B-51.1.1 Studies on carbon dioxide flux change due to the land use-change

Contact person Masayasu HAYASHI
Senior Researcher
National Institute for Resources and Environment
Ministry of Industrial Trade and Industry
Onogawa 16-3, Tsukuba, Ibaraki 305-8569, Japan
Phone;+81-298-58-8380 Fax;+81-298-58-8358
E-mail;hayashi@nire.go.jp

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Abstract

Land-use/cover features are changing due to the large scale deforestation in South Asia. The emission inventory of green-house gases, especially carbon dioxide (CO2) is investigated through the field observation . The main sources in this case are soil and covered vegetation. The flux from soil to the atmosphere is measured using the chamber and the flux from vegetation to the atmosphere is measured by the eddy correlation system over the canopy layer. Chambers were set at different land-use/cover in Pasirmayan, Jambi Province, Sumatra. Eddy-correlation system is to set up at Pusrehut, Kalimantan Timur.

The CO2 flux from soil is large during rainy season and small dry season. This tendency is found at all test sites. CO2 flux in dry season at open space after the slash-and-burn is smaller than other site due to the soil desiccation. The fluxes in rain and dry seasons are smaller than the former researches at the tropical moist forest and dry forest. Nitrogen isotope ratios (δ 15N) as well as CN ratios of soil organic matters (SOM) were determined. The results were compared with those for soil CO2 emission to determine possible relationship between the soil characteristics and the CO2 emission. The SOM accumulation was restricted in the top-soil (0-10 cm), demonstrating that the nitrogen dynamics in soil-plant system was under control of soil mineralization process. The δ 15N of SOM negatively correlated with the CN ratio, probably due to loss of isotopically lighter nitrogen by denitrification process during the nitrogen turnover. As the CN ratio is known to decrease as the SOM is decomposed, the δ 15N variation can be proposed as an indicator for the availability of easily decomposable organic matters (EDOM) in soil. The variation in CO2 emission from soils under different land-use during dry season was in accordance with the EDOM availability in top-soils that was predicted from the δ 15N variation. This fact suggests that the variation in soil CO2 emission among sites under different land-cover can be attributed to the change in availability of the EDOM.

The CO2 concentration over canopy layer shows typical diurnal change. Seasonal change in the trace of CO2 concentration is not found in one year observation since February 1998. This may say the characteristic feature for tropical rain forest but difference is found in satellite NDVI.

Key **Words** land-use/cover change, CO2 flux , soil organic matter, nitrogen isotope ratio, CO2 concentration

1. Introduction

land-use/cover features are changing due to the large scale deforestation in the tropical Asia. It is important for the prediction of the future CO_2 concentration in the atmosphere to estimate the changes the emission/absorption of the green-house gases, especially carbon dioxide, CO_2, due to the deforestation and the subsequent farmland or plantation. However, it is in controversy whether the tropical forest is a net sink for the atmospheric CO_2. Considerably large portion of the tropical forest has already been logged. Additional area will be converted into agricultural field to meet with the increasing food demand. There needs to assess effects of land-use/cover change on the carbon dynamics in the tropical forest area.

2. Objectives of the research

The main sources in this case are soil and vegetation. The flux from soil to the atmosphere is measured using chamber and the flux from vegetation to the atmosphere is by eddy correlation method over the canopy layer. The field campaign site is set at the protected forest area owned by Barito Pacific Timber Group, at Pasirmayan, Jambi province, Sumatra island through the discussion with the Indonesian counterpart, BIOTROP, 1997. Our sites include following land use/cover type; preserved primary forest (site-P), forest that had suffered selective logging (site-S), open area after forest clearing and subsequent burning (site-O), and rubber plantation on the former open plot (site-R).

Soil emission of CO_2 occurs through plant root respiration and oxidation of soil organic carbon by microbes. The forest reclamation may alter CO_2 production in the both processes as well as chemical characteristics of soil organic matters. We determined nitrogen isotope ratio of soil organic matters (SOM) to determine the change in chemical characteristics of SOM. The objective was to propose the nitrogen isotope ratio as a possible tool to implicate variation in soil CO_2 emission among sites with different land use/cover. For this purpose, relationship between the nitrogen isotope ratio of SOM and the soil CO_2 emission was analyzed.

Observation system by eddy-correlation method has to be set at the site for long term. The security at the Pasirmayan is doubted by the counterpart. Another candidate is proposed at PUSREHUT, an experimental forest of the Tropical Forest Research Center of The University of Mulawarman, Samarinda, Kalimantan Timur. It was too short time to clear the custom office the eddy correlation system. CO_2 concentration has been measuring using the hand carry instruments by the local staff since February, 1998.

Locations of the field campaign are listed at the Figure 1.

3. Materials and Methods

3.1. Soil CO_2 flux

The CO_2 flux at soil surface was determined by a static closed chamber technique. The CO_2 concentration was measured using TCD-gas chromatograph. Measurements were carried out monthly in principal during period from September 1997 to August 1998.

3.3. Isotopic determination

Soil samples were collected near the sites for gas flux monitoring in January and September 1997. The soils were air-dried, sieved, then portions were used for analyses of total carbon and nitrogen contents by a CHN-analyzer. The samples for isotopic measurements were treated with a diluted HCl solution and washed by distilled water to remove carbonate and inorganic nitrogen species. The samples were dried (60 oC), crashed, and homogenized using mortars. A 50-250 mg of sample was combusted in vacuo to convert any organic nitrogen to N2 1). The N2 produced was cryogenically separated and injected to a mass spectrometer (Finnigan Mat 252). The nitrogen isotope ratio was expressed in terms of δ notation as a per mill deviation from a reference material;

$$\delta\,15N\,(‰) = (Rsample / Rreference - 1) \times 1000$$

where R=15N/ 14N and atmospheric N2 was the reference. Reproducibility of the measurement was ±0.1‰.

4. Results and Discussion

4.1 CO2 flux from soil

Sampled air from chamber are send back Japan once a month by the cooperation of the local staff since September, 1997. The CO2 emission flux is small during the dry season (April –November) and large rainy season (December-March) as shown in Figure 2. This tendency is found in all sites. The flux in dry season at the open area after the slash-and-burn is smallest due to the soil desiccation. The fluxes in rain and dry seasons are smaller than the former summing up, 527mgCO2/m2/hr for tropical moist forests and 282mgCO2/m2/hr for tropical dry forests by Raich and Schlesinger,1992. More data accumulation will be necessary to estimate the annual statistics.

4.2. δ 15N of SOM in various tropical forests

Vertical profile of δ 15N-SOM at the site-P is illustrated together with those obtained in natural forests in Thailand (Fig. 3). The profiles can be divided in two groups. The first group consists of the profiles in the peat swamp and the mangrove forests. These profiles are well characterized by insignificant vertical change. The second group includes the profiles for the hilly forests including the site-P. The profiles of the second group are characterized by significant vertical changes in δ 15N. While the δ 15N-SOM differs among the forests of the second group, following common tendency in vertical change is obtained. The δ 15N-SOM is lowest in the top layer (0-10 cm) and reaches maximum at 10-30 cm layer. The δ 15N variation in the deeper soil layer than 30 cm is relatively small.

The suppression of SOM decomposition under water-logged conditions results in accumulation of organic nitrogen in the soils of the first group. The SOM accumulation is restricted in the top-soil of the second group, which is implicated by a rapid turnover of nitrogen in plant biomass-SOM system. Therefore, the vertical change in δ 15N-SOM may be a function of degree of decomposition of the SOM. The most probable mechanism for the higher-shift in δ 15N as depth in the forest soils is a preferential turnover of isotopically lighter nitrogen in an internal cycling. Preferential reduction of NO3- with low δ 15N would be a primary cause for making δ 15N of the remaining nitrogen in soil higher.

4.3. δ 15N-SOM difference between primary and disturbed forests

The δ 15N-SOM in the site-S was consistently lower than that in the site-P (Fig. 4). This is indication that the SOM in the site-S was different in chemical characteristics from that in the site-P. In the both sites, the δ 15N-SOM significantly related with the CN ratio (Fig. 5). The CN ratio of SOM is known to indicate degree of decomposition of the SOM; namely, the CN ratio decreases as the SOM is decomposed. The negative correlation between the δ 15N and the CN ratio in the SOM indicates that the δ 15N become higher as a result of the SOM decomposition. The lower δ 15N in the site-S suggests that the soil in the site S is more abundant in relatively fresh organic matters as compared with the soil in the site-P. This is probably due to the biomass-N that has been added to the soil at the site-S as a result of the selective logging. These results suggest that the soil of the site-S is richer in fresh organic matters than that of the site-P. In other words, the SOM in the site-P is more refractory than that in the site-S.

4.4. Variation in δ 15N of SOM due to land-use change

The δ 15N-SOM in top layer (0-10 cm) varied among the observation sites (Fig. 6). The δ 15N-SOM changed as the consequence of typical land-use/cover change in the study area; P→S→O→R. The fluctuation in between each stage of the land-use/cover change can be summarized as follows.

1) Selective logging (P→S): The δ 15N values in both top- and sub-soils become lower. This is due to the input of the fresh biomass-N having lower δ 15N to the soil.

2) Clear cutting and subsequent burning (S→O): The δ 15N values in both top- and sub- soils become higher. After clearing the forest, the surface soil is eroded due to an increased precipitation strength because of absence of forest canopy. When the former top-soil is washed away, then the former sub-soil with high δ 15N is exposed to the atmosphere. Because of little foliage, the input of fresh biomass-N with low δ 15N to the soil is negligible at this stage. As a result, the δ 15N difference between the top- and sub-soil is small in the open area.

3)Rubber plantation (O→R): While the sub-soil has relatively high δ 15N as that in the site-P , the top-soil exhibits low δ 15N as in the site-S. Note that the δ 15N values of top-soil are in the δ 15N range for plant materials.

This fact may reflect a rapid accumulation of the SOM derived from biomass production. The amount of fresh organic matters in the top-soil in the site-R is expected to be larger than that in the site-O. In the above context, the fluctuation in δ 15N of the SOM in the shallow layer along the land-use change can be linked to the change in amount of easily decomposable organic matters (EDOM) with low δ 15N that is provided as a fresh biomass-N to the soil. It is thus expected that the EDOM are more available in soils in the order, S>P>R>O.

4.5. Relationship between δ 15N of SOM and CO2 emission

The CO2 emission was varied in the order of S > P > R > O during dry season observation (Fig. 7). This order agrees with that for the availability of the EDOM which is indicated by the δ 15N variation in the shallow SOM. This fact suggest that the δ 15N of the shallow SOM can be applied as an indicator to predict dynamics of CO2 emission along the land-use change. However, during the rainy season, the CO2 emission was highly variable among the sites without above mentioned tendency. These facts demonstrate that factors other than the EDOM availability in soil would be a key control for the CO2 emission during rainy season.

5.6 CO2 concentration over the canopy layer

The CO2 concentration over the canopy layer shows typical diurnal change; sudden decrease at the morning due to the photosynthesis and low and stable concentration in day time and gradual increase from evening to early morning due to the respiration of the plant as shown I Figure 8. The diurnal change of the CO2 concentration is reflects the biological activity of the surrounding forest. Figure 9 shows the annual trend of the mean concentration (dot) and daily maximum (triangle) and minimum (triangle) which difference indicates the diurnal range. No seasonal trend found in both time trace for one year since February, 1998. This is supposed to be a tropical rain forest due to the less seasonal change in temperature and precipitation through the year. NDVI, Normalized Difference Vegetation Index, by NOAA pathfinder shows a difference for dry and rain season. This observation may not be representative due to the severe drought and frequent forest fires in Indonesia Islands in 1997 and 1998 caused by El Nino. It will be necessary to buck up by continuous observation with meteorological data.

6. Concluding remarks

The present study suggests that the seasonal, dry and rain, change in the CO2 flux from soil in the land-use/coverage changing area. In the estimation of the CO2 flux from land surface, it is important to obtain the back up meteorological data such as temperature, precipitation soil temperature and soil humidity. Moreover δ 15N characterization of SOM is useful in the fame work for the study on soil CO2 emission under variable land-use. The δ 15N-SOM can be applied to extrapolate point measurements of CO2 emission to regional scale. For the practical application, however, within-site variations of the δ 15N- SOM and the soil CO2 emission have to be known.

Reference

1) Minagawa M., Winter D.A. and Kaplan I.R. (1985) Comparison of Kjeldahl and combustion methods for measurement of nitrogen isotope ratios in organic matter. Anal. Chem. 56, 1859-1861.
2) Raich J.W. and W.H. Schlesinger, The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate, Tellus 44B, 81-99,1992.

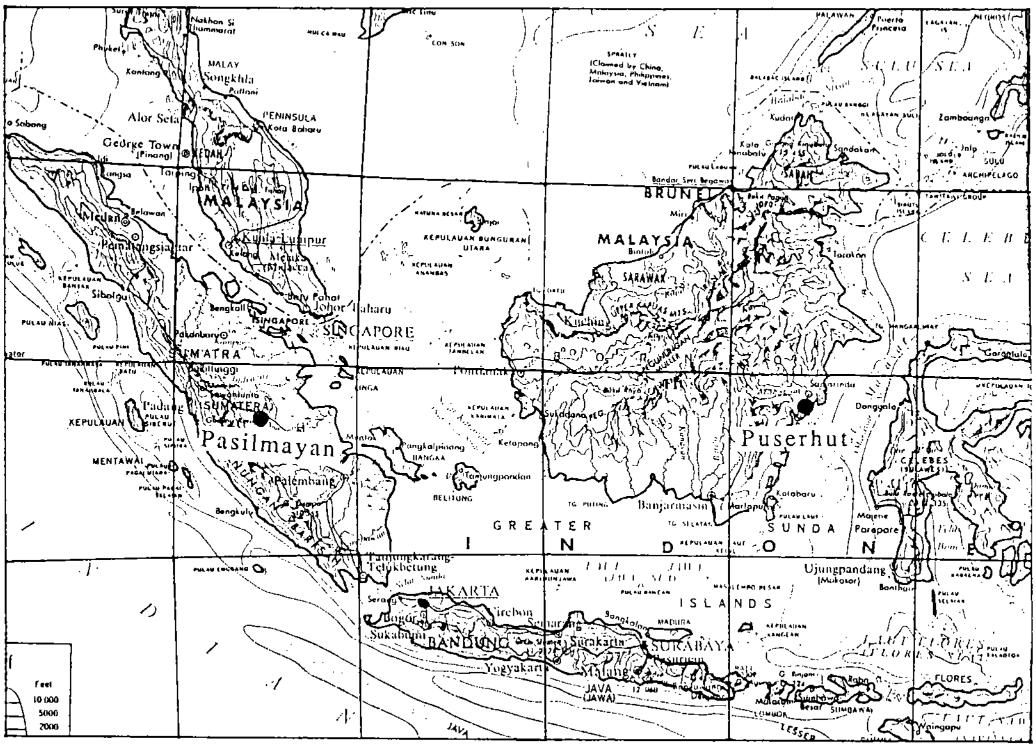

Figure 1. Locations of field campaigns in tropical Asia.

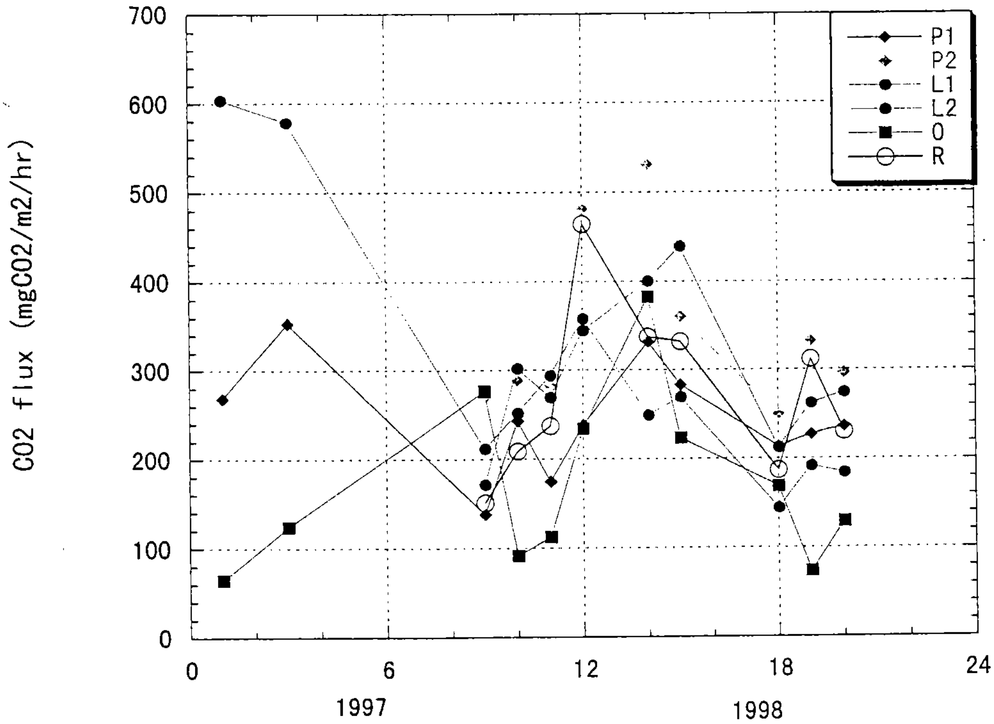

Figure 2. CO2 flux from soil to the atmosphere.
P1,P2; Primary forest, L1,L2;Logged forest, O; Open area after the slash-and-burn, R; Rubber plantation.

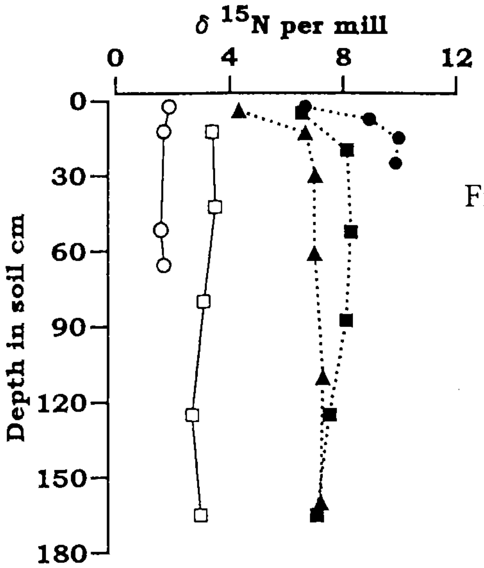

Figure 3. Vertical change in δ^{15}N-SOM in different tropical forests. Legends are as follows; ○– Peat swamp forest in Narathiwat, southern Thailand; □– Mangrove forest in Phang Nga, southern Thailand; ■–Hilly seasonal forest in Kanchanaburi, central Thailand; ▲–Hilly evergreen forest in Chiang Mai, northern Thailand; ●– Primary forest in Jambi, Indonesia (this study).

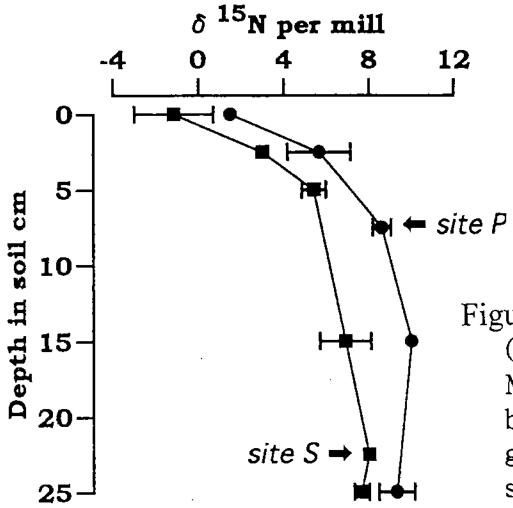

Figure 4. δ^{15}N-SOM in primary forest (site-P) and disturbed forest (site-S). Measurements at 0 cm depth in the both sites are for plant leaves and ground litter. Error bars denote standard deviation.

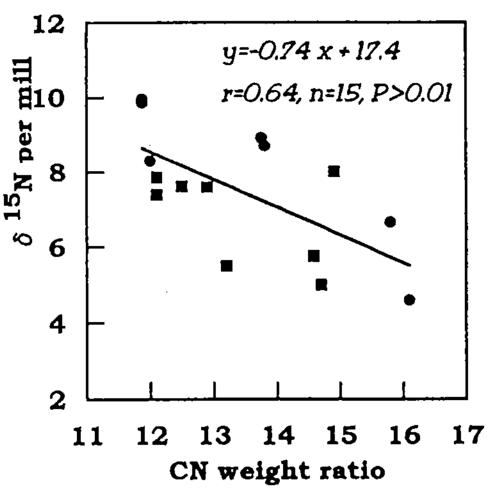

Figure 5. Correlation between CN weight ratio and δ^{15}N of SOM in the site-P (●) and the site-S (■).

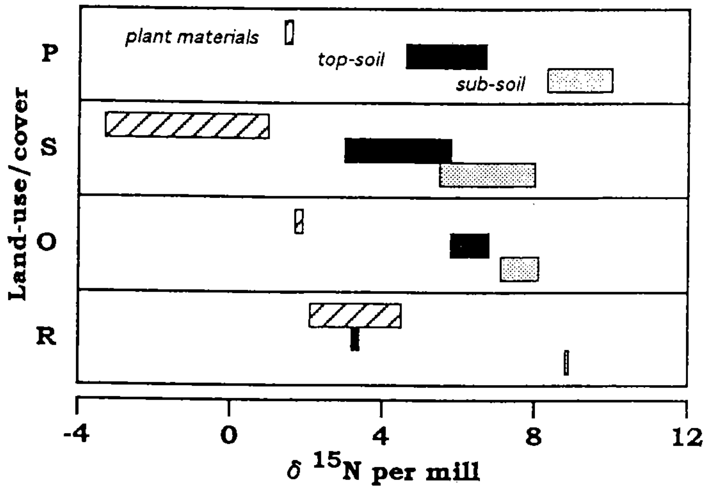

Figure 6. Variation in $\delta^{15}N$ of plant materials (leaves and/or ground litter), top-soil (<10 cm depth), and sub-soil (>10 cm depth) along the typical land-use/cover change in the study area (P→S→O→R).

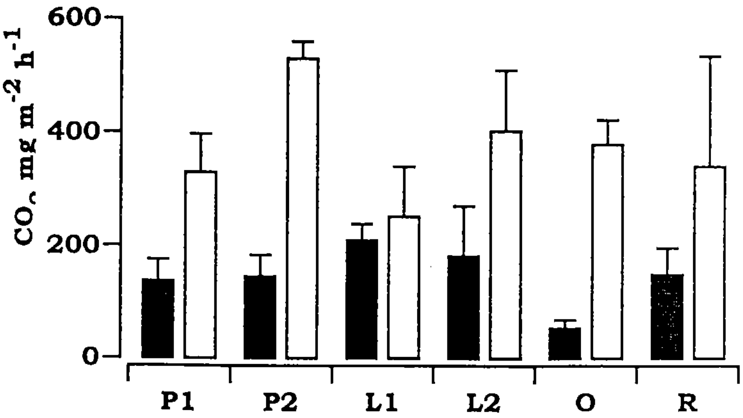

Figure 7. Emissions of CO_2 from soils under different land use during dry season (September 1997, filled bar) and wet season (February 1998, open bar). Bars denote standard deviation for measurements obtained by three static chambers.

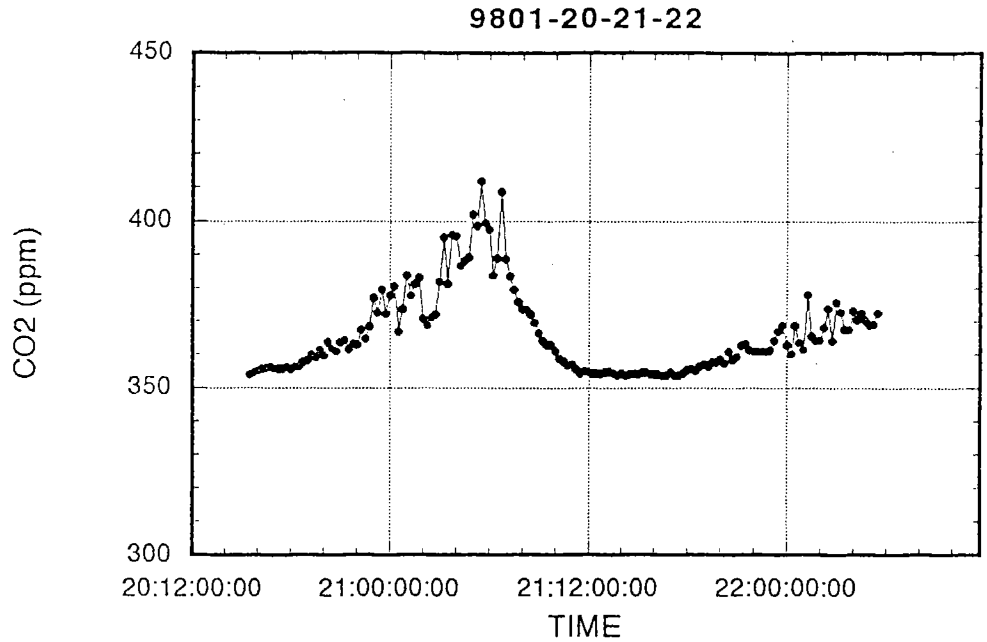

Figure 8. Typical example of the diurnal change of CO2 concentration over forest canopy layer.

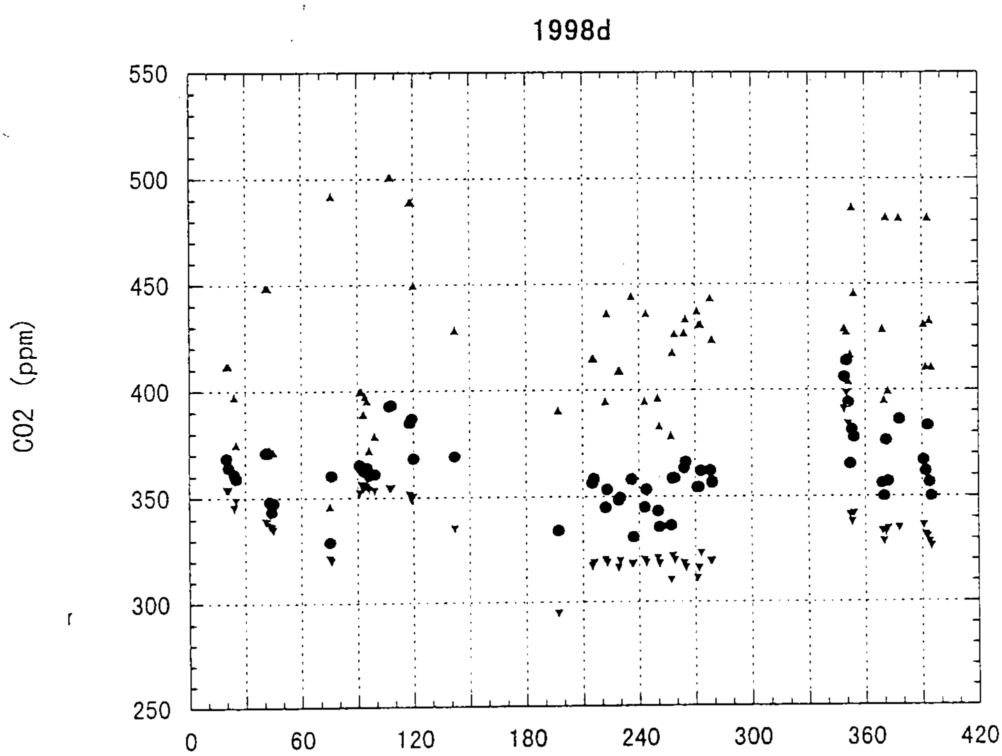

Figure 9. Seasonal trend of CO2 concentration (dot), its maximum and minimum (triangle) over tropical rain forests. Days starts since January first, 1998.