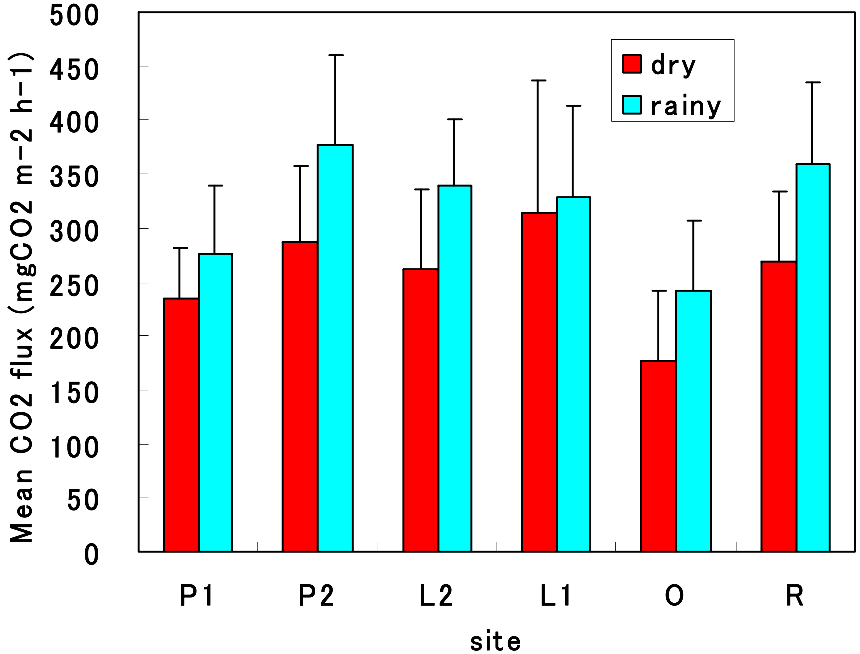


Relationship between CH_4 fluxes and clay contents of soils (%) in 0-10cm depth

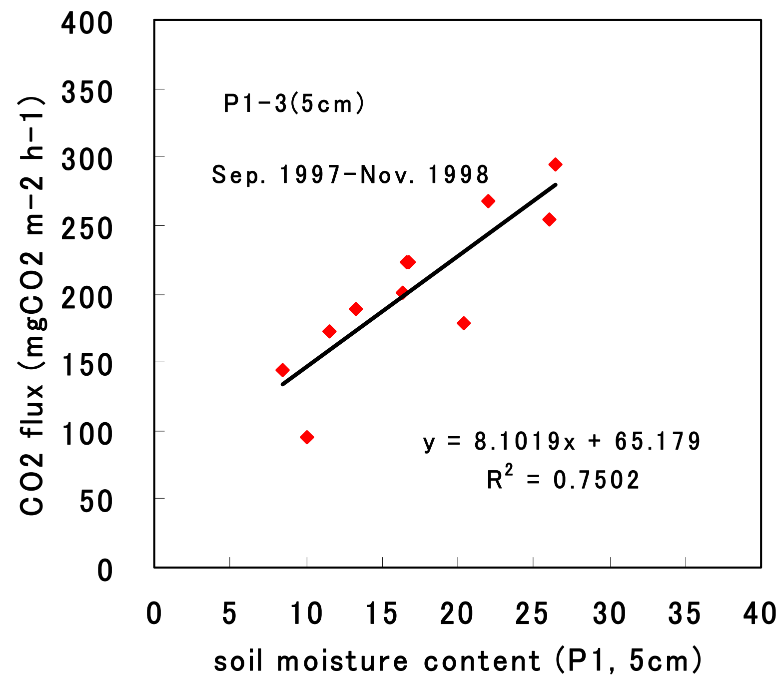




1. Monthly mean negative CH_4 fluxes at PM (-22.1, -11.8, -26.1 µgC m^{-2} h^{-1} at P1, P2, L2) were lower than those (-32.8±5.2 µgC m^{-2} h^{-1}) in other tropical rain forests (Potter et al., 1996).
2. Positive CH_4 fluxes were frequently measured, and could be derived from termites.
3. Monthly mean CH_4 fluxes with only negative flux were still affected by termites.
4. It strongly suggests that the real CH_4 oxidation potential of soils could be larger than the observed CH_4 uptake rates.



Mean CO_2 flux in dry and rainy seasons at 6 sites in PMRS



Relationship between CO_2 flux and soil moisture at 5cm depth at P1-3 during Sep.1997-Nov. 1998

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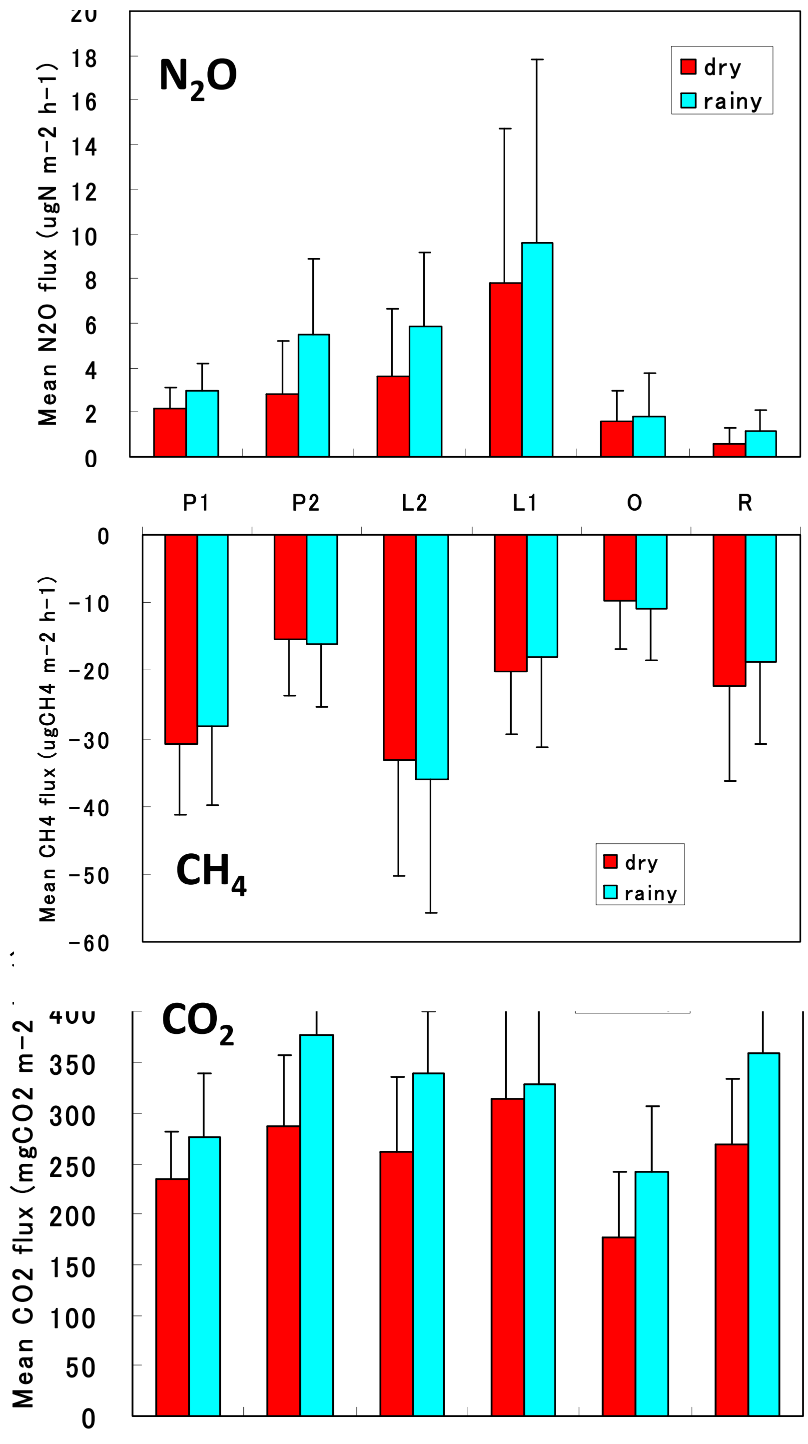
1. Monthly mean CO_2 fluxes at PMRS (70.4, 92.1, 83.2 mgC m^{-2} h^{-1} at P1, P2, L2) were lower than the averaged value in tropical and subtropical lowland moist forests (143 mgC m^{-2} h^{-1}) (Reich and Schlesinger, 1992) and comparable with relatively low CO_2 flux in tropical mountain areas (74-102 mgC m^{-2} h^{-1}) (Reich, 1998).
2. This relatively low CO_2 flux is possibly attributed to low vegetation biomass (170 Mg ha^{-1}), compared to a reasonable average of 300 Mg ha^{-1} for tropical rain forests (Laurance et al., 1998).
3 It makes the turnover rate of the carbon cycles of the ecosystems smaller in PMRS
4 The CO_2 fluxes at PMRS were lower than those of other ecosystems.

Monthly mean GHG fluxes (Sep. 97 - Mar. 02)

Land-use change

→



Change in GHG fluxes through spatial site distribution could be equivalent to real land-use change from P1 → L1 → R.

Conclusions

I. Humid tropical forest soils

1. N_2O emission was much lower than that in the other tropics.

   Annual N_2O emission in the tropics by IPCC was overestimated.

2. Nitrification was the major process of N_2O emission.
3. Heterotrophic nitrification is the main process of N_2O production.
4. CH_4 uptake was much lower than in temperate forests, and could be influenced by CH_4 emission by termites.
5. CO_2 emission was lower than in the other tropics, possibly due to low vegetation biomass.

2. Regional study on GHG fluxes from different ecosystems and soil types in Jambi, Sumatra

Period: Sep. 2001

Sites : 27 sites in Jambi

with 6 different land-use patterns

- **Forests (primary and logged-over)**
- **Cinnamon plantation**
- **Rubber plantation (young and old-10 years)**
- **Oil-palm plantation (young and old-10 years)**
- **Alang-alang grasslands**

with different soil types

(Udults, Ultisols and Entisols, Andisols)

Measurements:

- **Gas flux: CO_2, CH_4, N_2O (7 replicates)**
- **Soil gas : CO_2, CH_4, N_2O (0~30cm)**
- **Soil temperature, soil moisture**

Collection of soils:

- **Analysis of physical and chemical properties of soils**
- **Gas production potential of soils**
- **Nitrification and denitrification rates**
- **Microbial analysis**
- **Isotopic analysis**

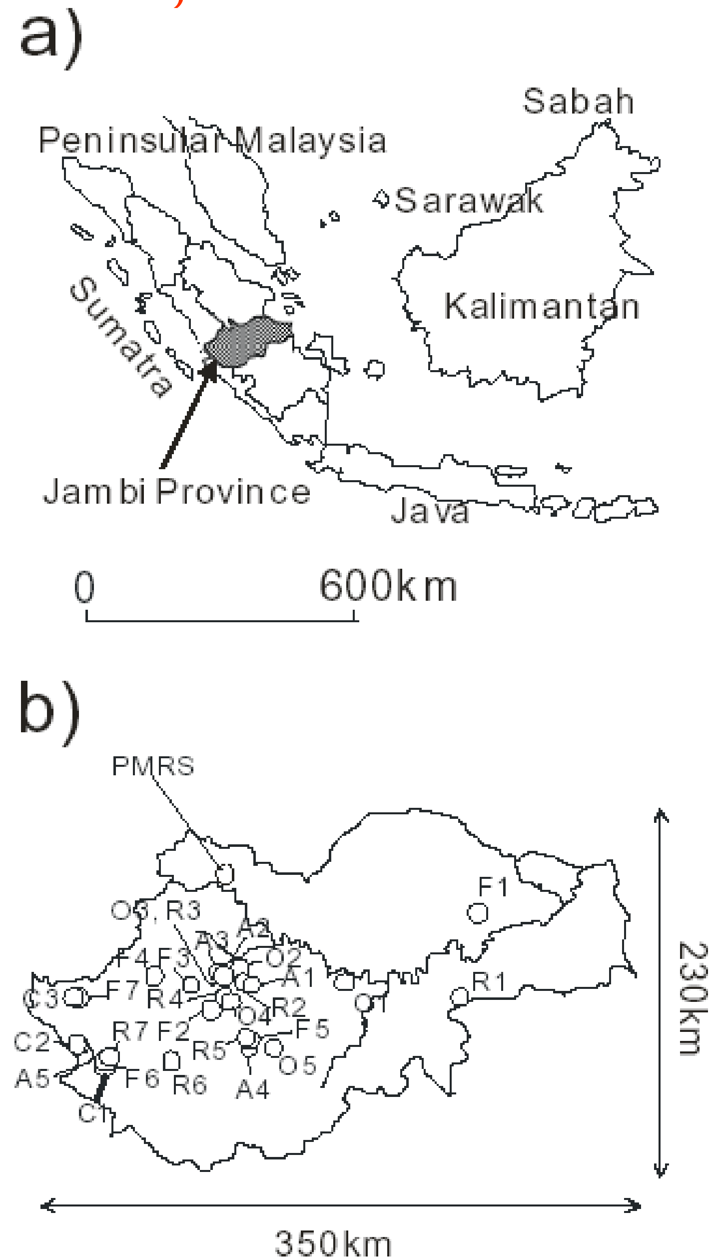


Table 2. Number of plots in each soil type and land-use

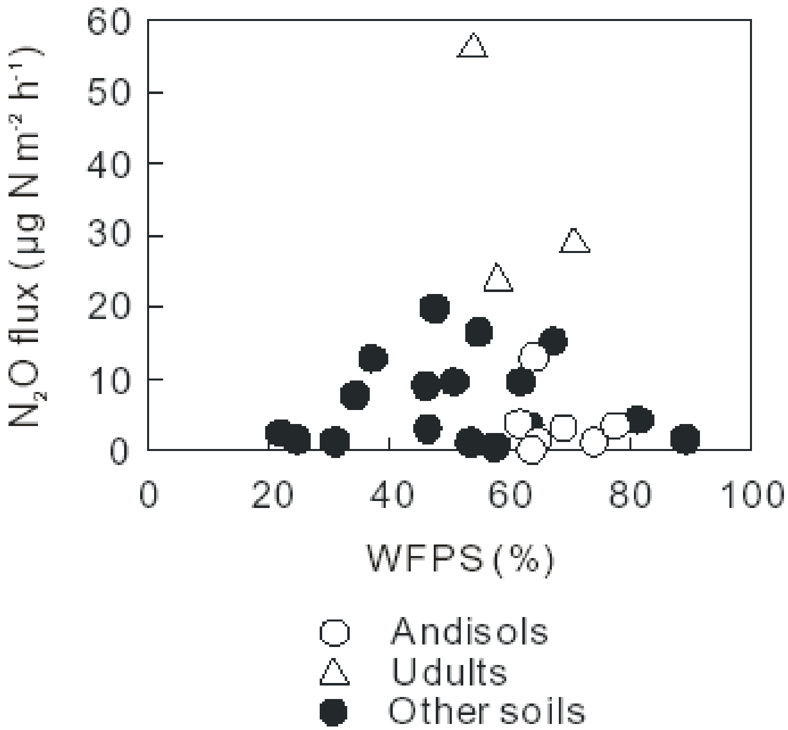
		land-use type[a]							
		F	C	oR	yR	oO	yO	A	total
soil type	Udults	1	0	1	0	0	1	0	3
	other Ultisols and Entisols	4	0	4	1	2	2	4	17
	Andisols	2	3	0	1	0	0	1	7
	total	7	3	5	2	2	3	5	27

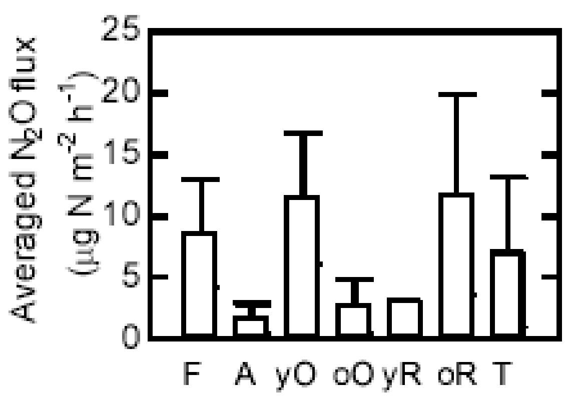
[a]see Table 1 about the land-use code

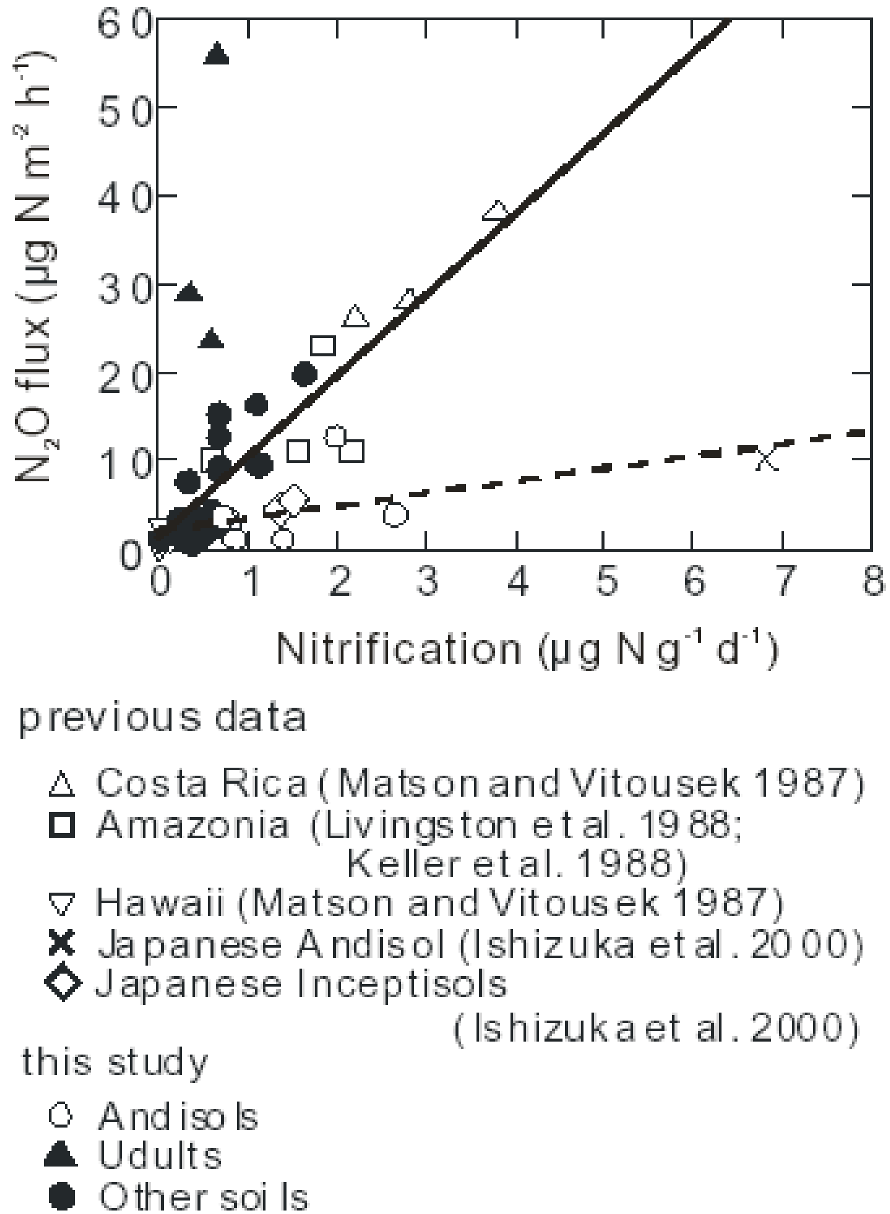
Land-use type

F : Forests (primary and logged-over)
C : Cinnamon plantation
yR, oR: Rubber plantation (young and old----10 years)
yO, oO: Oil-palm plantation (young and old----10 years)
A :Alang-alang grasslands

with different soil types (Udults, Ultisols and Entisols, Andisols)

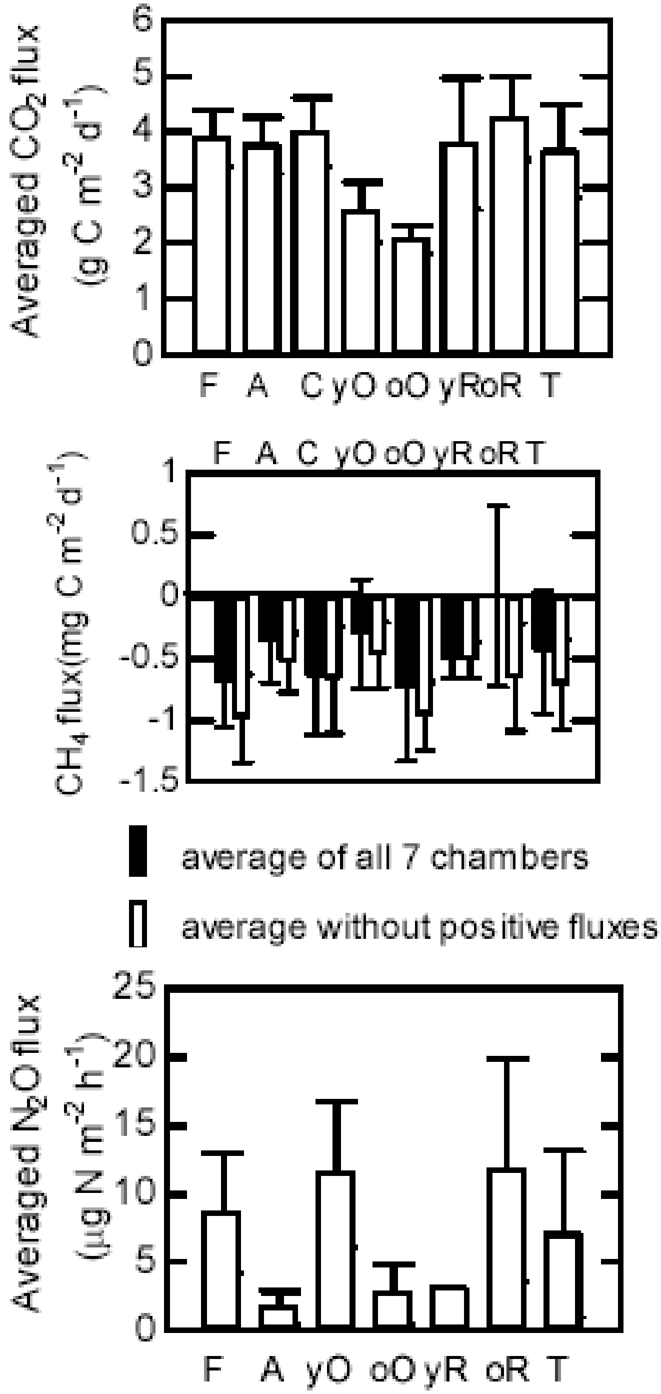






N_2O flux was affected by land-use pattern
N_2O flux from Alang-alang grasslands was lowest

In Andisols, the nitrification rates were only 1/7 of that in other soil types
N_2O flux was also affected by soil types



Averaged CO2 flux (g C m-2 d-1)
6
5
4
3
2
1
0
F A C yO oO yR oR T
F A C yO oO yR oR T
CH4 flux(mg C m-2 d-1)
1
0.5
0
-0.5
-1
-1.5
average of all 7 chambers
average without positive fluxes
Averaged N2O flux (µg N m-2 h-1)
25
20
15
10
5
0
F A yO oO yR oR T

STUDY ON LAND-USE/ LAND COVER CHANGE (LUCC) AND GREEN HOUSE GAS (GHG) EMISSION

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Daniel **MURDIYARSO***, Upik **ROSALIN**A* , Shigeto **SUDO****,

*** Bogor Agriculture University**
**** National Institute of Agro-Environmental Sciences**

OBJECTIVES :

- **DEVELOPMENT OF LAND-USE/ COVER SPATIAL DATA FROM REMOTELY SENSED IMAGERY PHOTOGRAPHS AND DIGITAL DATA**
  - **1986 – 1992 (JAMBI PROVINCE) : PHOTOGRAPHS, VISUAL INTERPRETATION**
  - **1993 – 2000 (PASIR MAYANG) : DIGITAL INTERPRETATION**
  - **1989,1992,1998 (MUARA SABAK): DIGITAL INTERPRETATION**
- **QUANTIFYING LUCC :**
  - **1986 – 1992 (JAMBI PROVINCE)**
  - **1993 – 2000 (PASIR MAYANG)**
  - **1989, 1992, 1998 (MUARA SABAK)**
- **QUANTIFYING ABOVEGROUND BIOMASS LOSS**
- **ESTIMATION OF REGIONAL GHG EMISSION FROM SOIL UNDER DIFFERENT LAND-USE/COVER (PASIR MAYANG)**
- **ESTIMATION OF REGIONAL GHG EMISSION FROM BIOMASS BURNING (MUARA SABAK)**

1. **Aboveground carbon stock data**

   Information of aboveground carbon stock is derived from the result of field measurements of above ground biomass conducted by Center for Tropical Biology, Bogor-Indonesia, and Alternative Slash and Burn project conducted by International Center for Agroforestry Research (ICRAF)

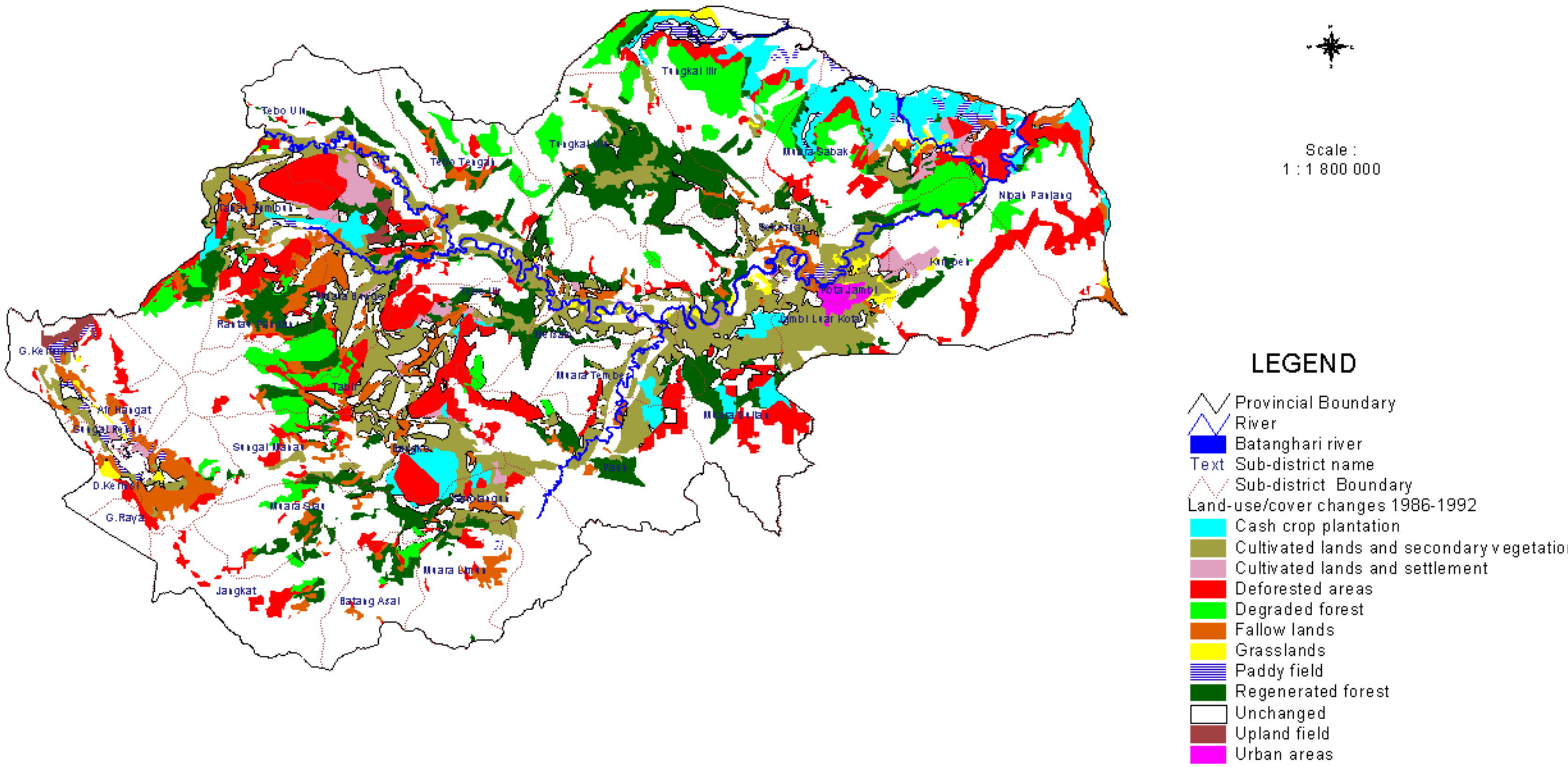
2. **Soil Greenhouse gases flux measurement**

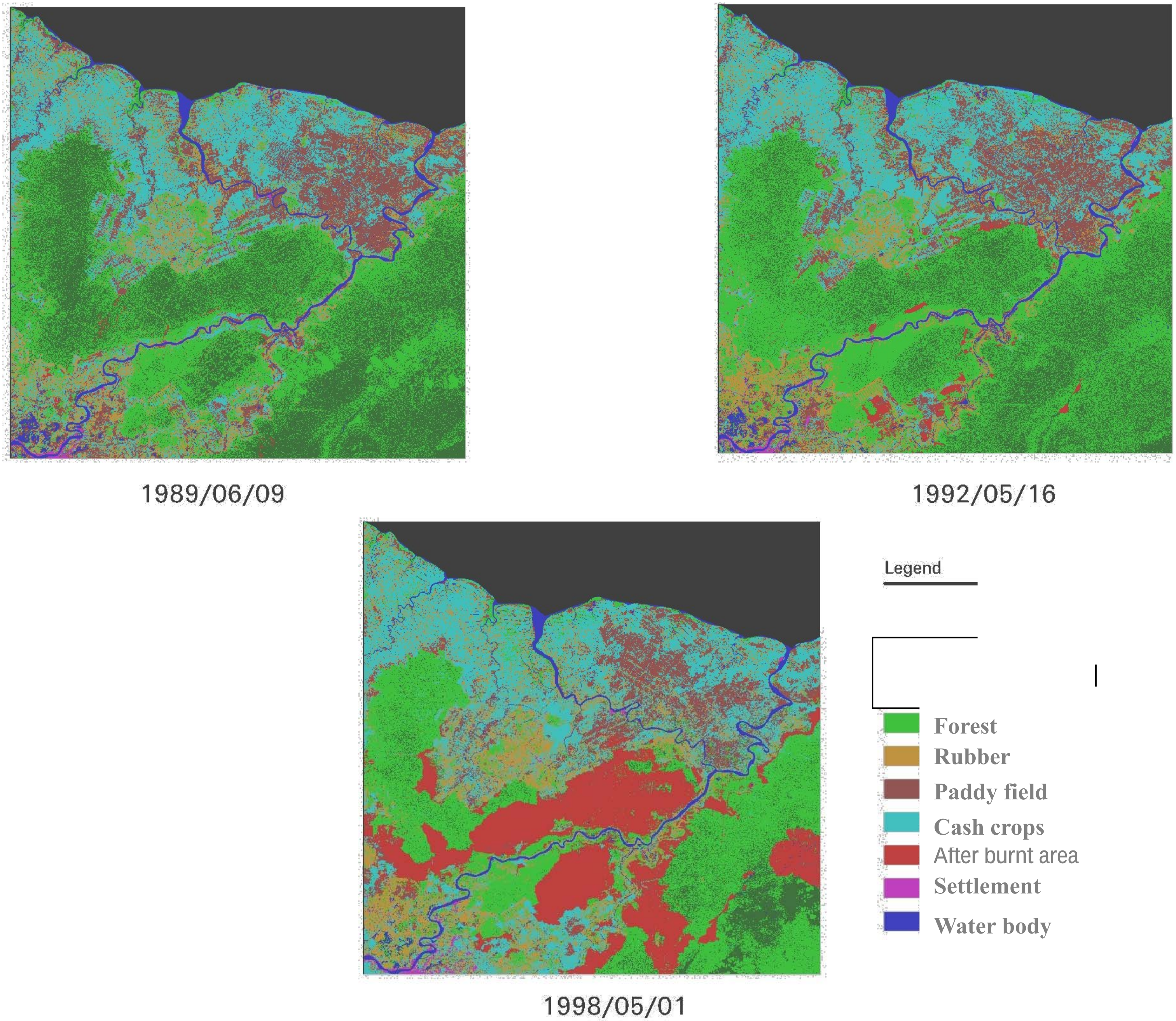
   Soil GHG emission were conducted by Impact Center of South East Asia, National Institute of Agro-environmental Sciences, Japan; Forestry and Forest Product Institute, Japan; and National Institute for Resources and Environment, Japan.

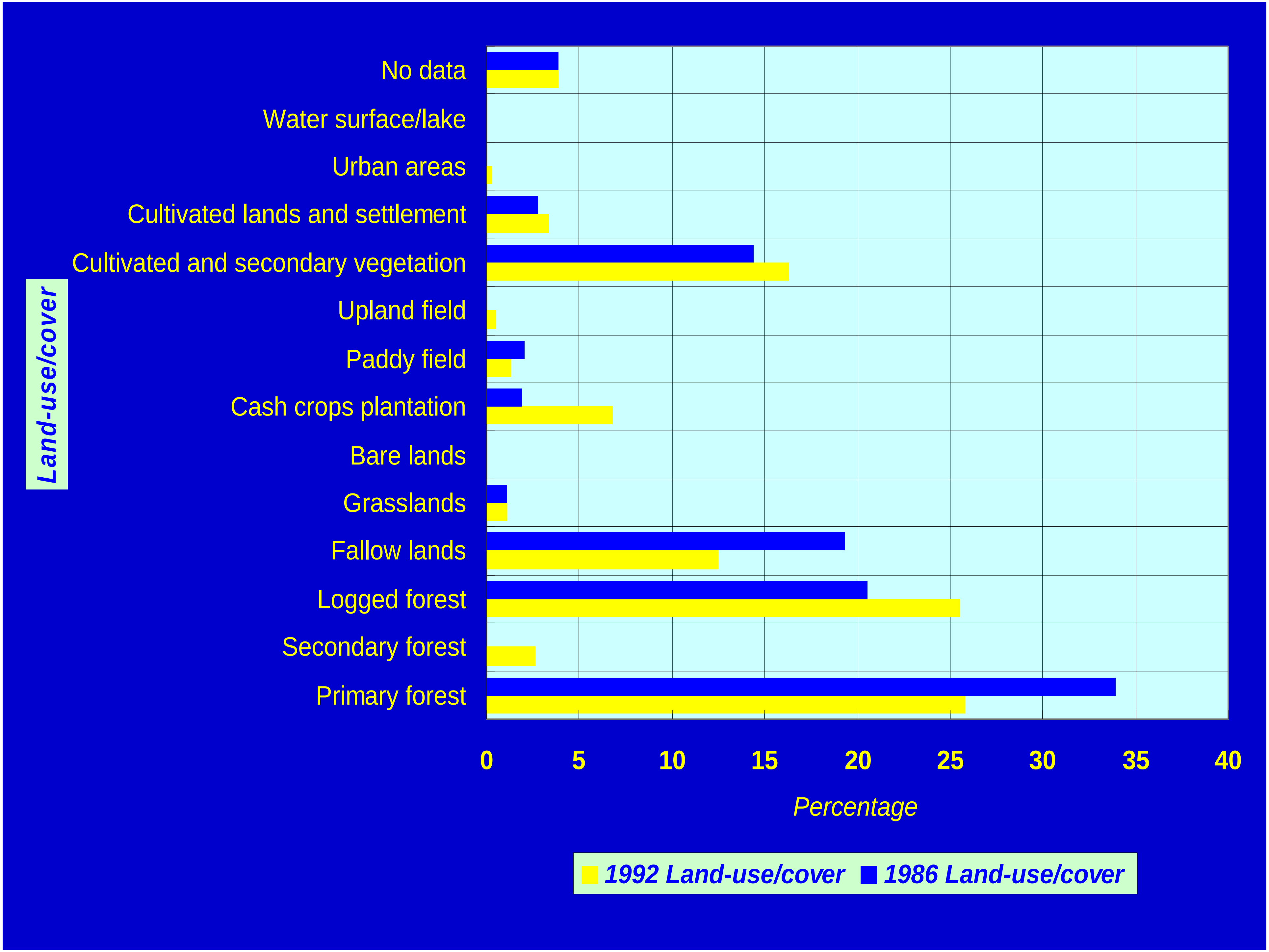
3. **Emission Ratio of Biomass Burning**

   Information of on-site burning emission ratio was derived from field measurement conducted in Sumatra-Indonesia, by National Institute for Resources and Environment, Japan and Fac. Forestry of IPB-Indonesia

Land-use/land cover changes between 1986 and 1992




1989/06/09
1992/05/16
1998/05/01
Legend
Forest
Rubber
Paddy field
Cash crops
After burnt area
Settlement
Water body


No data
Water surface/lake
Urban areas
Cultivated lands and settlement
Cultivated and secondary vegetation
Upland field
Paddy field
Cash crops plantation
Bare lands
Grasslands
Fallow lands
Logged forest
Secondary forest
Primary forest
Land-use/cover
0
5
10
15
20
25
30
35
40
Percentage
1992 Land-use/cover
1986 Land-use/cover

Land-use/Land cover	Carbon Dioxide (ton/hour)		Nitrous Oxide (kg/hour)		Methane (kg/hour)	
	1993	2000	1993	2000	1993	2000
Logged forest	233.467	178.482	7.102	5.429	-9,496.294	-7,259,752
Bush/Shrubs (fallow lands)	58.156	67.100	2.000	2.307	-4.406	-5,084
Rubber and Secondary vegetation (Rubber jungle)	30.348	75.917	1.301	3.254	-1.282	-3,206
Grasslands	18.870	8.724	0.344	0.159	0.000	0,000
Bare lands	6.085	45.863	0.131	0.987	-72.252	-544,554
Total	346.927	376.085	10.878	12.136	-9,574.234	-7,812,596

To estimate carbon released directly from forest fire into the atmosphere, we make some assumption as follows:

50% of biomass of forest were removed from the site before forest fire. This is due the fact that commercial logs were already harvested.

Emission ratio per CO_2 of secondary forest fire for CO, CH_4, N_2O, CH_3Cl, CH_3Br and CH_3I are 0.265, 0.0392, 0,00582, 0, 0 and 0, respectively

Gas conversion ratio from dry matter C to CO_2 is 0.5

GHG EMISSION FROM BIOMASS BURNING

6 345 545 TON CO_2

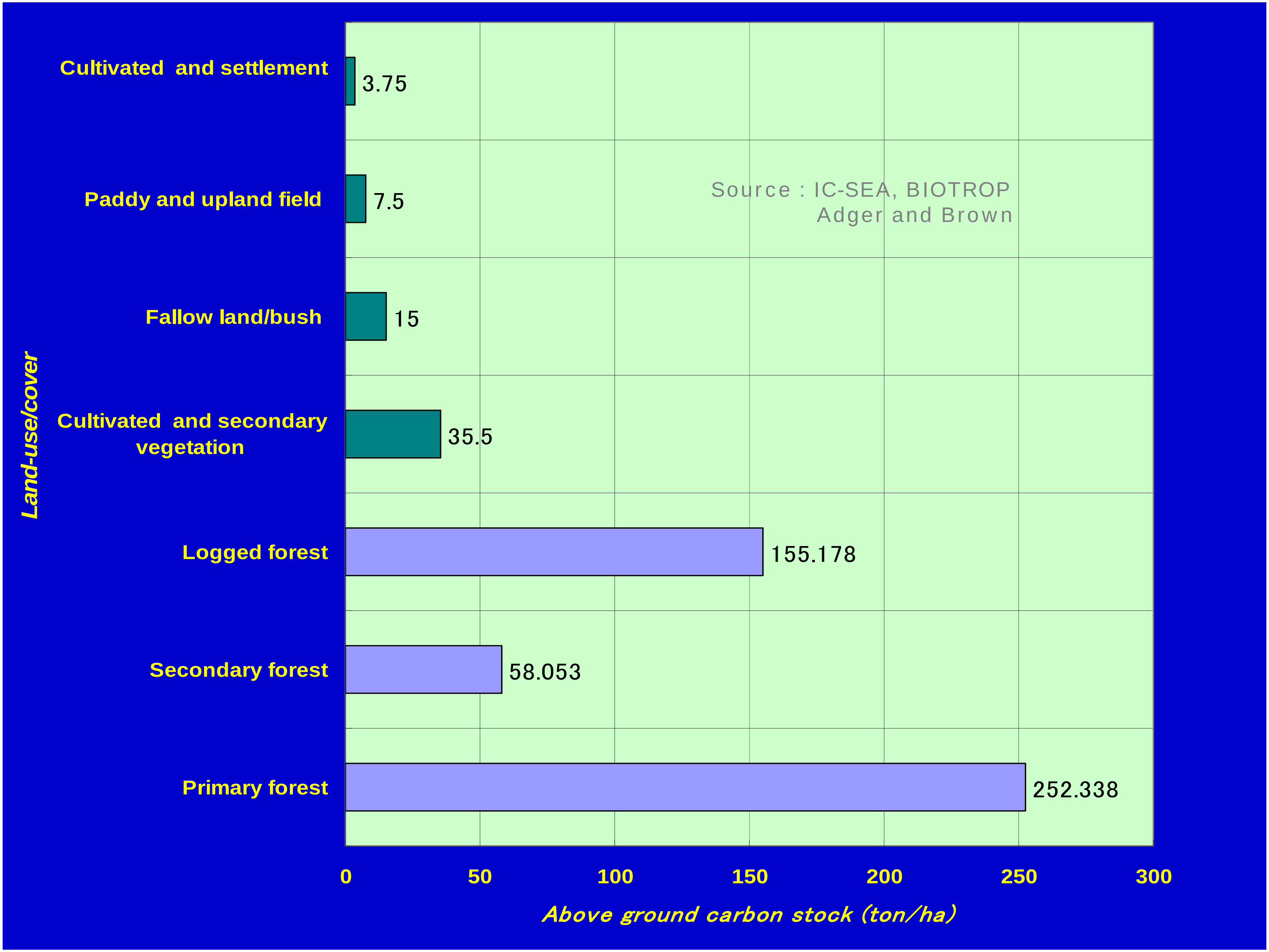
802.40 TON CH_4

119.13 TON N20

840 784.71 TON CO

Thank you very much for your attention.

Thank so much to many researchers in Indonesia for productive collaboration for a long time.


Cultivated and settlement
3.75
Paddy and upland field
7.5
Fallow land/bush
15
Cultivated and secondary vegetation
35.5
Logged forest
155.178
Secondary forest
58.053
Primary forest
252.338
Source : IC-SEA, BIOTROP
Adger and Brown
0
50
100
150
200
250
300
Above ground carbon stock (ton/ha)
Land-use/cover

Land-use/Land cover	Carbon stock per ha (ton C)	Area (ha)		Total above ground Carbon stock in (ton C)	
		1993	2000	1993	2000
Logged forest	155,2	66,273.25	50,664.75	10,285,608.40	7,863,169.20
Bush/Shrubs (fllow land)	15	10,014.50	11,554.75	150,217.50	173,321.25
Rubber and sec. vegetation	35,5	6,407.75	16,029.25	227,475.13	569,038.38
Grasslands	1,35	3,126.25	1,445.25	4,220.44	1,951.09
Barelands	0	973.75	7,339.00	0	0
Total		86,795.50	87,033.00	10,667,521.46	8,607,479.91

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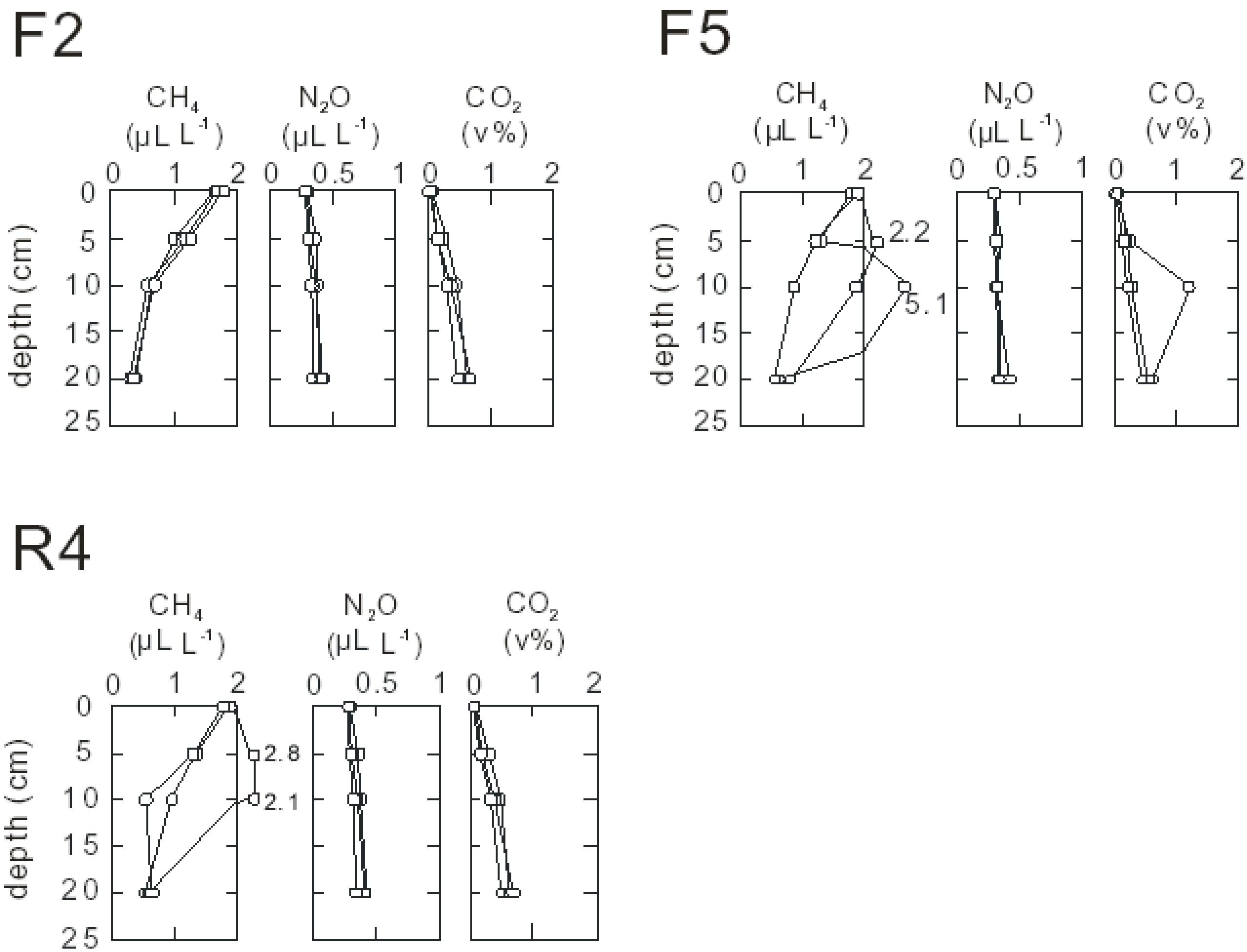
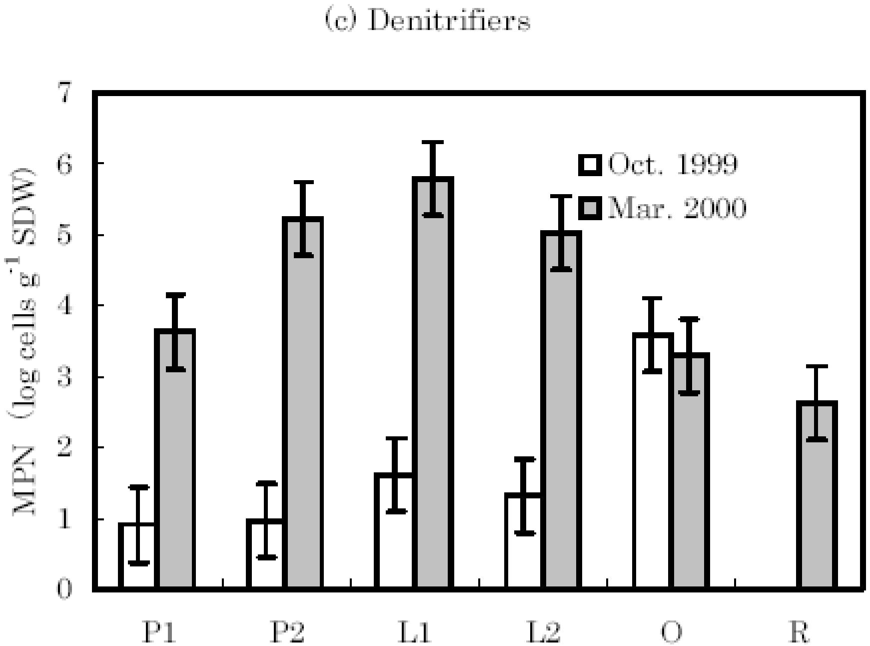
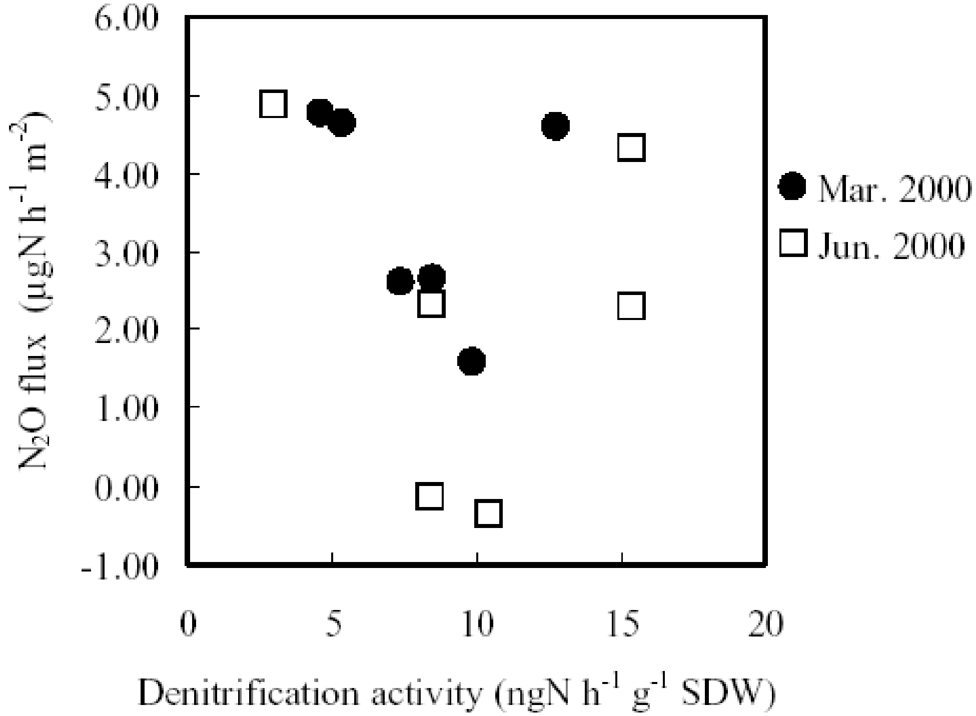
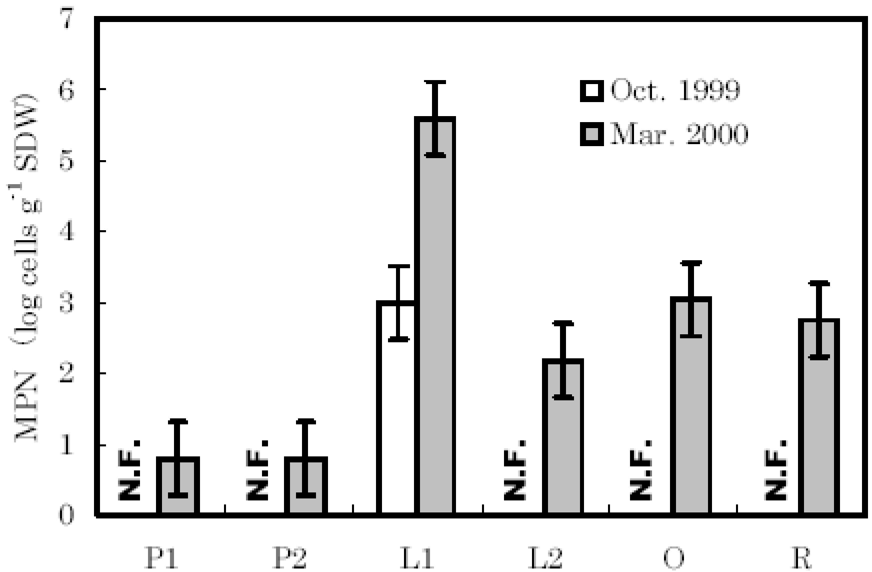

F2
F5
R4
CH_4 (μL L^{-1})
N_2O (μL L^{-1})
CO_2 (v%)
depth (cm)
0 1 2
0 0.5 1
0 5 10 15 20 25
2.2
5.1
2.8
2.1

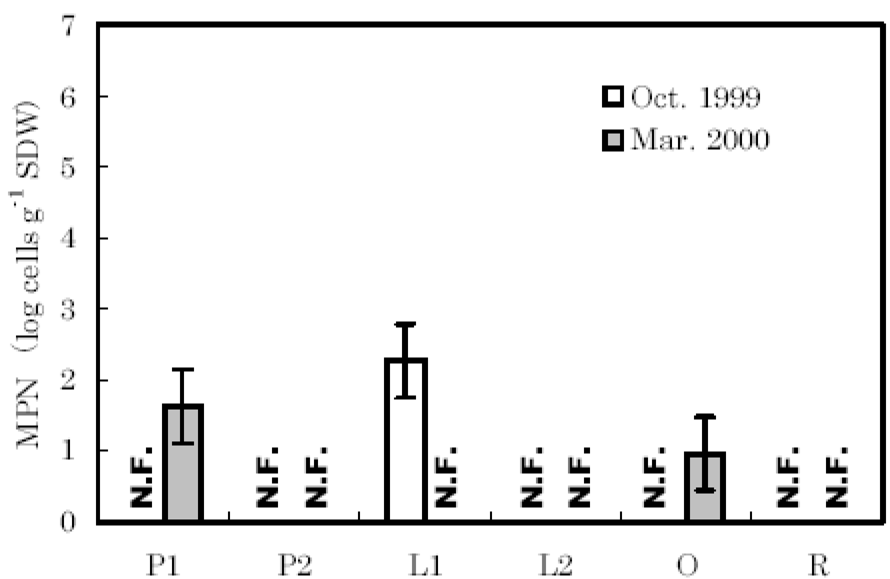

(c) Denitrifiers
Oct. 1999
Mar. 2000
MPN (log cells g-1 SDW)
P1
P2
L1
L2
O
R


N2O flux (µgN h-1 m-2)
Mar. 2000
Jun. 2000
Denitrification activity (ngN h-1 g-1 SDW)

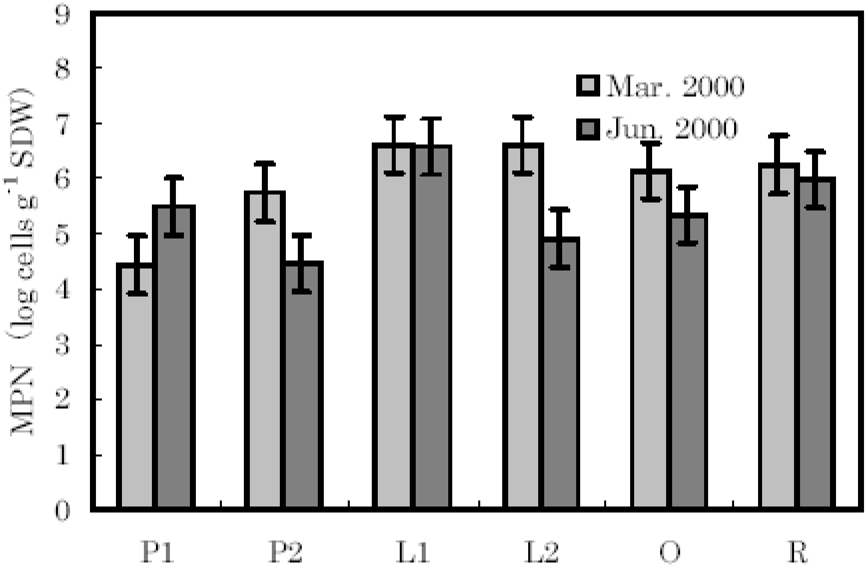
(b) Autotrophic nitrite oxidizers



(a) Autotrophic ammonia oxidizers



(d) Heterotrophic nitrifiers



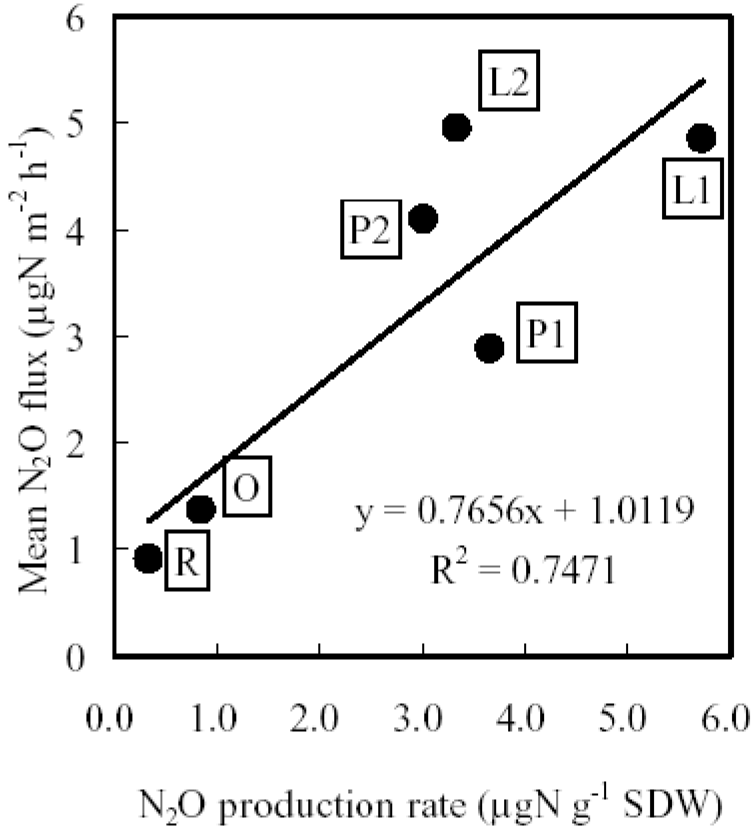
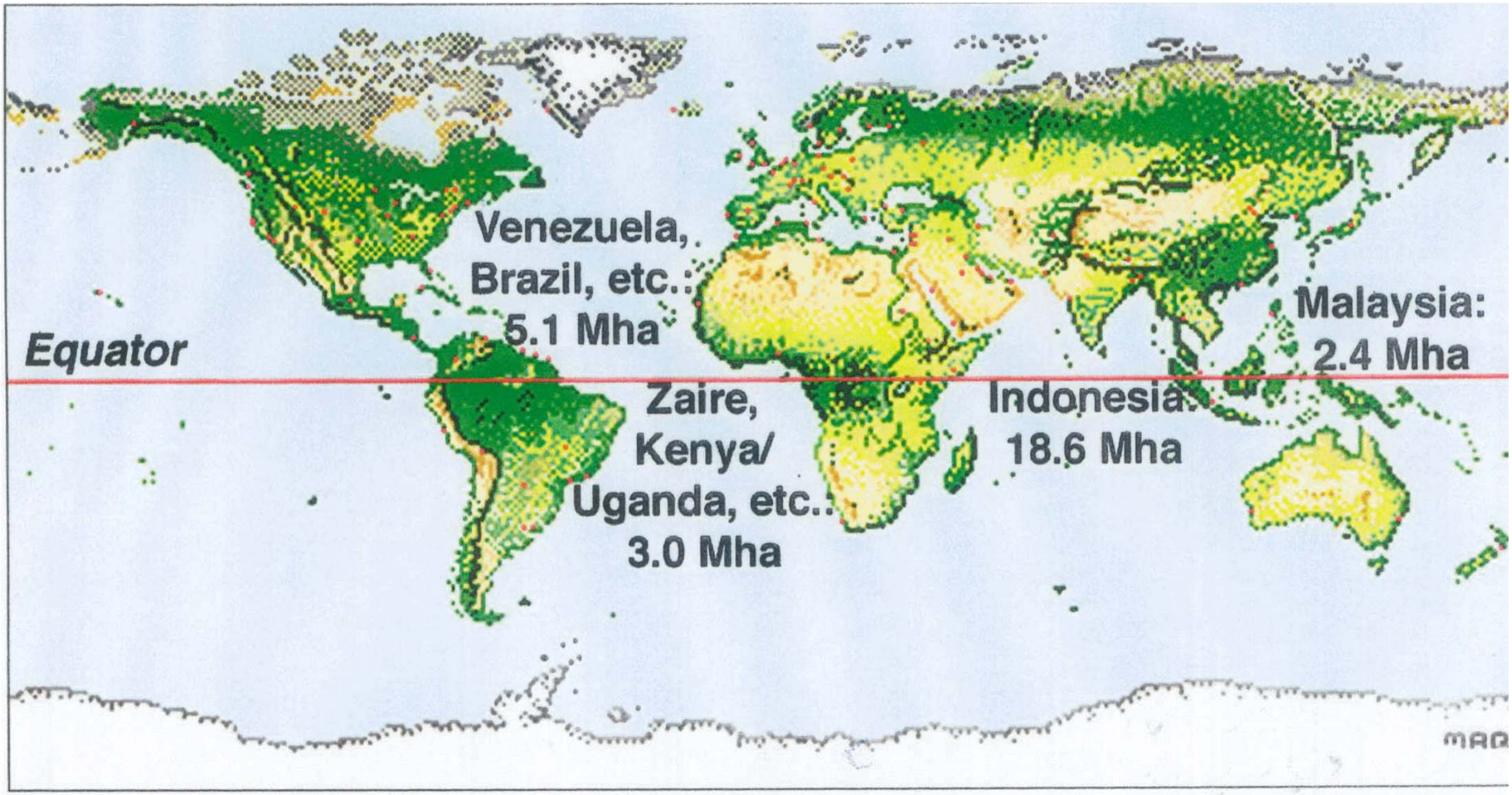


Table 2 Average of N_2O and NO production rate (μg N_2O-N or NO-N d^{-1} kg^{-1} SDW)

	N_2O			NO		
	$(NH_4)_2SO_4$	$(NH_4)_2SO_4$, citric acid	$(NH_4)_2SO_4$, citric acid, DCD	$(NH_4)_2SO_4$	$(NH_4)_2SO_4$, citric acid	$(NH_4)_2SO_4$, citric acid, DCD
P1	0.73	1.97	3.66	42.54	48.36	91.45
P2	0.81	1.91	3.02	57.50	28.57	47.54
L1	0.66	2.01	5.72	48.84	62.47	107.70
L2	0.49	1.35	3.34	3.01	32.88	70.55
O	0.29	0.90	0.86	16.23	25.22	40.24
R	0.05	0.16	0.34	7.48	6.67	18.40



Distribution of Tropical Peatlands

International Workshop
On
Land-Use Change and Greenhouse Gases, Soil C and Nutrient Cycling in the Tropics
19-21 Feb. 2002
Tsukuba, Japan

A special issue
of
Nutrient Cycling in Agroecosystems
On
Land-Use Change and Greenhouse Gases, Soil C and Nutrient Cycling in the Tropics
(Africa, America, and Asia)
To be published in 2004 (15 papers are included)

Ishizuka, S., H. Tsuruta and D. Murdiyarso: An intensive field study on CO_2, CH_4 and N_2O emissions from soils at four land-use types in Sumatra, Indonesia, Global Biogeochemical Cycles, 16, 1049, doi:10.1029/2001GB001614 (2002)

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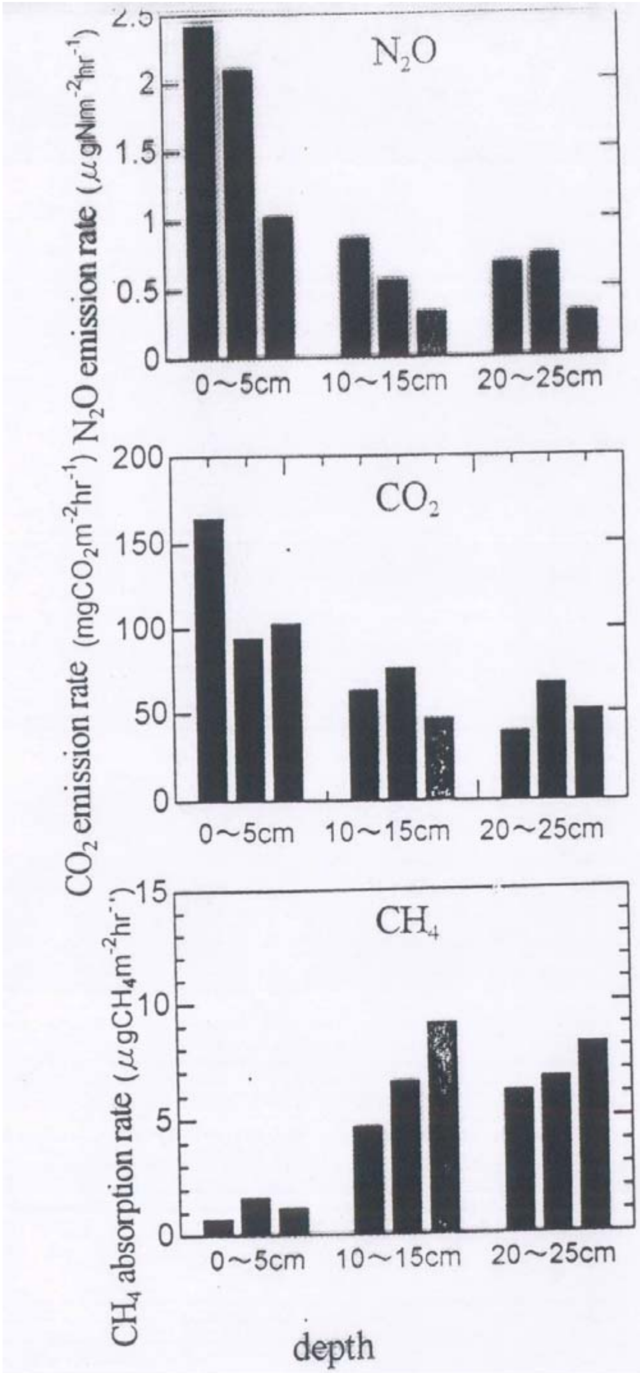
3. Intensive study on GHG fluxes at Pasirmayang Research sites

Period: Sep. 2001
Sites: 80 (grid---3m x 3m) including P1, P2

Measurements:

- Gas flux: CO_2, CH_4, N_2O (no replication)
- soil temperature


N$_2$O
N$_2$O emission rate (μgNm^{-2}hr^{-1})
0~5cm
10~15cm
20~25cm
CO$_2$
CO$_2$ emission rate (mgCO$_2$m^{-2}hr^{-1})
0~5cm
10~15cm
20~25cm
CH$_4$
CH$_4$ absorption rate (μgCH$_4$m^{-2}hr^{-1})
0~5cm
10~15cm
20~25cm
depth