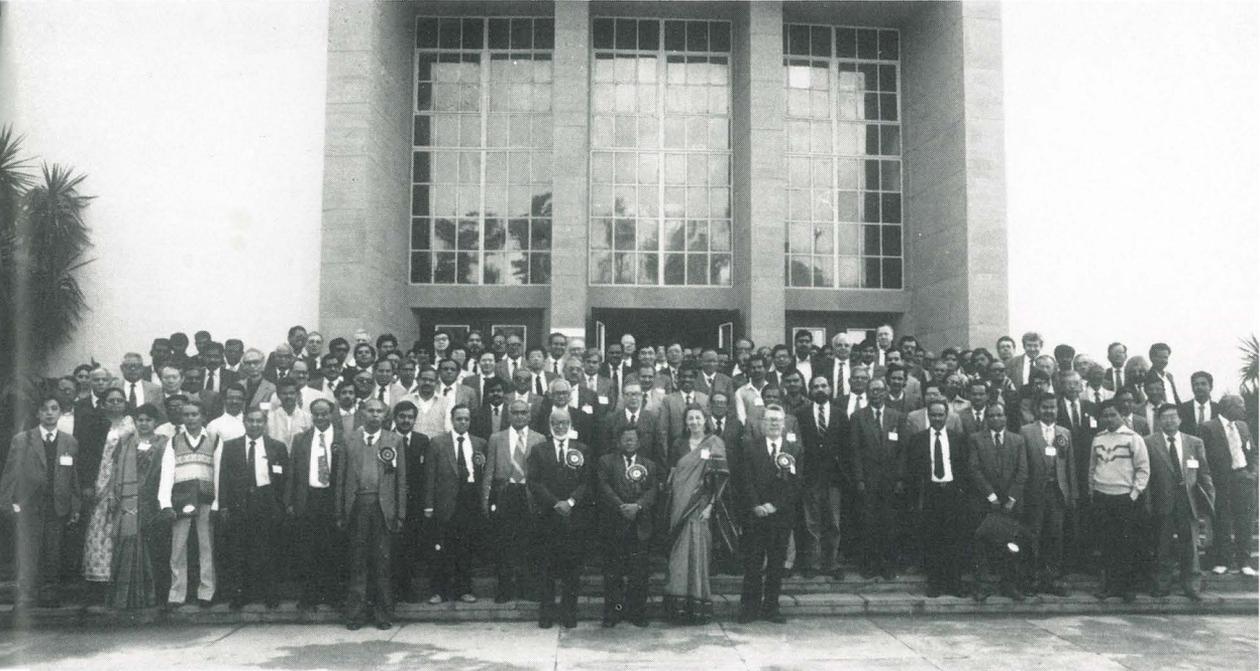


GLOBAL I G B P CHANGE

REPORT No. 18:1



Recommendations of the Asian Workshop New Delhi, India 11-15 February, 1991

The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP)
of the International Council of Scientific Unions (ICSU)

Stockholm, 1991

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LINKÖPINGS UNIVERSITET



**Recommendations
of the Asian Workshop
New Delhi, India
11-15 February, 1991**

Edited by R.R. Daniel

Produced by

The Committee on Science and Technology in
Developing Countries (COSTED)
and

The Indian National Committee for the IGBP
for the

International Geosphere-Biosphere Programme: A Study of Global Change (IGBP)
of the International Council of Scientific Unions (ICSU)

Stockholm, 1991

The Asian IGBP Workshop was jointly organized by: ICSU Committee on Science and Technology in Developing Countries (COSTED), the ICSU Scientific Committee for the IGBP, and the Indian National Committee for IGBP.

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The report was compiled by the editor from contributions by the Chairmen and Rapporteurs of the Four Working Groups and the Workshop participants.

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Cover Photograph: Participants who took part in the Asian Workshop

MESSAGE

The International Council of Scientific Unions (ICSU) has embarked on a major programme the "International Geosphere-Biosphere Programme: A Study of Global Change", referred to in brief as IGBP. The primary goal of IGBP is to describe and understand the various processes that operate within the total Earth system, and their relationships, so as to enable a prediction of changes in the global environment that are likely to take place, and particularly those which are influenced by human actions; this will make it possible for humankind to be forewarned about any possible hazardous consequences of pathways currently being pursued, and changes that need to be introduced to assure long-term sustainable development. This is the largest and most complex international cooperative programme ever undertaken.

A programme of this nature has, by definition to be, global in character, involving measurements at a number of locations on the Earth's surface, at various altitudes in the atmosphere and depths in the oceans, as a function of latitude and longitude. Three-fifths of the land area of the world is covered by the developing countries, who must, therefore, be participants in this programme, which will have to continue over several decades. There are immense intellectual challenges and rewards in this international effort to observe and analyze one of the most complex systems that we have ever tackled, the global ecosystem.

It is appropriate to the aims of the programme that an Asian Workshop on IGBP was organized in New Delhi from 11-15 February, 1991. The workshop brought together a large number of active scientists from different areas of activity in the Asian region, for discussions concerning the opportunities and challenges inherent in IGBP. At the Workshop, which was inaugurated by the Prime Minister of India, participation from the Asian region, and particularly from the China (CAST and Academy in Taipei), India, and Japan was excellent. Significant activities relating to IGBP are already being carried out in these countries. It is hoped that in the other Asian countries represented at this workshop, programmes relating to IGBP will now receive a greater impetus.

The Workshop particularly benefitted from the presence and contributions of Prof. Thomas Rosswall, Executive Director of IGBP, Prof. J.C.I. Dooge, President-Elect of ICSU, Prof. J.W.M. la Rivière, Secretary General of ICSU and Chairman of ICSU's Advisory Committee on Environment, and Mrs. Julia Martón-Lefèvre, Executive Secretary of ICSU.

The principal purpose of the Workshop was to initiate a process of interaction among scientists interested in IGBP in the Asian countries, and particularly to induct younger scientists into these programmes. It is hoped that this interaction, and creation of awareness, will facilitate cooperative efforts among the countries of the region, which will benefit the IGBP.

This Report, which includes the four rapporteur presentations by Chairmen of the Working Groups, and the main recommendations for national, regional and international participation in IGBP, has been published for wide distribution. Prof. R.R. Daniel, Secretary, COSTED, did a magnificent job in organizing this important Asian Workshop on IGBP and ensuring its undoubted success, as he also did in preparing this Report so rapidly.

Professor M.G.K. Menon
President, ICSU

FOREWORD

The IGBP has developed in a remarkable way since the Special Committee for the Programme was appointed by ICSU in early 1987. Over a period of three years, the international science community has been involved in the preparation of science plans for the initial Core Projects (IGBP Report 12). During that period more than 500 scientists worked on defining the science that was needed to narrow the uncertainties regarding global change and the fate of our planet. The SC-IGBP organized more than 50 working meetings in many different parts of the world to ensure the involvement of a representative cross-cut of the international science community in this process.

The IGBP is now recognized as a key component in our understanding of the functioning of the Earth system. The proposed science plan has received wide acclaim and internationally coordinated research has already been started in two of the projects and three more are expected to move into the implementation phase within the next year. In addition, the United Nations General Assembly has called on all nations to support the IGBP. Specifically, the UN also called on the international community to ensure the full involvement of the scientific communities in the developing countries in the IGBP.

At present, there are 47 national IGBP committees and we are very pleased with the national support for the IGBP. However, the distribution of national committees is uneven with relatively weak representation of developing countries, especially in Africa and Asia. The science of the IGBP Core Projects must be carried out in most, if not all, parts of the world. It is thus necessary for us to create an awareness in the scientific community of the IGBP, and its companion programmes the World Climate Research Programme (WCRP) and the Human Dimensions of Global Environmental Change (HDGEC). We must transmit the opportunities and excitement offered by the IGBP Core Projects and the necessity for scientists from developing countries to be involved in all facets of global change research; planning, and implementation of individual projects as well as regional assessments, data analysis, interpretation, synthesis and modelling.

One way by which the SC-IGBP attempts to stimulate the full involvement of developing country scientists in the IGBP is through regional conferences. The first arranged for the Southern Hemisphere was arranged in Swaziland (December 1989), the second was organized for South America in Brazil (April 1990) and this is the third such regional conference. We hope that the participants in the meeting will be

stimulated to get involved in global change research in general and IGBP Core Project research in particular. We hope to establish links to individuals and groups of scientists for the fostering of IGBP research all through Asia. We look forward to a strengthened involvement of Asian scientists in all aspects of IGBP research.

Professor James J. McCarthy
Chairman, Scientific Committee for the IGBP

PREFACE

Recognizing the importance of studying the Earth, its total environment and the intimate interconnections between their different constituent parts as an interactive feedback system, the International Council of Scientific Unions (ICSU) initiated detailed planning for the IGBP in 1986 by appointing a Special Committee to guide the planning and implementation of the programme. After a detailed and careful four-year study, and after 11 reports, the special committee and its many working groups came up with the 12th Report embodying a well-formulated approach and long-term global programme which was accepted by ICSU in 1990. ICSU has now constituted a regular Scientific Committee for IGBP (SC-IGBP). IGBP Report 12 now constitutes the primary source book for all future planning, management and strategies of IGBP. However, the original objective of IGBP: *"To describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human action"* remains unchanged. Furthermore, recognizing the scientific complementarity between IGBP and the World Climate Research Programme (WCRP) of the World Meteorological Organization (WMO) and ICSU, a close relationship has been established.

IGBP Report 12 has stated that in order to carry out research in all regions of the world, to obtain necessary understanding of global processes, there is a clear need to stimulate IGBP research in developing countries. It also became evident that special efforts, including the organization of regional meetings, will be needed to establish adequate familiarity with the scientific content and the interdisciplinary nature of IGBP in order to enable scientists from developing countries to participate in IGBP. Such regional meetings can also be utilized with great advantage to achieve a number of other desirable objectives such as: (i) to identify region-specific problems of relevance to IGBP; (ii) to familiarize scientists of the region with the national efforts in IGBP-related activities; (iii) to organize regional co-operation including observational and data networking; (iv) to arrange regional and international training opportunities; (v) to evolve recommendations for national, regional and global participation of developing countries and; (vi) to involve and expose decision makers to the nature and relevance of IGBP to developing countries. The Workshop organized in Delhi in 11-15 February, 1991 had precisely these goals.

Professor R.R. Daniel
April 1991

1. INTRODUCTION

The decision to organize the First Asian IGBP Workshop in India was taken as early as 1989 on a joint proposal made by the Indian National Committee for IGBP and the ICSU Committee on Science and Technology in Developing Countries (COSTED). Subsequently, it was agreed that the SC-IGBP would also be a joint sponsor of the Workshop. Preparatory action was soon initiated by setting up an International Programme Committee, the National Organization Committee (NOC) and a Local Organization Committee (LOC). Soon after, the decision was taken to hold the Workshop in Delhi during 11-15 February, 1991. In January 1991, there was some anxiety time because of a suggestion to postpone the meeting due to the Gulf War. However, after considerable consultation it was decided to keep to the original dates. All considered, this has turned out to be a wise decision and participation in the meeting did not suffer on account of it.

Of the total of about 200 participants, there were about 150 from developing countries namely Bangladesh, China (CAST and China Academy in Taipei), India (about 100, including 25 young scientists), Indonesia, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka and Thailand. There were also participants from Japan, Poland, U.K, U.S.A, and U.S.S.R. Furthermore, we were privileged to have for part of the time some of the ICSU Officers who had attended a meeting in Delhi just prior to the Workshop. They included, apart from Prof. M.G.K. Menon, the President, Prof. J.C.I. Dooge, the President Elect, Prof. W.E. Gordon, Vice-President, Prof. J.W.M. la Riviere, the Secretary General, and Ms. Julia Marton-Lefèvre, the Executive Secretary. Prof. Thomas Rosswall, Executive Director, IGBP, played a major role in organizing and conducting the scientific programme of the Workshop. Four active participants from Japan attended but no one from Australia New Zealand participated for different reasons. The largest delegations, after India, were from China (CAST) and China (Academy in Taipei) with eight from each.

The scientific programme comprised the following elements: two invited talks on the general framework and scientific programme content of IGBP; nine invited talks on IGBP-related problems and programmes unique or of special significance to the Asian activities for IGBP; about 30 contributed poster paper presentations; four working group discussions; and formulation of recommendations of the Workshop. On the evening of February 12, Prof. Thomas Rosswall delivered a general lecture on "Global Change - Research Challenge and Policy Dilemma" which was extremely well received by the audience. The Workshop was inaugurated by the Prime Minister of India.

It was recognized right at the outset that the recommendations from the four working group meetings and those from the Workshop in general would constitute one of the most important and useful outputs of the Workshop. The main topics of discussion at these working group meetings were the 10 IGBP Core Projects and other major elements described in IGBP Report 12. Each working group had a chairman, and a rapporteur to assist the chairman in preparing the report. Advance background papers based on IGBP Report 12, emphasizing elements of interest to the Asian region, were prepared and distributed to participants in advance. Since the first three working group meetings were held in parallel, each participant chose one working group of main interest for attendance. The fourth working group covered items of common interest including Regional Research Centers. Each working group had about six working hours with ample of time for discussion. Participants who had given advance notice of their intention and interest to raise major issues, emphasize issues of special interest to the region, or to draw attention to existing gaps and lacunae were given 5-10 minutes to present them. The summary and highlights of the working group deliberations were presented by the respective chairmen and discussed thoroughly at the plenary on the final day. Based on all these activities, the Chairman and convener of each working group prepared the final report.

The Workshop also decided to publish and distribute the proceedings of the Workshop as rapidly as possible. Notwithstanding, since even with our best efforts the preparation of the final proceedings may take about six months, it was proposed that the reports of the working groups and the recommendations of the Workshop may be printed and distributed on a more urgent basis. The hope is that such a report will provide the necessary basis for a variety of follow-up actions nationally and regionally. It can also be used to expedite decision making and facilitate fund raising. This report is the outcome of this expectation.

2. ISSUES AND RECOMMENDATIONS

The Workshop focused attention on the IGBP scientific issues of prime concern and interest to the Asian countries through: (a) Invited talks by experts from Asia and elsewhere on such issues; (b) presentation of national reports by representatives of participating countries; (c) extended and intensive discussions in four working group meetings and; (d) discussions, consultations and recommendations in the final plenary. In addition, the organizing committee prepared and circulated to the participants a few background notes to draw attention to some of the relevant points on topics for discussion, special information on matters of concern to the Asian region and the participation of developing countries in IGBP in general. Since the last item was generally endorsed by the Workshop and is of wider interest, it is reproduced below with minor changes in section 2.1. Sections 2.2 to 2.5 summarize the reports of the four working groups. These sections contain evident differences in style and presentation since they have been prepared by different pairs of chairmen and rapporteurs. No serious effort has been made to edit them in order to preserve the individuality of each working group report.

2.1 IGBP and Developing Country Interests -- Issues and Recommendations

- The ominous warnings of global changes emerge from almost all existing scientific data, interpretation and modelling. If it does set in over the coming century, the economic burden and human suffering are going to be felt in developing countries. It is therefore in the interest of every developing country to encourage and support IGBP activities because, among other things, this will help to generate and strengthen a self-reliant multi-disciplinary nucleus of scientific experts, who can provide advice to their decision makers. It is too risky to wait for the "proof" for global change. It may then be too late to take corrective action.
- It is the responsibility of scientists from developing countries to create necessary awareness in their decision makers to support these activities in the overall national interest. Where needed, the IGBP Core Projects may be able to extend consultancy to these scientists in the formulation of their national plans. Developing countries must express their serious interest by joining the IGBP as National Members and by making at least a token annual contribution.

- The tropical regions of the Earth's land surface (say $\pm 30^\circ$ latitude) are nearly all occupied by developing countries. There are a variety of IGBP-relevant scientific problems that relate to what is happening in these regions - on the land, to the vegetation, in the atmosphere and to life forms including humans. Hence, it is an excellent opportunity for developing countries to take organized and serious steps to address the problems and to participate in the benefits.
- In the absence of the ground-based information in tropical regions that is needed for IGBP projects, scientists in these and other regions will need to explore all possibilities for access to the critical data, including remote sensing. When such initiative is taken by scientists external to the region of interest, this research should only be pursued with the full involvement of scientists from the region.

A planned and serious effort is needed by developing countries, since ad hoc "cooperation" with advanced countries does not lead to enduring results that include national benefits or the development of self-reliant human resources.

- The SC-IGBP should consider a formal mechanism for facilitating developing countries' participation in the IGBP in a manner that ensures, among other things, that these activities are of national relevance and that they will lead to the growth of expert, interdisciplinary, self-reliant manpower. There is an urgent need to set up a Special Group for this purpose with at least half the members from developing countries to advise the SC-IGBP about suitable steps to be taken for promoting IGBP activities in developing countries. Links should be established with other ICSU bodies, such as the Committee on Science and Technology in Developing Countries (COSTED), the International Biosciences Network (IBN), the Committee on the Teaching of Science (CTS).
- Deliberate and planned effort should be pursued by the SC-IGBP to involve scientists from developing countries in the various committees and working groups. Even among developing countries such membership must be well distributed. Special efforts are to be taken to identify young and active scientists with leadership qualities for this purpose.
- The IGBP is planning a large number of Core Project open meetings, other planning workshops and scientific meetings during 1991-1992. All efforts are

to be taken to increase the participation of scientists from developing countries in these meetings.

- Most developing countries have institutions of higher learning in scientific education or research. Because the IGBP is interdisciplinary, almost any motivated scientist specialized in one or another scientific discipline can be trained in IGBP-related problems. When a properly motivated scientist is selected judiciously, training for the IGBP becomes the most crucial element. Therefore, the IGBP plan for developing countries must include training in all its dimensions - national, regional, international, on job, scientific exchange, etc.
- In IGBP studies, including those on the impact of global change on various Earth system components (projects like GCTE, GCEC, and BAHC), a good base-line data base is necessary. However many developing countries do not have such data available. Hence, collecting and systematizing such data is a pre-requisite. These data gaps need to be identified and the prime responsibility given to the developing countries. If we leave the full implementation of this task to the developing countries, the present dearth of scientists specialized in these fields will delay the tasks unduly.
- Regional Research Centers can play a crucial role in fostering and strengthening IGBP work in developing countries. The recommendations in the recent report from the Bellagio Workshop (IGBP Report 15) should be acted upon with some urgency. Every effort must be taken to set up at least one RRC each in South America, Africa and Asia expeditiously.
- IGBP Modelling: Modelling is involved at individual, micro- and macro-ecosystem levels in every core project. This is needed to understand and improve the studies on the key processes and systems. We also need global geosphere-biosphere models to realize the final goal of the IGBP. Developing countries often have few scientists knowledgeable about modelling techniques. They need special assistance to make a serious entry in this area. Of special need here is training and opportunities to work for extended periods with experts in the field.
- Developing countries: Their scientists, decision makers and their governments must have a commitment to support global change studies on a

long-term basis. They must demonstrate this commitment activity by extending encouragement and at least modest resources to their scientists.

2.2 Working Group I

Chairman: Dr. David Shen

Rapporteur: Dr. B.H. Subbaraya

Core Projects considered:

- International Global Atmospheric Chemistry Project (IGAC)
- Stratosphere-Troposphere Interaction and the Biosphere (STIB)
- Past Global Changes (PAGES)

2.2.1 IGAC and STIB: Total solar irradiance measurements for study of external forcing of atmospheric variability (IGAC/STIB)

Recent satellite measurements have shown that solar irradiance varies by about 0.08% over a solar cycle and it is generally believed that the total solar irradiance variations follow the variations in the high energy component most of which lies in the Lyman alpha line at 1216 Å. Further, a high degree of correlation has been established between the Lyman alpha variations of the full disk CaII K line emission at 3933 which can be monitored from the ground. The Kodaikanal solar observatory has been monitoring the CaK line emission for almost eighty years now. It is recommended that the data may be used to estimate the solar Lyman alpha flux variation in the past and further extend the study to solar irradiance variations.

It is further recommended that a precision radiometer, such as the ACRIM, may be flown on a future (Chinese or Indian) spacecraft to monitor the variability of total solar irradiance and enable the monitoring of external forcing parameters for atmospheric variability.

Tropical atmospheric chemistry (IGAC)

Measurements should be made of vertical profiles of trace gases such as O₃, CH₄, N₂O, CFC, H₂O, OH, DMS, which are important in atmospheric chemistry and greenhouse effect studies, by the use of balloons and satellite-borne and ground-based remote sensing techniques.

Development of ground-based infrared and millimeter wave techniques for monitoring total columnar content of some of the trace gases of interest in atmospheric chemistry should also be encouraged and implemented.

Inventory of trace-gas emissions in the tropical regions of Asia should be organized to include:

- Systematic and standardized methane flux measurements with properly designed sampling methods from rice paddies, swamps and marshes in all the countries in South and South-East Asia.
- Measurement of N₂O flux from different ecosystems in the Asian region.
- Standardized CO₂ monitoring to be carried out from selected remote site(s) in the Asian continent.

Aerosol and Radiation Budget Studies (IGAC/STIB)

There is a need for monitoring the short-term and long-term variations in the total aerosol loading, its size distribution and chemical composition from a network of stations in the Asian regions using multi-wavelength radiometers, size selector samples and lidars.

Studies are to be made of perturbations in the aerosol loading due to deserts and deforestation, as well as its consequences for climate including the monsoon. In addition, sources of dust particles in the atmosphere should be identified as well as dust chemistry and mineralogy.

Investigations should be made on the microstructure and radiation characteristics of clouds in the tropical (Monsoon) regions using both ground-based and aircraft-based techniques.

Acid Precipitation (IGAC/STIB)

Measurements of the pH value and determination of the sulfur and nitrogen cycles in the precipitation over the Asian subcontinent are important. Regular field measurements in different representative ecosystems in addition to measurement from the existing BAPMoN stations are also envisaged.

Boundary layer studies (STIB)

Studies of momentum flux, sensible heat flux, moisture and eddy diffusion as well as trace-gas transport across the boundary layer in different ecosystems of the Asian subcontinent are urgently needed. Measurements would include ground-based, tower-based, and aircraft measurements.

Stratosphere - troposphere exchanges processes (STIB)

Investigations are to be conducted on the dynamical parameters in the troposphere and stratosphere with a view to understanding exchange phenomena and their impact on trace-gas distributions.

Monitoring UV-B incidence at the ground (STIB)

It is important to establish a network of stations for monitoring the incidence of solar UV-B at ground, using filter photometers as well as monochrometers to study the problem of UV depletion and its impact on the biosphere.

Background atmospheric monitoring in Asia (BAMA)

Continuing and planned monitoring of the following parameters must be considered as a priority.

- (i) Trace-gas concentrations e.g., CH₄, CO, NO₂, O₃, PAN, CFCs and its substitutes
- (ii) UV-B incidence at ground
- (iii) Boundary layer parameter: ground- as well as tower-based
- (iv) Aerosol/CCN. Size distribution and chemical composition

It is recommended strongly that a working group be set up to identify the locations (sites), instruments, measurement methodology and standardization (calibration) procedures be set up. A network of stations representative of different ecosystems in different parts of the Asian subcontinent is to be established and a data collection, archival, dissemination system is to be evolved. This working group will report on the present status of ongoing and planned monitoring systems in different countries

in the Asian region and identify new activities and plan of work. It will also monitor the efficient operation of the network.

General Recommendations:

- Wherever necessary, training should be provided to scientists and technicians to maintain/operate the instruments/observatories.
- It may be important to provide funds in some cases to establish/maintain the observing stations.
- It is necessary to arrange for necessary resources to establish a data bank for archival and dissemination of the data at both national and regional levels.
- Special regional meetings should be convened for active scientists at regular intervals to discuss scientific and technical problems related to the above observational programmes.

2.2.2 PAGES

The working group recognized that there are many major opportunities in PAGES of importance to the Asian region. A phenomenon unique to the region is the Asian monsoon and information of great significance can be obtained through planned regional cooperation. For this reason, a detailed multidisciplinary study should be made of the Asian monsoon, both winter and summer, as recorded in various natural archives of deserts, loess, lakes, ice cores, marine cores, corals, etc. Research projects presently existing in China, India, Japan, Taiwan and other regions should be coordinated. For more recent periods, a high resolution of dating and quantitative data should be generated so that reliable models on a regional and global scale can be achieved.

Many countries in Asia keep old proxy historical data. China, India, Japan, Korea, Taiwan, etc., have started reconstruction of the past environment during this historical period. This information should be put into a unified data set under IGBP, and comparative analyses should be made on similar data sets from Europe, America and South Africa.

To better understand the triggering of the Ice Age, a stream III starting at about 2.5 million years is proposed and should be devoted exclusively to the initiation of the Ice Age.

After identification of Core Projects, the most crucial task for the future IGBP is to train young scientists in dealing with such a highly multidisciplinary research area. In this regard, some regional centers or institutes well equipped with necessary facilities should be set up for specific Core Projects depending upon the national interest where challenging opportunities could be offered to bright young scientists after training. This would ensure the success of the future IGBP.

Recognition and reconstruction of the palaeo- climate and palaeo- environmental condition in the Asian region is also important for a better understanding of global glacial-interglacial transition. It is therefore proposed to set up a cooperative research project among countries in Asia to study shore line variation, palaeomarine terrace, palaeotemperature indication from coral and chemical composition of marine sediment cores. The results of these studies must be related to the data from other regions.

2.3 Working Group II

Chairman: Dr. Patrick M. Holligan
Rapporteur: Dr. B.L.K. Somayjulu

Core Projects considered:

- Joint Global Ocean Flux Study (JGOFS)
- Global Ocean Euphotic Zone Study (GOEZO)
- Land-Ocean Interactions in the Coastal Zone (LOICZ)

2.3.1 Introduction

The discussion was divided into two parts, the first dealing with the two ocean projects, the Joint Global Ocean Flux Study (JGOFS) and the Global Ocean Euphotic Zone Study (GOEZO), and the second with the coastal project, Land-Ocean Interactions in the Coastal Zone (LOICZ). In each part, the chairman gave a brief description of the science and status of the projects, then the members of the working group reviewed relevant national plans, and finally a general discussion was held on the participation of Asian countries. The importance for the IGBP of

the involvement of less-developed countries was emphasized, and consideration given to the barriers that need to be overcome to allow this to happen. The latter include education on the objectives of IGBP, the availability of modern equipment for research, scientific training, access to data, and early involvement in planning. Another general point that was raised concerned the relationship between the objectives of the IGBP marine projects and of other national or regional projects in marine sciences; it is important to recognize that the latter are often concerned with issues lying outside the remit of the IGBP, but are not necessarily less important. Each country needs to consider support and participation in JGOFS, GOEZO and the LOICZ projects in the context of other research requirements.

2.3.2 JGOFS and GOEZO

Copies of the JGOFS and GOEZO core project descriptions (IGBP Report 12, Chapter 3, 1990) and the JGOFS Science Plan (JGOFS Report 5, SCOR, 1990) were available for inspection. It was noted that JGOFS is an established core project with a field programme that started in 1989, whereas GOEZO is a potential core project for the late 1990s that will build on the work of JGOFS and of the World Ocean Circulation Experiment (WOCE).

JGOFS activities in the Indian Ocean and Western Pacific were summarized:

Indian Ocean

Plans for work in the North-West Indian Ocean (NWIO) are underway with a joint Pakistan/USA study focussed mainly on coastal waters due to start in 1991, and with experiments in the upwelling regions of the Arabian Sea proposed for 1993-1995. The latter, at this stage, include research cruises by ships from India, the USA, Germany and the Netherlands. Also Taiwan is interested in participating. A major focus will be studies of nitrogen fluxes and "new" production, with particular emphasis on the importance of denitrification as a source of the greenhouse gas nitrous oxide. The results of recent research in the NWIO were presented at an International Symposium on the Oceanography of the Indian Ocean held at Goa, India in January 1991.

Bay of Bengal

The northern Bay of Bengal is a site of very large sediment influx to the ocean with important biogeochemical implications. Interest in future JGOFS experiments in this area is considerable, but there are no definite plans at present.

Western Pacific

There are various ongoing activities relevant to JGOFS by Japan, China, and Taiwan, with collaborative involvement of Korea and the Philippines, which are largely concerned with the ocean margins and include atmospheric transport studies and CO₂ measurements. Particular note was made of the ongoing (1984-1994) Kuroshio Edge Exchange Processes (KEEP) project by Taiwan to investigate exchanges across the shelf break, an understanding of which is important for the objectives of both JGOFS and the LOICZ project (see below).

Equatorial Indian Ocean

Joint studies by France and Indonesia in this region are concerned mainly with measurements of ocean-atmosphere CO₂ Fluxes.

Indian Ocean sector of the Southern Ocean

Future research initiatives relevant to JGOFS and GOEYS are expected. The region as a whole offers special opportunities for JGOFS in relation to the effects of monsoons, and of ocean margin exchanges and benthic processes on ocean productivity and carbon fluxes. China, Japan and Taiwan all have national committees for JGOFS, and one will probably be formed in India in the near future. Other countries having some capability for oceanic research and an interest in JGOFS, but no ongoing research that is directly related, include Sri Lanka and Thailand.

The main needs of South Asian countries to enable greater participation in JGOFS and GOEYS are:

- Improved communication with and, subject to active participation in the research, representation on IGBP planning and science committees.

- Resources and encouragement for the development of relevant regional studies (e.g., time-series investigations, smaller scale margin experiments) that would contribute directly to the IGBP project goals.
- Better knowledge of and regional capability in the scientific protocols established for each project. Improved opportunities for training, within the region when possible, are needed as well as resources for employing the core measuring techniques.
- Improved skills in numerical modelling techniques: It is also recognized that the case for allocating new resources to this aspect of research would be improved if modelers could link their work more directly to experimental and observational components of any field programme.

General Recommendations:

- Planning and information JGOFS networks should be established for both the Indian Ocean and Western Pacific areas. The one for the Indian Ocean would need to coordinate closely with the US planning group responsible for the 1994-1995 programme in the Arabian Sea. All South Asian countries should be encouraged to join.
- Each regional network should establish a strong link with the JGOFS Scientific Steering Committee and Project Office to promote participation of member countries in international initiatives, and the recognition of relevant regional or national projects (in particular time-series studies, and preliminary or follow-on work in sites of major campaigns such as the NWIO) as part of JGOFS.
- Regional plans for studies on air-sea interactions should be developed in the context of GOEYS, building on recognized established skills in meteorology, physical oceanography and gas-exchange measurements.
- A training programme should be initiated as soon as possible in modelling methods and core measurement techniques (see JGOFS Report 6), supported by appropriate investment into new equipment and software.

2.3.3 LOICZ

LOICZ is a proposed core project of the IGBP but a formal science plan is not yet available for general discussion and comment. The proceedings of a workshop held in late 1989 (IGBP Report 14, 1990) and an outline of the scientific issues relevant to the impacts of global change in the coastal zone (IGBP Report 12, Chapter 4, 1990) provide background information on the likely form and objectives of the LOICZ project.

Three major components are envisaged:

1. Studies of land-ocean interactions including the nature, quantities and fate of materials transported from land to sea; the dynamics of sediment erosion/accretion and coastal biogeomorphological processes; properties of the fresh seawater interface; and effects of ocean exchange processes including upwelling on the coastal zone. Particular attention is likely to be given to relative importance of interactions at different temporal and spatial scales, and to intermittent or episodic events (floods, storms, etc.).
2. Studies of biogeochemical cycling in the coastal zone with particular reference to carbon, nitrogen and other critical elements. A major focus will be the significance for the global carbon cycle of the burial of organic matter in coastal sediments, and the potential effects of eutrophication and of sediment biogeochemistry on this process.
3. Assessments and prediction of the impacts on coastal ecosystems of global changes in climate, in sea level, and in the activities of man, including land-use practices, loss of habitat due to coastal development, over exploitation of natural resources, marine waste disposal, and disturbance due to recreational activities.

Much of the research relevant to the objectives of the LOICZ will be carried out at the local or regional levels by individual countries. The IGBP should therefore serve as a means of communication between these national agencies, and new research carried out under the LOICZ project. The latter is likely to focus on the coastal areas of less well-developed countries, where changes of global significance occur but are likely to receive relatively little attention due to a lack of resources. There are important connections to be made between the LOICZ study and other IGBP projects such as GCTE and BAHC on land and JGOFS in the oceans.

Special relevance of the LOICZ project to South Asian countries

The South Asian region includes coastal areas of global significance in terms of dense and increasing human populations in the coastal zone; very large and variable discharges of freshwater, suspended sediment and dissolved matter to the coastal oceans; valuable coastal resources especially within delta systems; and important regions of interaction between the coastal ocean and open ocean such as the Indonesian shelf and northern Bay of Bengal.

Studies of how human activities on land (agriculture, deforestation, management of freshwater) and in the coastal zone (coastal development, waste disposal, recreation, fishing and marine culture) affect the land-sea boundary will not only help resolve immediate environmental problems, but also lay the basis for predicting the impacts of climate and sea level change. Particular concerns are the possibility of variations in the strength of monsoons, of increased frequency of storms and *El Niño* events, and of island submergence and groundwater salinisation. Both human activities and climate change will continue to have profound and widespread effects on coastal ecosystems, with serious consequences for human life.

General Recommendations:

To the LOICZ Project Planning Committee: During the planning phase of the project the following points should be taken into consideration:

The coastal zones of South Asia are undergoing rapid environmental change with very considerable socioeconomic consequences, so that high priority is attached to this IGBP project.

- Studies of the South Asian region are vital for a global synthesis of land-ocean interactions on account of the very large land-to-sea fluxes of water and suspended matter.
- A fully integrated approach to studies of land-ocean interactions will be required, including investigations of the combined effects of human activities, climate change and sea level rise, of the social and economic impacts of change in the coastal zone, and of the scientific basis for environmental prediction and for the development of mitigation policies.

- The establishment of a Regional Research Center in the Indonesian region with a focus on coastal studies would be a means of attracting international attention and financial support for the LOICZ project.

To national IGBP committees of South Asian countries: In view of importance attached to the LOICZ project in the context of national interests in the coastal zones it is recommended that:

- National committees should establish LOICZ working groups in order to provide information about priorities and needs to the Core Project Planning Committee.
- National databases on change in the coastal zone should be reviewed and updated.
- Resources (equipment, training) needed to participate in the project should be reviewed.

2.3.4 Special problems for South Asian countries

Certain basic requirements for active participation in IGBP marine projects were recognized. General awareness of global change problems in marine sciences needs to be increased by forming regional scientific networks and providing opportunities for relevant academic and technical training, especially for young scientists. There is a particular shortage of people skilled in numerical modelling and in remote sensing relevant to coastal and ocean processes, and regional training workshops will be required to address this problem. The various difficulties in establishing and maintaining high quality databases, comparable to those being formed by other participating countries will need to be addressed as soon as possible.

2.4 Working Group III

Chairman: Professor Thomas Rosswall

Rapporteur: Dr. M.K. Tiwari

Core Projects considered:

- Biospheric Aspects of Hydrological Cycle (BAHC)
- Global Change and Terrestrial Ecosystems (GCTE)
- Global Change and Ecological Complexity (GCEC)

2.4.1 BAHC

The BAHC Core Project aims at evaluating the effect of plant communities and ecosystems and terrain configurations on the hydrological cycle so as to gain an adequate quantitative inclusion of water transfer processes between the soil, the vegetation and the atmosphere in global change models. Certain measurements and experiments at plant level and on plots of a few km. in size are being conducted or are planned. While these experiments would yield better understanding of processes controls, the Working Group recommends that experiments be established at larger size fields, such as small natural watersheds in different ecosystems. Results from such experiments would help in developing generic models and also facilitate scaling up of relevant parameters to be put into GCMs. Long-term comparative studies of watersheds in differing ecosystems would help in arriving at a better understanding of the influence of vegetation on the hydrological cycle.

2.4.2 GCTE

The GCTE Core Project is aimed at developing the capability to predict the effects of changes in climate, atmospheric CO₂ and land use on terrestrial ecosystems and how these effects can lead to feedbacks to the physical climate system. The three different foci for activities by IGBP relate to:

- Changes in ecosystem physiology;
- Changes in ecosystem structure and;
- Study of impact of change on agriculture and forestry.

Simulation modelling as well as deriving information on ecosystem response to changing climate from palaeo records are relevant here. On the latter part and for land-cover mapping considerable expertise exists in the Asian countries. Recommendations that have emerged from the deliberations of this Working Group are listed below.

Exact definition of classification of types of vegetation or land-cover, that would be necessary for Global Biosphere Models to be developed for predicting global change has not yet been worked out. A meeting is planned by IGBP-DIS in June 1991 to discuss this. It is recommended to the National Committees of the Asian countries who already have the experience and the interest in preparing land-cover maps for global change studies to facilitate participation of their representative in this important meeting.

There is a need to promote modelling activities in Asian countries to predict changes in functional type over decades to centuries with increased CO₂ levels. At the moment this is done using Holdridge models, which are not adequate for IGBP purposes. A more refined model is being developed at present by the International Institute for Applied Systems Analysis (IIASA).

For assessing the impact of global change on agriculture, some modelling efforts are underway in industrialized countries. These, however, relate to single crop cultivation systems. Since in many countries in the Asian region a multi-crop cultivation system prevails, it is recommended to initiate modelling efforts assuming 3-crop systems, which will ideally suit the needs of most of the developing countries in the Asian region or elsewhere.

Monitoring and quantifying ecosystem changes are key activities identified under IGBP and in particular GCTE. However, at present, clarity and consensus do not exist on the methodology as well as definition of parameters needed for long-term ecosystem monitoring. Since many countries in the region have a keen interest and also the know-how for undertaking such efforts, it is recommended to IGBP to facilitate necessary consultations and dissemination of guidelines in this regard.

Studies to throw light on the pattern of vertical distribution of vegetation types on mountain slopes at different altitudes along with collateral long-term monitoring of parameters like fluxes, water flow, sedimentation rates, soil types and precipitation changes will provide very useful data in predicting changes in ecosystem structure with climate changes. This is also relevant for both BAHC and LOICZ. It is hence recommended to initiate such field studies in various mountainous countries.

A few experiments conducted in Asian countries have shown that water run-off and related effects of increased soil erosion, siltation, etc., in river basins can be effectively reduced by creating water reservoirs in upland regions. A systematic and extensive study of the effectiveness of such corrective measures has not been carried out so far. It is recommended to undertake these.

While utilizing satellite maps of various resolutions studying macroscale global change parameters, standard mathematical techniques have often to be resorted to for transforming quantitative ecological information from satellite maps of higher resolution to lower resolution or vice-versa. It is recommended to IGBP to facilitate exchange of necessary algorithms among scientists from various countries through the organization of training schools, etc.

Vegetation types in deserts are very sensitive to rainfall intensity changes. Considerable amounts of work on Thar Desert in India and Gobi Desert in China on changes in past thousands of years have been done using pollen, archaeological and historical records. It is recommended to augment these studies by linking them with palaeodata on rainfall intensity, hydrology and soil type to enable the building of ecosystem response models and also to elucidate various photosynthetic pathways adopted by nature.

Palaeo-studies on domestic plants used by human settlers and palaeopedological investigations at chosen sites in river basins to decipher palaeomonsoon, soil and rock material deposition events and rates will also provide useful information on past changes over time domains important for IGBP.

It is noted that Working Group I has recommended a meeting of palaeo-experts from various laboratories in the Asian Region to make the efforts of various groups intercomparable and standardized. It is recommended that comparison of results and techniques for the above-mentioned ecosystem response studies may also be discussed when the above meeting is organized.

Views were exchanged on the relevance of the palaeo-study on vegetation patterns in periods earlier than the last interglacial cycle. It was noted that these palaeorecords can serve as important bench marks to study ecosystem responses to large-scale geological changes. It is recommended to IGBP to have such studies considered under PAGES or GCTE.

It is recommended to take up coordinated studies of effect of increased UV-B radiation on wheat and rice, including different cultivars, that serve as major crops in Asian Countries and also assess the impact on productivity of these crops with global change. Coordination of this effort is especially important to facilitate countries which do not have necessary analytical facilities.

In this connection it is also recommended to undertake research efforts to grow crop species which have higher resistance to UV-B doses and also deep-water rice.

Efforts ongoing in a few laboratories in Asia on understanding the effects of increased temperature and CO₂ on selected plant species. While it was generally recommended to intensify such studies, it was found necessary to first focus these on important crop-types that meet primary food demands or those which may give better yields. It was also pointed out that unless planned and defined properly,

some of these experiments may give spurious results. For example, a plant may grow better in a controlled experiment not because of changed temperature or CO₂ but just because of protection provided to it from other natural or man-induced adverse factors.

With increasing population there is already a demand for higher crop yield. Global Change factors, such as increased temperature, may involve constraints by reducing crop-yield. In Asian and many other developing countries where cultivation is animal-based and not mechanized, reduced crop-yield resulting from increased temperature, e.g., would reduce fodder availability and thus the number of animals sustainable for agriculture. In view of these and other inter-linked issues it is necessary to take an integrated look at the prevalent agricultural practices, the present agricultural energy scenario, demands for productivity and their sustainability under predicted global change trends.

Studies of semi-arid areas at or near transition zones between woody and grassland vegetation are important. Such and related desertification studies are not being adequately addressed in the Asian region at present.

Systematic study in selected Asian regions on loss of C, P, N, S from land-clearing operations and their pathways need also to be augmented.

For efforts under GCTE, BAHC and GCEC a variety of maps of the Asian countries or the continent at various degrees of resolutions are needed. Noting that several such maps are already in use it is recommended that various National Committees may compile information on the unrestricted maps of their countries or the Asian region available to the scientific community at large. Soil maps, land-cover maps including vegetation types, topographic maps indicating also catchment areas and watersheds, agroclimatic or agroecological maps and palaeomaps on any of the above aspects are relevant. The map availability information is recommended to be exchanged among Asian countries and also with IGBP.

2.4.3 GCEC

This potential Core Project has not achieved enough clarity yet. The primary objective of this Potential Core Project relates to predictability of the effect of changes in land-use, atmospheric chemistry and climate on existing ecological complexity. IGBP has proposed to SCOPE and IUBS to undertake initial analysis to

answer the following two important questions related to ecological/biological diversity before a science plan for GCEC can be evolved:

What kinds of diversity (genetic, populational, community), singly or in combination, and in which kinds of ecosystems are ecologically important? What will the likely effects be of global change, land-use and climate, on the diversity of those ecosystems (genes, species, communities) if diversity is of vital importance?

In the present Working Group, views were exchanged on possible theme areas for scientific studies in the context of the Asian Region. The following were considered important to start with and hence were recommended.

Bioreserves in Asia, that already exist in relevant ecosystem zones and which were known to be stable in past years but have of late started exhibiting changes in diversity due to anthropogenic or other influences, may be utilized for monitoring with regard to species disappearances and attendant changes in ecosystem function (namely productivity, nutrient cycling, and response to disturbance). In such studies, catastrophe-prone zones could be given special attention.

Since implications of disappearing species on viability of the ecosystem to which they belong is far from understood, it is recommended to facilitate preservation of germplasms that have not yet become extinct.

Recommendations on studies of interest also to Working Groups I & II:

- (i) The fury and frequency of floods in Bangladesh have already assumed alarming proportions. There is an important and urgent need to understand natural and anthropogenic processes leading to this, the implications of inundations caused by increased floods to the coastal and estuarine ecosystems, to predict future trends, and to evolve suitable mitigation strategies. This calls for an extensive study of deforestation, soil erosion, siltation and sediment transport processes in the upland catchment areas/basins of Ganges and Brahmaputra rivers lying in Nepal, India and China. It is also important to study effects of increasing salinity on the estuarine fauna and flora.

It is recommended that these countries may mount/augment research/monitoring efforts in this direction and also pave the way to integrate scientific results emanating from such studies to meet the objectives stated above.

- (ii) It is recommended to set up a few CO₂ monitoring stations in selected ecological zones in Asia to facilitate study of regional and seasonal variations in CO₂ exchange by terrestrial biota.
- (iii) It was pointed out that in the event of ice-sheet melting and due to increased global temperatures, the earth's rotation rate will be affected because the moment of inertia of the total earth system has to be conserved. This minute change can be monitored using VLBI technique. Since China has already established a VLBI radio dish and India is in the process of setting up one, a collaborative programme between these two countries to indirectly monitor effective overall sea-level rise over a period of time is extremely worthwhile. It is recommended to facilitate undertaking such a programme.

General Recommendations:

- (i) Many activities listed in IGBP Report 12 under BAHC, GCTE, and GCEC, for example, biomass estimation, flux monitoring, etc., are not highlighted in this Working Group report since the Working Group fully agrees with the importance of these for global change studies. Many of these are already planned in Asian countries supported.

Working Group III deliberations have resulted in identifying a large number of activities of significance, in particular to the Asian Region, in relation to IGBP. Since resources available within various countries may not permit mounting too many experiments, there is a distinct need for interested countries to set priorities these in order of relative regional importance. Further, wherever inter-country information exchange or cooperation is desired a suitable mechanism for follow-up is essential. This issue needs to be addressed soon through existing channels of Asian regional cooperation and also through IGBP.

- (i) Information about special data and training services of importance to Core Projects considered by Working Group-III was exchanged by the participating countries. There is a need for IGBP and COSTED to encourage mutual utilization of these in the Asian Region.

2.5 Working Group IV

Chairman: Professor Thomas Rosswall

Rapporteur: Professor R.R. Daniel

Topics covered:

- Data and Information Systems (DIS)
- Global Analysis, Interpretation and Modelling (GAIM)
- Global Change System for Analysis, Research and Training (START)
- Regional co-operation

The following points summarize the salient issues raised during the Working Group deliberations and the general discussion, and the recommendations that ensued.

2.5.1 Data and Information Systems (DIS)

The meeting stressed the need for an efficient data and information system. Scientists, especially in less-developed countries, must be assured access to relevant data bases in order to be able to put their research into a global context. LDCs currently often lack efficient communication systems that provide access to data bases. It is also important that national data archives are identified and that information about such national programmes are communicated to all scientists involved in global change research.

The meeting welcomed the IGBP initiative to prepare a Directory of Directories as part of IGBP-DIS and requested all National Committees to assist in the compilation of national data bases relevant for global change research. It was recommended that national committees and IGBP-DIS assist in the establishment of training courses for the use of remote-sensing technologies and GIS. The National Remote Sensing Agency (NRSA), India, expressed its willingness to make available data from the Indian Remote Sensing Satellite (IRS) for users from the Asian region. The Indian offer in this respect was gratefully acknowledged.

The meeting noted the importance of UNEP/GRID for the development of geographically referenced global data sets, especially for terrestrial data, and urged UNEP to take appropriate steps to assure that this data is easily available to scientists in the region.

The meeting welcomed the initiative from the Second World Climate Conference to establish a Global Climate Observing System and stressed the need for full participation of Asian scientists in this endeavour.

It requested the IGBP Secretariat to provide further information on GCOS, and national committees to inform their relevant governmental bodies of the importance of this initiative for global change research. It noted that this issue will be discussed by the International Oceanographic Commission (IOC of the United Nations Educational, Scientific and Cultural Organization (Unesco)) and the WMO Congress. It further stressed the need for UNEP involvement in this activity and requested the National Committees to ensure that their national delegations to United Nations (UN) bodies (WMO, Unesco, UNEP) are fully informed about this initiative and its importance.

The meeting urged ICSU and IGBP to ensure that national governments are aware of the importance of free and unhindered access to data relevant to global change research. It is essential that data can be freely exchanged between scientists in different countries, and the meeting noted with concern that not all countries adhere to a principle of free and unhindered exchange of scientific data.

The meeting further recommended that the National Committees in China, India and Japan communicate IGBP needs for remotely-sensed data to their relevant space agencies. Links between the scientific community involved in global change research and the space agencies responsible for remote sensing of the Earth's environment need to be improved, both nationally and internationally.

2.5.2 Global Analysis, Interpretation and Modelling (GAIM)

The meeting noted that Asian scientists should be involved in all aspects of IGBP research including the further planning of GAIM. In order to strengthen the possibilities for this involvement, all national committees are urged to initiate training courses in modelling techniques. The meeting noted that such training was offered from India. In many instances, training courses can be organized in a regional context. The meeting also noted that the Center for Earth and Environmental Sciences in Trieste plans to arrange training in General Circulation Modelling techniques to scientists from developing countries.

2.5.3 Global Change System for Analysis, Research and Training (START)

The meeting strongly endorsed the START initiative as outlined in IGBP Report 15. The meeting considered the establishment of Regional Research Networks with affiliated Regional Research Centers as an essential component of the global change research effort. Especially for developing countries, this initiative is important to ensure that scientists from such regions are involved in all aspects of global change research. The meeting recommended that National Committees inform their governments about this need and especially that this issue should be brought to the attention of the delegations to the UNEP Governing Council and the 1992 UN Conference on Environment and Development (UNCED). National Committees should stress the importance of delegations expressing a desire for the establishment of START in their national report to UNCED. Such support will be important in order to convince governments in industrialized nations of the need for them to assist in the financing of RRCs and RRNs in regions with primarily developing countries.

The meeting gratefully noted the important statements by IGBP Committees in China (CAST and Academy in Taipei) and India that they wished to be considered for hosting RRCs. The meeting also stressed the importance of the Indonesian region and South East Asia in relation to vital global change processes and that an RRC in this region should receive high priority. The meeting recommended that the START Standing Committee take appropriate steps for the early establishment of RRCs with affiliated RRCs in the Tropical Asian Monsoon Region and Temperate East Asia.

2.5.4 Regional Co-operation

The meeting recognized the importance of future regional IGBP meetings and recommended that such meetings may consider also aspects relevant to the World Climate Research Programme and the emerging programme on Human Dimension of Global Environmental Change. As a priority, a regional meeting for South East Asia should be organized in 1992, as the participation from that region was weak at the present meeting.

In order to ensure that Asian countries are appropriately involved in global change research, it was strongly recommended that countries where no IGBP committees exist at present should consider appropriate steps for their establishment. National Committees are important:

- To prepare national priority plans for global change research.
- For more efficient communication between the international and national science communities.
- To show that developing countries consider global change research as a national priority.
- To establish a national resource base for advice to governments in relation to global change matters.
- To provide mechanisms for international funding of the participation of scientists from the countries of the region at important IGBP meetings.

The meeting noted with concern that very few Asian scientists are members of the SC-IGBP and its subsidiary bodies and recommended that the SC-IGBP take note of this fact when reviewing the composition of its Scientific Advisory Committees, Standing Committees and Core Project Planning Committees.

India generously offered fellowships for Asian scientists involved in global change research to collaborate with Indian scientists and for training leading to the degree of Ph.D. Other National Committees should consider similar arrangements within their own countries.

COSTED offered to help coordinate the activities in the region, and this generous offer was gratefully accepted. Details of the relative roles of the IGBP Secretariat and COSTED should be worked out and communicated to the National Committees.

A second meeting for Asia should be considered for 1993 and the National Committees should suggest items for discussion at the second meeting. Offers to host the second Asian meeting were received from the IGBP committees in Thailand and China (Academy in Taipei).

3. GENERAL RECOMMENDATIONS

In the concluding session of the workshop, a number of very important general recommendations were formulated. These recommendations stemmed from a compulsive recognition that unless certain special handicaps, constraints and deficiencies are removed or lessened, the full and durable participation of scientists of the Third World in a programme like IGBP will remain a good intention or at most symbolic. It is therefore stressed that these recommendations be given very special attention by decision makers, regional bodies, SC-IGBP, ICSU and ICSU bodies, UN bodies and international funding agencies.

Recognizing that the developing countries are most vulnerable to the impact of global changes both in terms of economics and human welfare, and recognizing that IGBP provides a unique opportunity for developing countries to build an expert and self-reliant manpower in the intensely interdisciplinary field of basic sciences on environment and development, all developing countries are encouraged to join IGBP and participate in it. There must be a national commitment to the programme and it must be manifest in action by governments extending encouragement and at least modest resources to their scientists.

Nearly all of the rich and varied tropical regions of the World (say $\pm 30^\circ$ latitude of all Earth's land surface), which are also the repository of the bulk of the global genetic diversity, are occupied by developing countries. They, therefore, have the privilege and responsibility to study and understand this total environment scientifically. The applications and benefits from them are immediate and immeasurable.

The ICSU Scientific Committee on IGBP (SC-IGBP) should make special efforts to understand the problems of developing countries and take such steps that will encourage, enable and strengthen genuine participation of developing countries in all phases and aspects of IGBP. As a first step it is strongly recommended that, both as a measure of its seriousness in this matter and to prepare actual plans and steps, SC-IGBP set up a working group or sub-committee to advise it on these matters. At least half the members of this working group should be from developing countries. Representatives of other concerned ICSU Bodies like COSTED, IBN, CTS etc., may also be included in this group. This must be considered as a single most important step by IGBP to give concrete shape to its intention.

Urgent steps are to be taken by ICSU and SC-IGBP to set up, in the first instance, a few Regional Research Centers in different regions of the developing world. In many ways these can act as the starting points for many important IGBP activities in developing countries.

In view of the objectives and intrinsic scientific content of IGBP, its intensely interdisciplinary nature, and the dearth of suitable manpower in developing countries, training has become a decisive element in all components of IGBP. It covers different levels of manpower: Researchers, technicians, and managers; it requires training opportunities at the national, regional and international levels; and it involves different scientific areas, core projects, techniques and methods.

An important requirement of IGBP activities is a scientific and studied utilization of remote-sensing data for a wide variety of purposes. For doing this effectively, scientists from developing countries will require suitable training, access to data preferably free of charge, and opportunities for regional and global co-operation.

Many developing countries are finding it extremely difficult to formulate scientific programmes which have the right combination of IGBP focus, national relevance, and resource demands (both human and material resources). Here consultations with IGBP experts can be extremely useful. It is recommended that ICSU-IGBP examine this matter sympathetically.

IGBP studies at all levels are system studies involving interdisciplinary explicit and subtle interconnections, feedback loops and nonlinear processes. An understanding of these complex processes, to develop a capability to predict long-term changes, necessitates a hierarchy of models culminating in a global geosphere-biosphere model. This, therefore, becomes the driving force of all IGBP projects. Without at least a modest capability in this the participation of developing countries will remain incomplete. Every effort is therefore to be taken at all levels -- IGBP, national, regional and global -- to assist developing countries in this endeavour.

Many IGBP activities involving measurements of different parameters, fluxes, intensities, etc., and long-term monitoring of changes, whether it be in trace-gas sources and sinks, sealevel rise, global warming, biological diversity, or ecology, require modern instruments and methods. Developing countries are again weak in this. They require special consideration and assistance.

4. SUMMARY AND CONCLUSIONS

The present workshop has been instrumental, among other things, in highlighting the numerous bottlenecks that are faced by developing countries. These bottlenecks hamper and weaken the effective participation of scientists from these countries in IGBP. The long list of recommendations is perhaps a reflection of this, and the complexity of the programme. Initiatives to tackle them, come to grips with realities and devise steps and action plans have to originate at a number of points simultaneously. At the country level initiatives must start with serious efforts by scientists and decision makers. At the regional level, regional academies, societies and other concerned bodies should be the initiators and at the international level initiation should be taken by SC-IGBP, ICSU and other ICSU bodies, UN bodies and other concerned bodies. As a single most important step, SC-IGBP must consider constituting a special working group for this purpose.

5. APPENDICES

1. Acronyms
2. Participant List
3. IGBP Reports

1. ACRONYMS

BAHC	Biospheric Aspects of Hydrological Cycles
BAMA	Background Atmospheric Monitoring in Asia
BAPMoN	Background Air Pollution Monitoring
COSTED	Committee on Science and Technology in Developing Countries
CTS	Committee on Teaching of Science
DIS	Data and Information Systems
GAIM	Global Analysis, Interpretation and Modelling
GCEC	Global Change and Ecological Complexities
GCTE	Global Change and Terrestrial Ecosystems
GOEZO	Global Ocean Euphotic Zone Study
IBN	International BioSciences Network
ICSU	International Council of Scientific Unions
IGAC	International Global Atmospheric Chemistry Project
IGBP	The International Geosphere-Biosphere Programme: A Study of Global Change
IIASA	International Institute for Applied Systems Analysis
IOC	International Oceanographic Commission (Unesco)
IRS	Indian Remote Sensing Satellite
JGOFS	Joint Global Ocean Flux Study
KEEP	Kuroshio Edge Exchange Processes
LOC	Local Organization Committee
LOICZ	Land-Ocean Interactions in the Coastal Zone
NOC	National Organization Committee
NRSA	National Remote Sensing Agency
NWIO	North West Indian Ocean
PAGES	Past Global Changes
RRCs	Regional Research Centers
SC-IGBP	Scientific Committee for IGBP
START	Global Change System for Analysis, Research and Training
STIB	Stratosphere-Troposphere Interaction and the Biosphere
UN	United Nation
UNCED	UN Conference on Environment and Development
Unesco	United Nations Educational, Scientific and Cultural Organization
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment

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New Delhi, India, 11-15 February, 1991

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