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Methane Emission from Thai Paddy Fields

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Introduction

Methane has been in recent years received a special attention as one of the important greenhouse gases. Among the sources of CH_4 emission, paddy fields are estimated to contribute 50-150 Tg/yr of the total emission, 375-717 Tg/yr.

Since the data on CH_4 emission rates from tropical paddy fields have been few, the total CH_4 emission amounts from the paddy fields in the world have been estimated using the data from temperate paddy fields. But the climate and the distributed soil types in the tropics are different from those in the temperate regions. Generally acid sulfate soils and red yellow podzolic soils are widely distributed in the tropics, while they cover the small areas in the temperate region. Therefore, the direct measurements of CH_4 emission from the various tropical paddy fields are urgently requested.

The special porject "Dynamism of Greenhouse Effect Gases in Terrestrial Ecosystem in Asia" in the main framework entitled "Studies of Global Environmental Change with Special Reference to Asia and Pacific Regions" under the support of Grant-in-Aid for Creative Basic Science from the Ministry of Education, Science and Culture of Japan started in 1990 aiming the integral resolution of the world-scale environmental problems. Under this project, we are surveying the CH_4 emission rates from typical Thai paddy fields in cooperation with Thai counterpart scientists in Kasetsart University.

Experimental fields and cultivation of rice plants

Three experimental fields were selected from Rice Experimental Stations in Thailand in this experiment (Fig.1). Two were irrigated paddy fields located in Ratchaburi and Pathumthani Provinces on the central alluvial plain. The soils were classified as Fulvic Tropaquept with

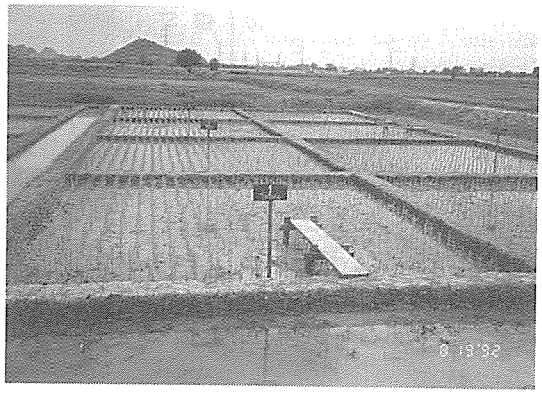

Photo 1. Ratchaburi Rice Experiment Station.

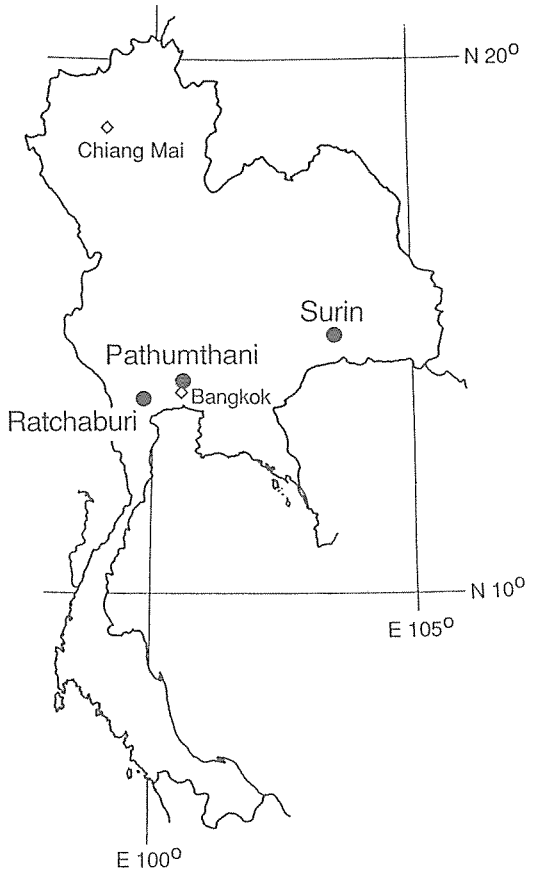

Fig.1. Location of experimental sites.

parent material of fresh water sediments and Sulfic Tropaquept with brackish water sediment, respectively. The other one was a rain fed paddy field in Surin Province, Northeast Thailand. The soil was classified as Anthraquic Paleaquult. These soil types are the dominant soil types of paddy fields in Thailand.

Each experimental field consisted of three plots; no fertilizer applied plot (NF-plot), chemical fertilizer applied plot (CF-plot), and organic material applied plot (OM-plot). Rice plants (*Oryza sativa* var. *Indica*) were cultivated during rainy season from August to November in 1992.

Measurement of CH_4 emission

Methane emission rates were measured every week throughout the growth period using the closed chamber method (Photos 1-3). The air samples from the closed chamber were sent to Kasetsart University, Bangkok, within a few days after sampling and the CH_4 content in the tube was determined with gas chromatograph.

Methane emission from 3 Thai paddy fields

Figure 2 shows the mean rates of the CH_4 emission during the whole growth period from each plot of 3 paddy fields. The mean CH_4 emission rates from NF-plots decreased in the order of Surin (red yellow podzolic soil), Ratchaburi (fresh water alluvial soil), and Pathumthani (acid sulfate soil) with the ratio of 26:2:1. The

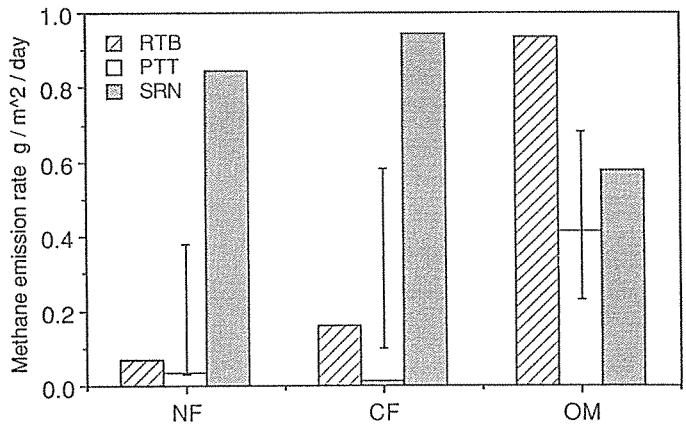

Fig.2. Mean rates of methane emission during the whole growth period from NF-, CF- and OM-plots of 3 experimental sites.

Photo 2. Pathumthani Rice Experiment Station.

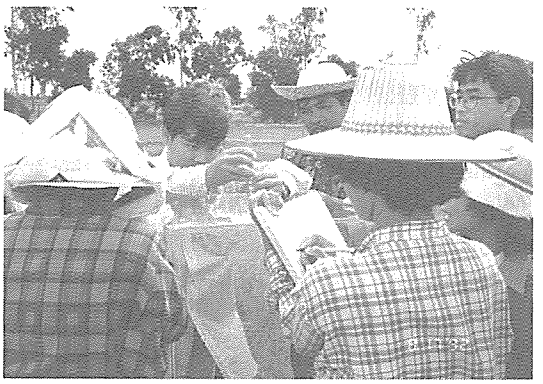

Photo 3. Surin Rice Experiment Station.

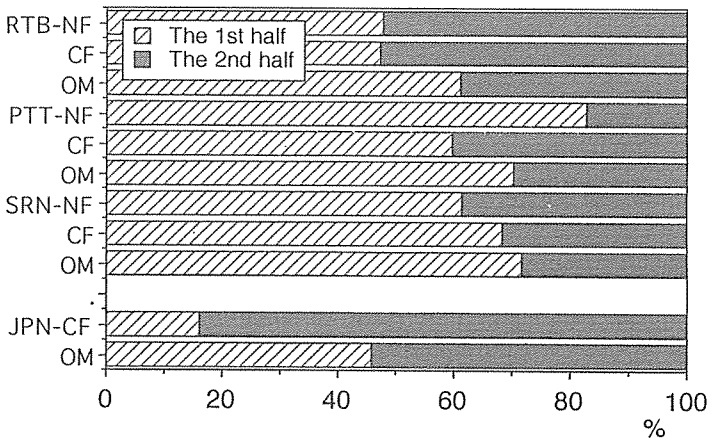

Fig.3. Percent distribution of methane emission in the first and second halves of growth period from each plot in Thailand and in Japan.

same decreasing tendency among the fields was also observed in the CF-plots. In the paddy fields at Ratchaburi and Surin, the application of chemical fertilizer increased the mean CH_4 emission rates 1.1-2.3 times compared with the respective NF-plots, while its effects was not observed in the Pathumthani paddy field. The mean CH_4 emission rates from the Ratchaburi paddy field increased greatly by incorporation of fresh *Sesvania rostrata*, which was 13 times as large as that of the Ratchaburi NF-plot. Acceleration of CH_4 emission rates by organic material application was also observed in the Pathumthani paddy field. On the other hand, the application of manured rice straw on the surface of Surin paddy field had an adverse effect on CH_4 emission rates.

The seasonal means of CH_4 emission rates from paddy fields have been reported by many reserchers in the last decade. The range of reported mean CH_4 emission rates is also shown in Fig. 2. The mean CH_4 emission rates from the NF- and CF-plots of the acid sulfate soil in Thailand (Pathumthani) were much lower, while those values of the red yellow podzolic soil (Surin) were much higher than the mean CH_4 emission rates from the same plots in other countries such as U.S.A., Italy, Philippines and Japan. The mean CH_4 emission rates from Ratchaburi NF- and CF-plots fell into the lower levels of the reported range. The mean CH_4 emission rates from the OM-plots in Thailand

were within the range of reported values (Pathumthani and Surin paddy fields) or higher than that (Ratchaburi paddy field).

The very low CH_4 emission rates from Pathumthani paddy filed were due to the soil properties of acid sulfate paddy field. Low pH of this soil and active consumption of hydrogen by sulfate reducing bacteria might suppress the CH_4 formation. On the contrary, Surin soil contained the small amounts of free iron, and the soil might be reduced easily to such a very low level as that of CH_4 formation.

Figure 3 shows the percent distribution of CH_4 emission in the first and second halves of growth period from each plot in Thailand and Japan. As shown in Fig. 3, the CH_4 emissions from the NF-, CF- and manure applied plots were mainly in the second half of growth period in Japan, while the CH_4 was mainly emitted in the first half of growth period in Thailand.

The total CH_4 emissions were calculated to be 4-59 gC/m^2 in the fresh water alluvial paddy field, 0.6-17 gC/m^2 in the acid sulfate paddy field and 21-35gC/m^2 in the red yellow podzolic paddy field, respectively. The present experiment suggested the importance to consider not only the dominant soil types of tropical paddy fields but also the kind of fertilizer applied to the respective types of paddy fields to estimate the total amounts of CH_4 emission from the paddy fields in the world.

(Nagoya University)

Methane Emission from Paddy Field and Tropical Peatlands

Kazuyuki Inubushi

Concentration of atmospheric methane (CH_4) has been increasing very rapidly at the rate of approximately 0.7-1.0% per year, and present mixing ratio is about 1.7-1.8 ppmv. Compared with the concentration in the pre-industrial period, it has more than doubled within 150 years. Methane has strong infrared absorbing potential and its increase may induce global warming. Since methane is terminal product of anaerobic decomposition process of organic matter, dominant global sources of biogenic methane are anaerobic environments such as natural wetlands, swamps, marshes and paddy fields (Schutz et al., 1990).

This report introduces briefly (1) a series of experiments for investigating mechanism and control of methane emission from paddy soil ecosystem conducted in our laboratory, and (2) preliminary measurements of methane emission

Fig.1. Chamber method for determining methane flux through rice planted in pots.

from tropical peatlands.

Mechanism of methane formation and emission from paddy field

Total area of world paddy field is estimated to be about 1.45 million km^2, which is approximately 10% of the global cropland, but distributed mostly in South and Southeast Asias. Present estimation of methane emission from paddy field contains still big variations, but the mechanism of methane emissin has been revealed recently. Methane is formed under strongly reduced conditions by methanogenic bacteria. The amounts of methane formation were found to be roughly proportional to the soil organic matter contents and increased by addition of organic carbon such as glucose and rice straw.

Possible routes of methane formed in soil to the atmosphere are (i) diffusion, (ii) ebullition and (iii) transportation by rice plant. Our pot experiments confirmed the third mechanism was predominant pathway of methance emission from paddy field (Inubushi et al., 1989). Some part of methane was oxidized to CO_2 by methanotrophic bacteria during this transportation. Fig. 1 shows the chamber method to collect gas samples for determining methane flux rate through rice plant.

Practicability of reducing methane emission from paddy field

The amount of methane emission from paddy field is influenced by many factors; namely soil environmental factors including redox potential and temperature, plant factors like varieties, growth stage and vegetation density of rice plant. Therefore these factors should be considered carefully to reduce methane emission from paddy field, while present crop productivity of the field must be maintained.

To examine practicability of reducing methane emission from paddy soil-rice plant ecosystem, a series of pot experiments was conducted to see the effects of water managements, including percolation and mid-drying, incorporation timing of straw, and transplanting timing (Inubushi et al., 1991).

Percolation reduced methane formation since the percolating water brings dissolved oxygen to the reduced soil. But when soil was rich in easily decomposable organic matter, the effect of percolation was quite the reverse. As Takai et al. (1974) proposed, these results imply that the percolating water contains not only dissolved oxygen but also substrates for methanogenic bacteria like organic acids and CO_2, and toxic substances for methanogenesis or sulfate which enhance the activity of sulfate reducing bacteria.

Mid-drying is another promising farmer's practice. Irrigation was interrupted for 1 week in mid-summer and soil surface was dried up. During mid-drying, spike of methane flux was detected only 2-3 days probably due to soil crack through which accumulated methane was released. After reflooding, however, methane emission was much less than undried plots.

Straw application is important to maintain soil fertility in Japan, because other organic manures became less popular for busy farmers. But application of straw enhanced methane formation. Incorporation timing of straw, par-

Fig.2. Chamber method for determining methane flux in paddy field.

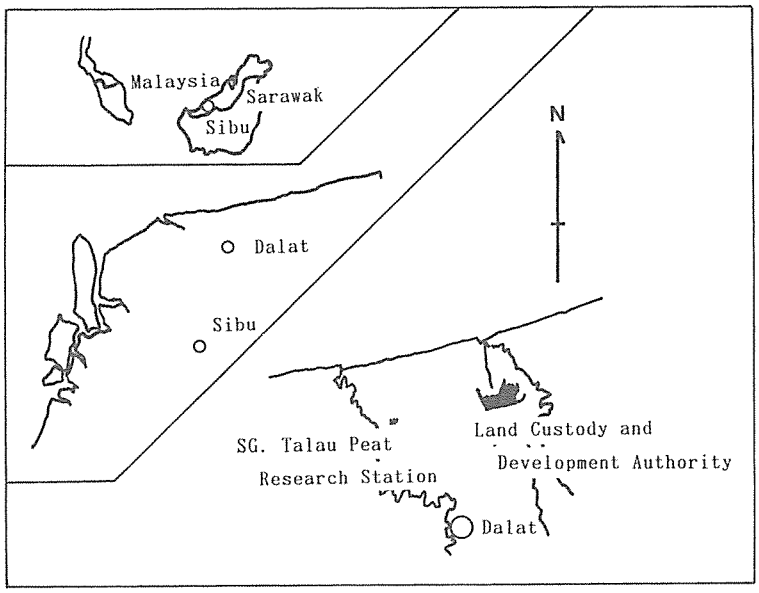

Fig.3. Map of the study sites in Sarawak, Malaysia.

ticularly advance to the flooding, was exmained in respect of reducing methane emission in pot experiment. Incorporation of straw 1 or 2 months before submerging reduced methane emission to 15-50% in comparison with the pot incorporated at submerging time.

Shifting transplant timing for 1 or 2 months late made the flux decreased to less than 10% in the pot experiment. Field examination of the practicability of this technique is now conducting (Fig.2).

Methane emission from tropical peatlands

Although total area of tropical peatland (0.52 million km^2) is about 10% of world natural wetland (Kyuma, 1986, Bouwman, 1990), two thirds of it are distributed in Southeast Asia and potentially important for agriculture and aquaculture.

Nevertheless there are few knowledge about methane emission from tropical peatlands (Bouwman, 1990).

Cooperative research was launched in 1992 with Malaysian researchers to characterize tropical peat for sustainable land use (Team

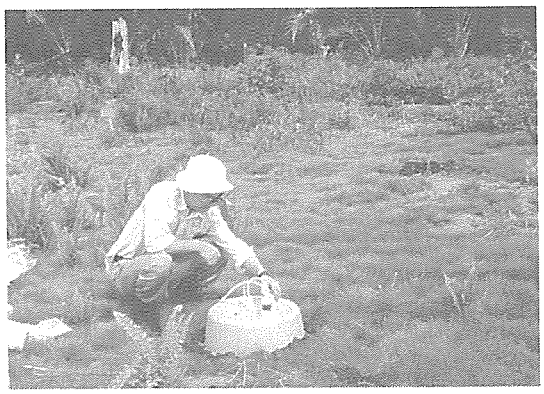

Fig.4. Measuring methane flux from peatland surface.

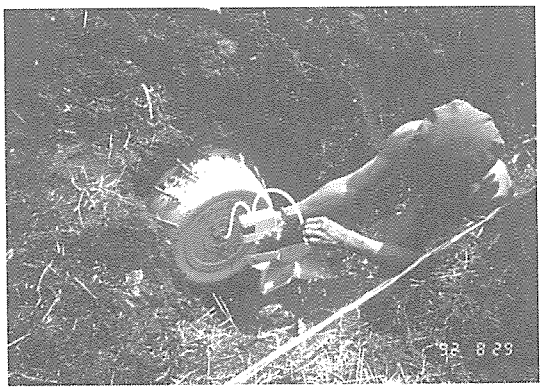

Fig.5. Gas sampling from deeper layer of peat soil.

Fig.6. Biomass burning of swamp forest and gas sampling.

Leader, K. Yonebayashi, Kyoto Pref. Univ.; Malaysian Researchers, Lim Ching Pang, Dept. Agric., Sarawak and others). The research areas are selected in SG. Talau, Dalat Peat Research Station and Estet Pelita Sdn Bhd, Mukah, Sarawak (Fig.3).

Air samples were collected from surface (Fig. 4) and deeper soil layers (Fig.5) in peatland and also burning site of swamp forest (Fig.6), then their methane contents were analyzed. Methane emissin from soil surface was relatively small, but quite large from deeper layers, indicating that methane is formed and stored in deeper part of peatland but not emitted so much to the atmosphere probably due to oxidation near the soil surface. Biomass burning gas also contained high concetration of methane. These phenomena should be examined more quantitatively for sustainable reclamation of tropical peatland.

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(Mie University)

A Research Project on Destruction of Tropical Forests and the Process of Ecological Change in Southeast Asia

Kunio Suzuki

Recent explosive growth of human activities affected directly the biosphere and inevitably led the ecosystem's environment to degradation in global scale. In order to clarify the basic mechanism of environmental changes in global scale, the new research study project was organized under international, inter-institutional cooperation among Japan, Southeast Asia and others, to carry out a long-term observation of the ecosystem changes. The research project has been organized and funded by the Ministry of Education, Science and Culture of the Japanese Government. The project, entitled "Studies of Global Environmental Change with Special Reference to Asia and Pacific Regions (Representative: Prof. Emeritus Saburo Tamura), started in 1990 and will finish in 1995. The project will put its stress upon biological processes in the equatorial regions.

The research project on destruction of tropical forests and the process of ecological changes in Southeast Asia has been handled by a subgroup called "Tropical Forest Team (TFT)", led by Prof. Kazutake Kyuma.

1. Object of the project (TFT)

The research primarily focuses upon the tropical forests of Southeast Asia. Studies will be the exploitation of virgin forests, structural changes of plant life and forests by shifting cultivation, forest reviving process, ecology and physiology of flora and fauna, earth and water environment, nutritional recycling, gas metabolism, etc. will be studied. It will be conducted under a long-range surveillance program to analyze the little-known plant-life structure and the function of the tropical forests, and their linkage to the environment. The impact of human disruption will be also to clarify the role of tropical forests in protecting the global environment.

The primary object will be the construction of swamp forests, broadly surveying Southeast Asia. The second will be to compare the present situation of tropical forests in Southeast Asia, Latin America, etc.; it will be made by on-the-spot surveys and by analysis of existing data through international cooperation with European and American researchers. In this way the structural and functional characteristics of Southeast Asian tropical forests will be clarified. The data accumulated concernig Southeast Asian tropical forests will be made available internationally.

2. Research plan and method

The team has been conducting the research program centered around the following five topics.

1) Deterioration of the biotic structure of tropical forests' ecology, and analysis of its recovery process

Typical Southeast Asian tropical forest has been selected as the site of long-term ecological observation (Photo 1). Clarified will be the recovery process of plant life disrupted by such activities as timber harvesting and shifting cultivation, and the reproduction mechanism of virgin forests. Also to be clarified will be the plant-life recovery process by the forests' natural reproduction function. This will be done by tracing the forest structure as well as animal/

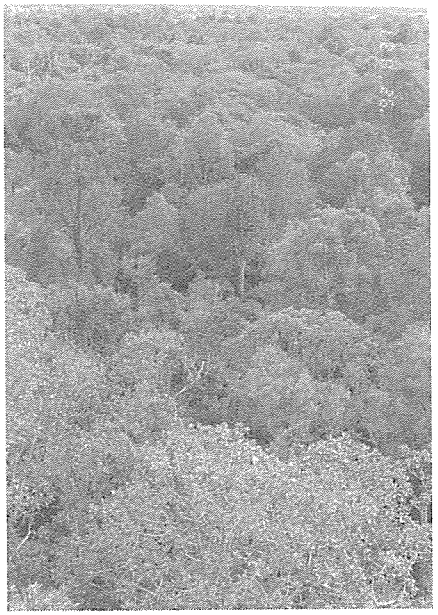


Photo 1. Tropical swamp forest in Narathiwat, Thailand. Most of the natural forest has been developed by burning, agricultural use and pasturage.

plant linkage, their influence upon the enviroment and their ecology and physiology that comprise the mechanism of natural reproduction. Experiments will be conducted to accelerate the recovery process of plant life. In addition to long-term, fixed-point observation, the transition from humid to dry land, and from lowlands to highlands that differentiate the tropical forest grouping will be investigated to clarify the linkage between forest structure and its habitat.

2) The impact of tropical forest destruction upon basin environment

Assessed along with the above forest ecological survey will be the impact upon the ambient environment, of forest degradation by timber harvesting and shifting cultivation. Special emphasis will be laid upon minor meteorological fluctuations, rain-flood patterns, and soil erosion. But disruption of the nutritional recycle and the change of flora and fauna microorganisms are also observed in connection with virgin forests. This is done to clarify the contribution of these factors to the recovery process of forests. Furthermore, the impact of large-scale disruption upon the downstream agricultural ecology and habitat environment will be assessed.

3) Balloon analysis of dynamic tropical forests

Chronological ecological fluctuations will be traced with plant-life and agronomic maps to clarify the process of tropical forest deterioration and recovery. Balloons will be used to observe micrometeorological fluctuations such as the movement of heat, moisture, carbon dioxide, and methane. This will be done to comprehend the environmental characteristics of tropical forests, savannas, and developing areas. These findings will clarify the impact of ecological/micrometeorological movements upon the global environment.

4) Research on gas metabolism in the ecological system

One of the major sources of the methane gas that contributes to global warming is believed to be tropical forests. This is particularly true of the anaerobic environment of swamp forests in Southeast Asia, plus the intestinal tracts of soil animals such as white ants generated at deforestation sites by lumbering or fire. But the ecological system of tropical forests as a contributor of methane generation has not been formally assessed. By this research project, methane emissions throughout the year will be measured at specific blocks at swamp forests and deforestation sites by lumbering or fire. In this way we will be able to assess these sites as methane sources as well as to guage the impact of land utilization. The metabolic route will be identified by measuring the naturally existing rate of stable isotopes.

5) Comparative study of tropical forests on three continents

Expanding the results of the above four research projects, the structural and functional

characteristics of Southeast Asian islands' tropical forest ecology will be determined by comparing them with continental African and Amazonian tropical forests.

3. Features and creativity of the research project

The population of Southeast Asia is far denser than that of tropical Africa and America. The deterioration of the ecological system in Southeast Asia is also outstandingly larger in impact and magnitude.

Our research projects will feature an in-depth study focused upon the ecology of Southeast Asian tropical forests as well as their background, constituents, and ecological transformation process caused by human activities. The project will also identify the unique and common natures of Southeast Asian tropical forests compared with their Amazonian and other tropical regions. Another major project feature is to give the research broad and objective perspectives by cooperating and communicating with the researchers of developing countries.

The next notable feature of this research project is the serious attention devoted to the ecology of tropical swamp forests. This mainly prevails in the developing areas that characterize Southeast Asian forests-area and that have been ignored in conventional research programs. This project extends its research from the swamp forests to lowland and highland forests to comprehend the tropical forests as a whole.

(Yokohama National University)

The Framework of the Future MAB Programme

Yusho Aruga

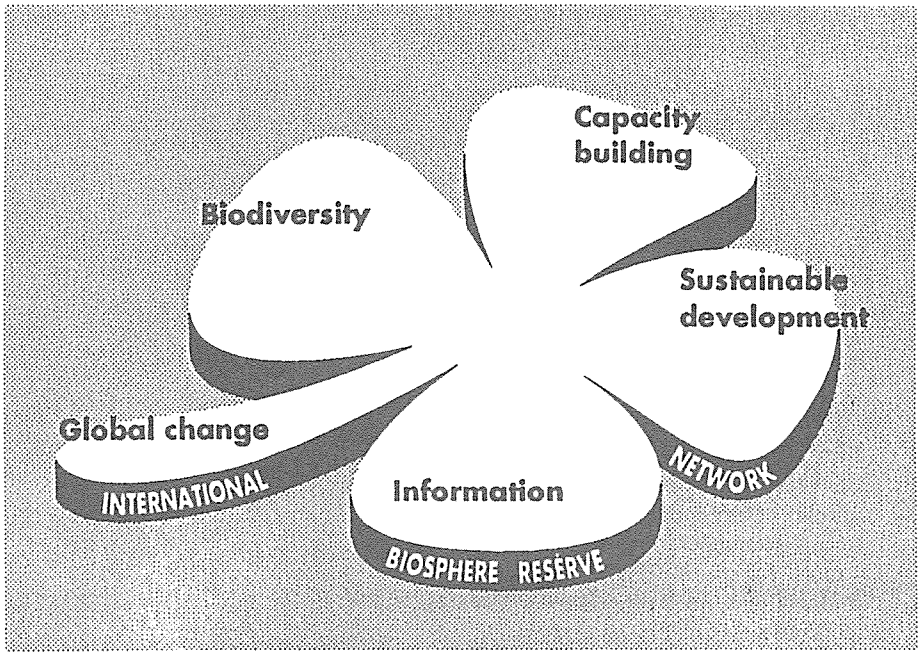
The Twelfth Session of the International Coordinating Council for the Programme on Man and the Biosphere (MAB) was held at UNESCO Headquarters, Paris, 25-29 January 1993. Discussions were made on strategic future planning of MAB (1996-2001) based on the UNESCO response to UNCED. For these discussions, the following figure and explanations were presented as the document SC-93/CONF.215/5/A.B Add.

MAB is, by its very nature, a programme on environment and development and thus is preadapted to respond to the concerns and results of the United Nations Conference on Environment and Development.

It is proposed that there would be four priority thematic areas which would build upon past MAB experience and would use as far as possible the logistic base of the international biosphere reserve network.

Conserving and sustainably using biodiversity

UNESCO's role and niche is to take a vigourous role in mobilising the scientific community to contribute to the scientific underpinning for the Convention on Biological Diversity. This area will cover initiatives such as: the IUBS/SCOPE/UNESCO programme *Diversitas* seeking to promote research on the ecosystem function, origins and maintenance of biodiversity, as well as inventorying and monitoring; the UNESCO-WWF-Kew Gardens "Peo-



ple and Plants" Programme aimed at recording and utilizing traditional ecological knowledge, especially of plants in tropical regions.

Exploring approaches to sustainable development in regional units

The concept of sustainable development has been much discussed but rarely put to the test at the largish scale at which societies manage resources. Three main types of action are envisaged: field (or regional) laboratories of sustainable development; comparative analyses of approaches and issues related to sustainable development in particular geographic or ecological regions, or physiographic units: comparative field studies for designing sustainable ecological systems.

Communicating information on environment and development

An informed and literate population as regards environment and development is a *sine qua non* of a democratic society. The sensible management of our planet will only begin when the large majority of public opinion overwhelmingly demands it. On a trial basis, multi-media information materials might be generated on ecology and sustainable development within particular geoecological region(s), such as the humid tropics. Close ties could also be developed with initiatives geared directly at producing materials for educational puposes such as those within the evolving UNESCO Programe "Education 2000", or those following the ECO-ED Conference (Toronto, 1992).

Building up capacities and fitting institutional functioning and training to emerging problems of environment and development

Environment and development issues are by their very nature cross-cutting and cross-sectoral. Yet institutions and training programmes remain sectoral and are not geared to tackling these complex problems. The past MAB experience in training and institution building can act as a starting point for responding to the increased demands for countries to address them. The proposed action would be an

inter-woven combination of analyses and assessment, advisory services, promoting South-South cooperation, training programmes and operational field projects.

A fifth ares would be a contribution to the proposed **Global Terrestrial Observing System** (GTOS) designed to detect the responses of terrestrial systems (natural and agroecosystems) to global change, based on an array of field sites. This would be a collaborative initiative with UNEP, FAO, WMO, IGBP-ICSU and the OSS (Observatoire du Sahara et du Sahel).

(Tokyo University of Fisheries)