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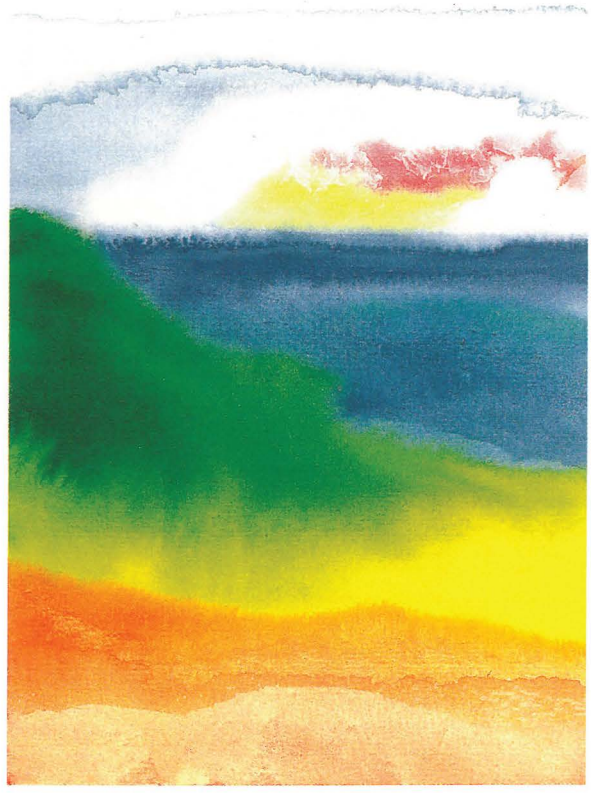

BAHC-IGAC-GCTE Science Task Team

Report of First Meeting

The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP)
of the International Council of Scientific Unions (ICSU)
Stockholm, 1995

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Massachusetts Institute of Technology
Cambridge, Massachusetts, USA
10-12 January, 1994

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Executive Summary

Within the framework of its terms of reference, the Task Team discussed and developed recommendations for multi-Core Project collaboration within the International Geosphere-Biosphere Programme (IGBP) under three headings:

- Process studies in terrestrial environments
- Integrated modelling efforts
- Partnership with developing country scientists

Three interrelated themes were considered under process studies:

- Transects and large-scale land surface experiments (T/LSEs)
- Fire
- Wetlands

The Task Team identified three categories of T/LSEs: Active/completed, planned, and conceptual. For one example T/LSE in each category the Task Team identified actions that should be taken to insure maximum scientific benefit. The examples and underlying strategic concepts for each are:

Savannas in the Long Term (SALT)

SALT conducts water budget studies both at the site level (either detailed or simplified according to facilities available, and at the regional scale using remote sensing. Such studies might be conducted in association with BAHC in order to develop the best possible upscaling approach of local to regional water budgets. Significant added value may be realised by combining the results of this ongoing effort with those from past BAHC (HAPEX-SAHEL - Hydrologic Atmospheric Pilot Experiment in the Sahel) and IGAC (DECAFE - Dynamique et Chimie Atmospherique en Forêt Equatoriale) field studies that have been conducted in the same region of West Africa.

Large-Scale Biosphere-Atmosphere Experiment in Amazonia

Representatives of BAHC (Biospheric Aspects of the Hydrological Cycle), IGAC (International Global Atmospheric Chemistry project), and GCTE (Global Change and Terrestrial Ecosystems) should become involved formally as soon as possible in planning for this linked land-surface experiment and biogeochemical cycling study in the Amazon region. Urgent action is required to avoid counter-productive duplication of effort that would result from independent planning within the Core Projects of the IGBP for related research, and from uncoordinated interaction with other groups working in the Amazon.

IGBP Northern Eurasia Study

Because of Northern Eurasia's size and uniqueness with respect to wetland and bog environments, its susceptibility to future land use change, and its potential for extensive biomass burning, this Task Team should, during the next 6 to 9 months, lead initial development of a prospectus for a coordinated IGBP research project in the Northern Eurasian boreal/tundra region.

The Task Team noted four aspects of fire research that would benefit from increased joint attention by BAHC, IGAC, and GCTE: 1) the long-term effects of burning versus protection on soil chemistry, 2) the composition of fire plumes from a variety of regions, 3) collection and sharing of satellite data and field data for their interpretation, and 4) development of predictive capabilities for future fire frequency and extent with changing climate and land-use patterns.

The Task Team identified two main themes under which BAHC, IGAC, and GCTE research in wetlands potentially could be linked: 1) the carbon cycle in wetlands and associated stream systems, and 2) trace gas emissions, in particular those of methane and nitrous oxide.

The Task Team identified an increasingly urgent need to bring together the modelling communities within BAHC, IGAC, and GCTE, and recommends that this be done in the format of a science conference on terrestrial systems modelling. The goals of such a conference should be: 1) to inventory key data requirements in each of the Core Project modelling efforts, 2) to identify and develop model components for processes of common interest (e.g., C and N cycles, phenology), and 3) to develop a coordinated and detailed methodology for applying models across the full spectrum of scale, from point through patch and landscape to regional and global domains. The Task Team noted that it would be highly desirable for GAIM (Global Analysis, Interpretation and Modelling) to take the lead in organising this conference in consultation with IGBP-DIS (IGBP-Data and Information System).

The Task Team agreed that BAHC, IGAC, and GCTE (and perhaps other Core Projects) can benefit from collaboration with each other in respect to their developing country interaction in several ways: 1) Many developing countries have to be approached in a top-down fashion wherein a single, coordinated approach from a group of Core Projects would be better than several individual approaches, 2) A crucial first step is often to establish functional contact networks in developing countries: Core Projects should share contacts and experiences, and 3) The Core Projects must ensure that the three-way interaction among Core Projects, developing countries, and the Global Change System for Analysis, Research and Training (START) is functional and that it achieves mutual objectives.

The Task Team concluded that its discussions were most fruitful and timely, and that they should serve as a good first step toward increasing the efficiency of the IGBP as a whole, and of the Core Projects concerned. It is proposed that a second Task Team meeting be convened approximately in October, 1994. The specific objectives of this meeting would be to:

- Review in detail the status of planning for studies in the Amazon region (Large-Scale Biosphere-Atmosphere Experiment in Amazonia) and identify further actions necessary to ensure that participation of BAHC, IGAC, and GCTE scientists in this planning is adequate

- Draft a prospectus for an integrated IGBP Northern Eurasia Study (additional experts from the 3 Core Projects may be invited)

- Review progress on planning for a scientific conference on modelling relevant to BAHC, IGAC, and GCTE (GAIM representative to be invited)

- Determine specific ways in which START can assist BAHC, IGAC, and GCTE in fostering partnerships with developing country scientists in key regions (START representative to be invited)

Introduction and Objectives

Biosphere-atmosphere exchange of certain elements and compounds is a controlling factor in climate and in terrestrial productivity. Exchanges between the atmosphere and terrestrial ecosystems are complicated because they involve physical, biological, and chemical processes at the land surface, chemical and radiative processes in the atmosphere, and transport processes in both the atmosphere and terrestrial ecosystems. There are, however, many gaps in the understanding of these processes. Some of these gaps can be addressed best through cooperative field experiments and modelling efforts involving scientists with expertise in biogeochemistry and ecology of terrestrial environments and in the atmospheric and hydrological sciences. Specifically, the potential exists for beneficial collaboration among researchers involved in the BAHC, IGAC, and GCTE Core Projects of the IGBP. It is necessary for these projects to identify how collaborative planning and execution of field work, modelling efforts, and partnerships with developing country scientists might lead to scientific advances and to benefits to the global community greater than an individual Core Project could achieve alone.

In recognition of this, in September, 1993, the Officers of the SC-IGBP accepted a proposal from the Core Project offices to establish and hold a first meeting of a joint "BAHC-IGAC-GCTE Science Task Team". The goal of the Task Team is to ensure effective communication among the terrestrial, hydrological, and atmospheric research communities within IGBP and to assist with the planning and coordination of joint studies. The specific objectives of the Task Team are to:

- Review the available information on proposed hydrological and biogeochemical exchange studies in terrestrial environments which would benefit from coordination among BAHC, IGAC, and GCTE
- Discuss the feasibility of coordinated field experiments and to evaluate the manpower resources required to undertake them
- Prioritise among proposed coordinated field activities in the context of the BAHC, IGAC, and GCTE implementation plans
- Promote the development of relevant coupled atmosphere-terrestrial biosphere biogeochemical models
- Make recommendations to the Scientific Steering Committees (SSCs) of BAHC, IGAC, and GCTE on the above within a specified period, say, two years

The Task Team may disband after that period unless reconstituted by all three SSCs. The remainder of this document summarises the discussions that took place during the first meeting of the Task Team.

Process Studies in Terrestrial Environments

The Task Team noted the difficulties in collaboration among the hydrological, atmospheric chemical, and ecological studies in the past due to the different time and, especially, space scales of the studies. Major hydrological land-surface experiments and, to some extent, trace-gas flux field studies tend to be intensive field campaigns carried out over short time spans at one or two sites. Ecological studies, on the other hand, require a number of sites distributed along an environmental gradient of order 1000 km long operating over decadal time scales. This mismatch of scales has often vitiated collaboration in the past.

IGBP could play an important role in improving collaboration by ensuring that the land-surface experiments and transects are coordinated so that the latter are carried out at one or more sites along the transects. The land-surface experiments would benefit from much more extensive background understanding of the ecology of their study regions, thus allowing extension of their results in time and space, and the ecological studies would be enhanced by detailed, fine-scale investigations of important processes at one or more of their sites. The transects also provide the framework for the scaling up of models of various types and for the linkage of remote sensing data to the ground-based studies.

The Task Team recommends that IGBP strive to improve collaboration on terrestrial process studies by i) developing transects to incorporate sites of past land-surface experiments, ii) assisting the development of projects in the planning phase to achieve better collaboration, and iii) taking the lead in defining the science plans for new terrestrial process studies.

Transects/Large-Scale Land Surface Experiments (T/LSEs)

The Task Team identified several regions in which T/LSEs have been established or conducted, are being planned, or have been conceived. A selection of these is given in Table 1.

For one example T/LSE in each category (active/completed, planned, conceptual) the team developed recommendations for strategies to insure maximum scientific benefit. A summary of the examples is given in Table 2 and in the following paragraphs.

Savannas in the Long Term (SALT)

This active program is based on an integrated study of the processes linking the mechanisms of energy and matter flows to those of species and vegetation dynamics in the West African savannas region. For so doing, detailed process studies (common minimum data set and specialised topics) are conducted at 9 major and a number of secondary sites in 5 countries. SALT aims at analysing the expression of functional and dynamic processes at different spatial and temporal scales, i.e., understanding the ecological mechanisms of changes in systems properties considered at increasing spatial scales from patch to region.

Table 1. Selected Process Studies in Terrestrial Environments.

Region	BAHC	IGAC	GCTE*
Humid tropics	LBA	BIBEX (STARE) BATGE (EXPRESSO)	Amazonia Central Africa SE Asia
Semi-arid tropics	HAPEX-SAHEL	BATGE (DECAFE) BIBEX (SAFARI)	SALT Southern Africa NATT
Temperate	FIFE	TRAGEX (TRAGNET) MILOX	U.S. Prairies China
Temperate (Land-use change)	EFEDA	TRAGEX (Europe)	Europe
Boreal/tundra	BOREAS Tundra	HESS BIBEX	Canada Alaska Scandinavia Siberia

* Location of existing, developing, or proposed transects

Table 2. Example Studies for Initial Collaborative Efforts.

Region	BAHC	IGAC	GCTE
Active/completed			
Semi-arid tropics	HAPEX-SAHEL	BATGE (DECAFE) BIBEX	SALT
Planned			
Humid tropics	LBA	BIBEX (STARE) BATGE	Amazonia
Conceptual			
Boreal/tundra	Tundra	HESS BIBEX	Siberia

Spatialisation is accomplished using both bottom-up and top-down approaches. Thematic maps produced at site scale (30 x 30 km) are extended to the square degree and interpolated between sites using satellite imagery. Surface parameters (vegetation, soil, fire) are also studied directly at the regional level. The range of studies includes primary production and soil biological processes, soil-vegetation-atmosphere interactions, soil surface characteristics and consequences on soil water status and water/wind erosion, vegetation structure and dynamics, ecosystem responses to disturbances (e.g., climate, fire, grazing, cultivation), and modifications of water flows from small catchments as an integrative and diagnostic element of vegetation and soil changes. Integrating processes over larger scales involves establishing relationships between satellite imagery and field measurements under four themes: a) identification and hierarchical classification of land cover types, b) biomass, phenology, and primary production, c) hydrological modelling using remote sensing, and d) detection of fires and monitoring burned areas and biomass in space and time.

The Task Team recommended three specific actions:

1. Nomination of key contact people,

2. Exchange of briefings of existing work in West Africa, and of relevant data, among the Core Projects (via the Core Project Offices - CPOs), resulting in

3. Enhanced data flow and, if possible, modifications to experiments that will add value to ultimate products.

The key person identified for GCTE is J.-C. Menaut, and those for IGAC are R.A. Delmas and J.S. Levine. Key BAHC people are to be determined. Menaut and Delmas have been in communication with each other for some time, so interaction between IGAC and GCTE is already occurring, and will continue. They will prepare a summary of collaborative activities and circulate it to the CPOs. Menaut will also prepare a briefing on current BAHC-related research in SALT and send it to the BAHC CPO. Relevant BAHC Focus leaders will then respond and possibilities for collaboration explored from there. The BAHC CPO will identify a HAPEX-SAHEL representative who will prepare a briefing for circulation to the CPOs on ecological/data studies that would add value to (extend in space and time) this completed study.

Large-Scale Biosphere-Atmosphere Experiment in Amazonia

Although the importance of human-driven land-use change in altering biogeochemical cycles for nearly all regions of the world was recognised, the Task Team placed priority on land-use change in the humid tropics because of its significance for the global carbon cycle. The working group report on land-use change from the recent GCTE Transects Workshop (Marconi Conference Center, Marshall, CA (USA), August 1993; see Appendix 1) was discussed and endorsed as an appropriate framework for IGBP studies on land-use change in the humid tropics.

The Large-Scale Biosphere-Atmosphere Experiment in Amazonia project plans, which call for a coordinated land-surface experiment and biogeochemical cycling study in the Amazon basin, were reviewed briefly in light of the objectives of the three Core Projects. The Task Team noted that although the biogeochemistry/ecology theme has a number of

components that address some Core Project objectives, it does not address fully their major objectives and thus might benefit from some modifications and additions. The Task Team agreed that the working group report from the GCTE Transects Workshop provides a useful structure around which an integrated Amazonian study can be developed (within the context of a pan-tropical series of comprehensive studies involving Southeast Asia and equatorial Africa as well). The report could provide a new impetus for bringing many of the groups involved in Amazonian research together with the Large-Scale Biosphere-Atmosphere Experiment in Amazonia initiative to achieve a coordinated study on land-use change in the humid tropics.

The Task Team identified several specific actions for furthering development of collaborative IGBP research in the Amazon:

- There is a growing feeling among many people involved in Amazonian research that the various planned and proposed biogeochemical studies should be coordinated to achieve maximum efficiency. An opportunity exists for IGBP to play a leadership role in working with other groups (e.g., GEWEX, the EC, NASA, the U.K. TIGER program, alternatives to Slash-and-Burn) to develop a collaborative effort in the Amazon.

- A key meeting will be held on 18 March 1994 in Washington, DC, to bring together some of the main players in Amazonian research to integrate their plans into a more coordinated project. Task Team members A. Becker and J. Shuttleworth will participate in this meeting. The Task Team recommends that GCTE and IGAC representatives should attend as well to represent these Core Projects' interests.

- The working group report for an integrated IGBP study of land-use change in the humid tropics from the GCTE Transects Workshop (Appendix 1) should be circulated to the SSCs of BAHC, IGAC, and GCTE and to the Scientific Committee of the IGBP (SC-IGBP) for modification, as appropriate, and approval as the agreed IGBP framework for such studies.

IGBP Northern Eurasia Study

The idea of a coordinated, IGBP-initiated study in the Northern Eurasian boreal/tundra region originated during this Task Team meeting. Because of its size and uniqueness with respect to wetland and bog environments, its importance in the global C cycle, its susceptibility to future land use change, and its biomass burning potential, the Task Team agreed that it is essential to characterise, study, and monitor this hitherto not sufficiently studied region. Specifically, it is recommended that during the next 6 to 9 months, the Task Team should pursue initial development of this idea into a prospectus for a coordinated IGBP research project in the Northern Eurasian boreal/tundra region which can be sent to relevant Russian institutions and IGBP bodies for consideration, review, and further specification. The major aspects of the effort and the suggested time frame are as follows:

- By the end of March identify and have the CPOs contact additional key people about contributing to an IGBP Northern Eurasia Study.

- By the end of July have each Core Project team develop a "desired conceptual framework" from its perspective.

- By the end of September have the CPOs merge the framework documents into a single, integrated draft study prospectus.

- During a second Task Team meeting in October discuss and finalise the project prospectus and determine a plan for proceeding further.

Some considerations relevant to developing this prospectus are described in the remaining sections of this report.

Fire

Fire exerts an important influence on terrestrial ecosystem structure, functioning, and dynamics and has a drastic seasonal impact on the radiative, energy and water budgets of fire-prone or accidentally burned areas. It is a major direct source to the atmosphere of the radiatively active gases carbon dioxide, methane and nitrous oxide, and of other nitrogen oxides, carbon monoxide, hydrocarbons, and halocarbons that have a major influence on the distribution of atmospheric ozone. Water vapour, aerosols, and vertical convective currents resulting from fire lead to the formation of cumulus clouds and precipitation, and thus directly influence regional hydrological cycles.

Fire alters the structure of plant canopies, especially leaf area and distribution, and changes land-surface albedo by replacing standing biomass with ash and bare ground. Removal of vegetation impacts water runoff from land surfaces and its infiltration into the soil. Fire impacts the biogeochemical cycling of nitrogen in soil resulting in post-burn enhancement of emission fluxes of nitrous and nitric oxides from some ecosystems. Although the phenomenon is short-lived and may not be of significant importance, the long-term effects of burning versus protection on soil chemistry are unclear and require further study.

The trace gas composition of fire plumes depends strongly on fuel type and, therefore, varies widely according to the type of ecosystem burned (e.g., savanna versus forest). Very recent measurements in African fire plumes suggest that fire may be a globally significant source of methyl bromide. Bromine atoms released from methyl bromide contribute to stratospheric ozone destruction. Fire plume composition data from other regions are necessary for construction of realistic global emissions inventories.

BAHC, IGAC, and GCTE have different but complementary objectives in regard to satellite imagery. For example, fire timing and extent, and amount and composition of burnt biomass are of interest to GCTE, real-time information on fire occurrence and location, plume transport and dispersion would benefit IGAC, and resulting atmospheric turbidity data are important for BAHC. Close collaboration in sharing satellite data and field data for their verification must be encouraged.

Recent observations from space indicate that fire is much more widespread than previously believed. For example, the May 1987 burn of more than 60,000 km^2 of boreal forest in north-eastern Asia demonstrates that major fires are not restricted to the tropics. Satellite observations also indicate that fire frequency is increasing with time. Global climate change may lead to greater frequency and extent of fire. Conversely, global land-use change may alter burning practices, leading to landscape fragmentation, increased

cultivated area, and, consequently, decreased fire frequency and extent. The prediction of future fire frequency and extent with changing climate and land-use patterns is very important and should be a very high research priority.

Wetlands

The Task Team noted that the role of freshwater ecological research is under discussion within the IGBP and will be addressed specifically at the March SC-IGBP meeting in Bonn. The decisions taken by the SC-IGBP will likely affect the organisational structure of freshwater research within IGBP and, thus, the way in which collaborative work may be developed. Nevertheless, the Task Team discussed the issue and noted areas in which the three Core Projects can work together now on wetlands problems.

Wetlands have a number of special characteristics that provide cross-cutting themes of interest to IGBP. With respect to hydrology and BAHC, wetlands comprise large water storage reservoirs that generally evaporate water at the potential rate and influence overall system response and water balance at basin or continental scales. For example, distributed hydrology models which are being used to link hydrology with ecosystem processes focus in part on the dynamics of water-saturated areas of watersheds to predict discharge and spatial patterns of evapotranspiration and soil drying. Although varying in size, these saturated areas are common to watersheds of all biome types. Wetlands surrounding lakes and swamps fluctuate greatly in size and influence pathways of water return to the atmosphere. This is also characteristic of many river basins that approach continental scale such as the Nile and the Amazon. The following table (Table 3) contains some examples of BAHC, IGAC, and GCTE interests that relate to wetlands.

Table 3.

Core Project:	**BAHC**	**IGAC**	**GCTE**
Major interests:	Basin hydrology Continental hydrology	CH_4 emissions N_2O emissions	Carbon cycle Carbon storage
Related efforts: (present or planned)	BOREAS NOPEX	HESS TRAGEX RICE	Alaskan transect N. Europe transect Rice production network

Due to the large potential changes in the water table and in soil moisture in the uppermost layer of soils, wetlands dynamics offer a great potential for monitoring and analysis with remote sensing techniques such as synthetic aperture radar. It is possible that ecosystem manipulations relevant to potential global climate change, even at large scales, may be easier to carry out in wetlands than in other ecosystem types via water table alteration and/or modifications of water chemistry.

The potential linkages among BAHC, IGAC, and GCTE can be focused on two main points: 1) the carbon cycle in wetlands and associated stream systems, and 2) trace gas emissions, in particular methane and nitrous oxide. Due to alternating flooding and

draining of wetland soils, linkages in the carbon cycle take on added importance with resultant large changes in momentary carbon fluxes affecting net production, respiration and decomposition, carbon storage, methane generation, or export in stream systems. Organic carbon transport in stream and river systems is a component of the BAHC operational plan, and in many systems presently under study provides additional links to ecosystem function where food chains are tied to peat or organic particulates (e.g., tundra streams). Anaerobic soil conditions cause wetlands to be highly active methane generating systems in rice-growing areas of the world, in river delta regions, in temperate and boreal peat lands, and in Arctic tundra. The Siberian marshes that are little studied could well be one of the largest sources of methane on the planet. Peat land drainage related to land-use change in warm climates may create "hot spots" of nitrous oxide production, resulting in flux rates greater than have been detected until now anywhere in the world. Thus, the Task Team recommends that, wherever appropriate, BAHC, IGAC, and GCTE collaborate on wetlands research involving carbon cycle studies and trace gas emissions. The high-latitude T/LSEs offer a good opportunity for collaboration in the northern wetlands. In particular, the proposed IGBP Northern Eurasia Study would provide an excellent opportunity for the integrated planning and execution of a wetlands research program involving all three Core Projects.

Modelling

In recognition of the commonality in purpose among BAHC, IGAC, and GCTE, the Task Team identified an important opportunity to coordinate modelling efforts and thereby enhance the ultimate productivity of each of the Core Projects. The study of global change with an emphasis on land-atmosphere feedback argues strongly for an integrative modelling approach in terms of both data utilisation and algorithm development. As a first step, it will be necessary to understand fully the data and information requirements of each of the individual Core Project modelling efforts in order to coordinate these efforts sensibly.

A key theme common to all Core Projects is the development of tools to scale dynamics generated at smaller scales into sequentially larger spatial and temporal domains. The scales span several orders of magnitude over space and time so that providing a framework for the integration of dynamics poses a significant intellectual challenge. Thus, the flux chamber experiments of IGAC must ultimately be extrapolated to generate regional and global emissions inventories. A similar progression of ecosystem modelling in GCTE and of Soil-Vegetation Atmosphere Transfer (SVAT) modelling in BAHC will transfer dynamics from patch to stand scales, to regions and drainage basins, and finally to continental and global domains. The Task Team identified the need for common definitions of scale, adoption of standard techniques for cross-scale aggregation/ disaggregation, and the development of a common data assimilation protocol for passing information among the individual and potentially linked Core Project models.

To achieve this, a science conference on terrestrial systems modelling should occur before the end of 1995. The goals of this conference should be to:

- Inventory key data requirements in each of the Core Project modelling efforts
- Identify and develop model components for processes of common interest (e.g., C and N cycles, phenology)
- Develop a coordinated and detailed methodology for applying models across the full spectrum of scale, from point through patch and landscape to regional and global domains

To ensure greatest benefit from this conference, it should be cast as a scientific rather than as a strategic planning meeting. The participants should be modellers who are active in each Core Project and capable of exchanging detailed technical information. A series of scientific task groups should be formed to pursue specific, collaborative modelling projects. Illustrative cooperative activities could be cast with one or more Core Projects taking the lead on particular issues. Possibilities include evapotranspiration functions (BAHC), atmosphere-land surface trace gas and aerosol exchange processes (IGAC), carbon and nitrogen cycling (GCTE), and phenological drivers (BAHC, IGAC, and GCTE). Specific work plans for collaborative efforts should emerge from this conference along with a clear map of cross-Core Project activities. The Task Team notes that it would be highly desirable for GAIM to take the lead in organising this conference in consultation with IGBP-DIS.

Partnership with Developing Country Scientists

The Task Team agreed that it is crucial to the success of IGBP activities in key areas that two separate science agendas do not develop, one for the Core Projects and one for START. The Core Projects must actively ensure that interaction with scientists from developing countries takes place. They must not assume that START will accomplish this, or that simply "keeping the door open" is sufficient.

Core Projects that have had operational contacts with START are seriously concerned that START is inadequately linked to the central science agenda of the IGBP, especially in Africa and Latin America. On its currently perceived track START may become an impediment to, rather than a facilitator of Core Project research in some regions.

The appropriate model for interaction with developing country scientists depends a great deal on local circumstances and culture. There are several successful paradigms: SALT, DECAFE, SAFARI, GCTE activities in SE Asia, and the GCTE rice production network. Some general principles emerge:

- Developing country scientists should be engaged as equal partners, rather than exclusively as trainees, field assistants, or token participants.
- Developing country scientists must be involved right from the outset of the planning process so that the activity is jointly owned.
- Shared research activities should lead the interaction, rather than institution building, training, or "capacity building". These latter efforts should follow naturally from the science requirements.
- The IGBP Core Projects must be sensitive to local priorities.

The Core Projects can benefit from collaboration with each other in respect to their developing country interaction in the following ways:

- Many developing countries have to be approached in a top-down fashion. In these cases a single, coordinated approach from a group of Core Projects, perhaps through START, would be better than several individual approaches.
- A crucial step is often to establish functional contact networks in developing countries. Core Projects should share contacts and experiences.
- The Core Projects must ensure that the three-way Core Project - developing country - START interaction is functional and that it achieves mutual objectives. Whenever possible, such interactions should build on existing collaborative research programs, some of which may already include a partnership/training component.

Next Steps

The Task Team concluded that its discussions were most fruitful and timely, and that this meeting was a good first step toward increasing the efficiency of the implementation of the Core Projects concerned and of the IGBP as a whole. The participants agreed that a second Task Team meeting approximately in October, 1994, is very desirable. The specific objectives of this meeting would be to:

- Review in detail the status of planning for studies in the Amazon region (the Large-Scale Biosphere-Atmosphere Experiment in Amazonia) and identify further actions necessary to ensure that participation of BAHC, IGAC, and GCTE scientists in this planning is adequate
- Draft a prospectus for an integrated IGBP Northern Eurasia Study (additional experts from the 3 Core Projects may be invited)
- Review progress on planning for a scientific conference on modelling relevant to BAHC, IGAC, and GCTE (GAIM representative to be invited)
- Determine specific ways in which START can assist BAHC, IGAC, and GCTE in fostering partnerships with developing country scientists in key regions (START representative to be invited)

In keeping with the cooperative spirit underlying the team's origin, the participants agreed that the Task Team should not have a formal Chair. Rather, the responsibility for convening future meetings of the Task Team should be rotated among the Core Project Offices of BAHC, IGAC, and GCTE. The GCTE Core Project Office will bear this responsibility for a second meeting provided, of course, that the SSCs of the three Core Projects accept the recommendation that such a meeting should be convened.

Appendix 1
GCTE Transects Workshop Working Group Report on Land-Use Change in the Humid Tropics

Why Transects in the Humid Tropics?

The humid tropics are a high priority region for global change studies because of the significant impact of land-use change (usually the conversion of forests to agricultural use) on biogeochemical cycles, particularly the global carbon cycle. The impact occurs in two phases: (i) the initial clearing of the forests, the techniques of which are important in determining the short-term alterations to biogeochemical cycles, and (ii) the type and intensity of the subsequent agricultural use, which are critical in determining the longer term effects.

In addition to biogeochemistry, the conversion/intensification sequence impacts on other important, related ecosystem processes. These include the biotic control of water and energy exchange between the land surface and the atmosphere; the composition, and structure and production of regrowth forests; and ecological complexity and its relationship to ecosystem function.

In these transect studies the primary focus is on biogeochemical cycles. The overall objective of the studies is to determine the effects of land clearing and subsequent land use on quantities, pathways and processes of carbon and nutrient loss (or gain). The studies will also examine the effects on the hydrological cycle and on the composition, structure and production of regrowth forests. Although studies of the impacts of clearing and subsequent land use on the complexity/function relationship are not included in the design of these transects, the transects do offer an excellent framework for their later inclusion, as well as for collaborative work on climate change impacts on tropical agriculture and for other GCTE Focus 3 studies.

The use of the term "transect" here refers to a "conceptual" transect rather than a physically contiguous transect based on a variation in a controlling environmental parameter such as temperature or precipitation. For land-use change in the humid tropics, the controlling parameter on which the gradient is based is intensity of land use (normally determined by agricultural strategies and techniques).

Which Transects?

We propose six studies, two for each of the three major humid tropical regions - Central and South America, Central Africa and Southeast Asia. In each case one study will focus on forests at the wetter end of the range while the other will be centred on drier tropical

forests. The dry tropical forests are important because they are experiencing rapid rates of land conversion, the conversion from forest to agriculture is usually permanent, and the rates of gas emission (particularly N_2O) are high.

The comparison of a wet with a dry tropical forest in each of the three regions will give insights into how precipitation may modulate the responses of biogeochemical cycles to land-use change. Thus, although dry, closed canopy forests are not normally considered to be part of the humid tropics, they will be for the purposes of this study.

Table 4 below presents the locations of the transects, with question marks indicating locations that are only notional at this stage. The three locations without question marks are areas where known existing or planned projects can form parts of a study.

Table 4.

	Humid Forest	Dry Forest
Central/South America	Amazon	Mexico
Southeast Asia	Sumatra	Thailand (?)
Central Africa	Cameroon (?)	?

An Integrated IGBP Approach

Studies on land-use change in the tropics are important components of a number of IGBP core projects and framework activities, including IGAC, BAHC, GCTE and LOICZ (Land-Ocean Interactions in the Coastal Zone). Below the objectives of each are briefly summarised.

IGAC

IGAC's interest in the tropics is primarily through two of its Activities - BATGE and BIBEX. BATGE's objectives include to:

- Determine fluxes of trace gases between tropical biomes and the atmosphere
- Determine factors that control these fluxes
- Assess effects of land-use change on fluxes
- Predict impact on fluxes of changes in climate and land use, including soil physical, chemical and microbial status, surface vegetation and atmospheric processes

The objectives of BIBEX include:

- To characterise production of gases and aerosols from biomass burning
- To determine the consequences of burning for regional and global atmospheric chemistry and climate
- To determine the effects of fire on post-fire exchanges of trace gases
- To determine the biogeochemical consequences of deposition of burning products

BAHC

BAHC has four major objectives in the tropics:

- To determine the role of vegetation in modulating the transfer of water and energy from the land surface to the atmosphere. This includes not only the gross changes associated with the conversion of forest to agriculture, but also the more subtle changes associated with changes in land management practices and the resultant changes in biogeochemistry
- To determine runoff generation dynamics at "patch" level (infiltration, overland flow, quick return subsurface flows, including macropore flow/interflow and groundwater recharge) for present and future land use conditions
- To determine the element fluxes (waterborne transport) associated with all of the runoff components
- To develop predictive models that integrate over a river basin the individual patch-scale runoff and waterborne transport processes, and to determine the impact of land-use change on these processes

GCTE

GCTE has a number of objectives in the tropics:

- To determine the effects of land clearing and agricultural intensification on quantities and pathways of carbon and nutrient loss (and their regulation)
- To determine the interactive effects of clearing/intensification, soil and climate on the structure, composition and production of subsequent regrowth forests
- To determine the interactive effects of clearing/intensification and climate on soil erosion
- To determine the effects of clearing/intensification on the ecological complexity/ecosystem function relationship in humid tropical systems
- To determine the impacts of change in atmospheric composition and climate on tropical agricultural systems

LOICZ

LOICZ has one major objective related to land-use change in the tropics:

- To determine the influence of land-use change, particularly the conversion from forest to agriculture, on the delivery of sediments from land via river systems to the coastal sea

The Research Design

The framework for the IGBP transects in the humid tropics is based on an integration of the relevant components of the IGAC, BAHC, GCTE and LOICZ operational plans. The transects will have five elements - (i) intensive process studies (the "budget-closing experiment") at one or possibly two sites in each transect; (ii) a more extensive network of observational studies along the major gradient (land-use intensity); (iii) networks of measurements and associated algorithms designed for scaling results to the region; (iv) remote sensing studies to determine the extent, rate and type of land conversion and subsequent land use; (v) modelling studies to synthesise and integrate the experiment results and to quantify the consequences of future land-use change scenarios.

(i) Intensive process studies

Although a number of biogeochemical studies have already been carried out in the humid tropics, particularly in the Amazon Basin, there has not yet been a study which closes element budgets associated with the land-clearing process. Thus, the intensive process study proposed here aims to measure all the major pathways of element loss, hydrologic as well as atmospheric, during and following land clearing.

The study will be based on a small watershed scale (a few km) and carried out over a 5-year period to follow the biogeochemical changes associated with the conversion of primary forest to agricultural use. Both atmospheric and hydrological pathways of element loss will be measured, as well as changes in soil pools. The large pulse of element loss (again both atmospheric and hydrological) during and immediately after the clearing (burning) of the forest will be measured. The change in element fluxes with the subsequent agricultural use of the land over a 3-4 year period will be determined. In short, an intensive biogeochemical process study of the land cover conversion process itself will be undertaken.

Atmospheric measurements will include both chamber and tower-based (eddy correlation) measurements of emissions of important trace gases (e.g., NO, N_2O, CH_4, CO, CO_2). Hydrological fluxes will be determined by measurement of stream flow, sediment loads and chemistry in the watershed. Soil-plant process measurements include soil moisture and structure, litter decomposition rates, and microbial process measurements. The measurement regime will be carried out throughout the 5-year period, before, during and after land clearing.

The land clearing technique and subsequent land use adopted for the study will be chosen to be representative of the region. Table 5 shows a matrix of clearing technique (slash-and-burn, mechanical, targeted logging) and land-use type (pasture, agriculture - low to high input, plantation forestry, regrowth) with representative combinations for Central/South America and Southeast Asia indicated. These are suggestions only at this stage. More discussion and consultation with groups working in the regions is required before a final selection is made.

Table 5.

	Conversion Technique		
Land-Use	**Slash-and-Burn**	**Mechanised**	**"Targeted" Logging**
Pasture	Mexico	Amazon	✕
Low Input ↓ Agriculture ↓ High Input	Sumatra		✕
Plantation Forestry	✕		✕
Post-logging Regrowth	✕	✕	Malaysia

☐ = Suggested location for intensive (budget-closing) experiment.

Site characteristics:

1. Soil: high → low fertility
2. Land-use history
3. Climate: wet-dry; seasonality
4. Vegetation
5. Topography

(ii) Extensive network

The intensive process study will be complemented by a regional network of sites measuring element fluxes on plots of various land-use types and histories [e.g., chronosequence studies]. This network will form the primary gradient for the humid tropics transects. The sites, of course, will not be physically contiguous or form a linear pattern in physical space, but will be organised by intensity of land-use to form a conceptual transect.

The network will consist of small, plot-scale sites at which a number of processes are measured. Atmospheric exchange will be monitored by standardised chamber measurements of important trace gases (NO, N_2O, CH_4, CO, CO_2). Soil measurements include soil moisture dynamics; groundwater chemistry, carbon, nitrogen and phosphorous stocks; carbon and nitrogen isotopes; microbial biomass; and nitrogen mineralisation and nitrification.

At some sites, tower-based land-atmosphere energy and trace gas exchange measurements (sensible and latent heat, CO_2, HCs, O_3, CH_4, NO, NOx, N_2O) will be made. This will be aimed at determining the biotic control on water and energy fluxes, in addition to element fluxes, from the land surface and will provide an excellent set of reliable data for the validation and improvement of land-surface models in General Circulation Models (GCMs).

At sites where agriculture has been abandoned or where the forest has been allowed to regrow directly after clearing, the species and functional type composition, structure, biomass, and leaf area index of the regrowth forest will also be determined. At some of these sites leaf-chamber measurements of NMHC, CO_2, NOx, H_2O, CO, O_3, as well as tower-based measurements of trace gas, water and energy exchange, will be made to determine the variations with functional type in canopy exchange processes.

The following characteristics will be determined for each site: soil properties (physical, chemical, biological); land-use history; climate (precipitation (particularly seasonality), temperature, wind speed/direction, radiation); vegetation composition, structure and biomass; topography - hillslope and structure.

Considerable effort is required to coordinate and integrate the extensive site network (particularly in the Amazon basin, where existing work will probably provide most of the sites needed for the network). A special effort should be made to standardise measurement techniques and data protocols as far as possible, and to identify and include those sites with long-term studies.

(iii) Scaling up / extrapolation

The scaling-up of the hydrological fluxes of elements to the region will be centred on a basin-wide network of hydrological stations measuring water flow, sediment loads and water chemistry. The latter is particularly important for closing element budgets on a watershed and basin basis. Such a network already exists in the Amazon basin.

Scaling up the small scale measurements of trace gas emissions from the individual sites in the transect will be accomplished by using aircraft flights and the boundary-layer averaging technique. The latter will rely on those sites within the extensive network that have tower-based measurements of gas fluxes. The flights will include measurements of atmospheric stability, depth of mixed layer, radiation, O_3, CO_2, H_2O, HCs, NO, NO_2, PAN, organic nitrates, NOy, HCHO, H_2O_2, and aerosols for studying and modelling chemical transformations in the atmosphere.

(iv) Remote sensing

Remote sensing studies will provide the extent and rate of land cover conversion in the regions. Such a study has already been completed for the Amazon basin, and plans for similar studies in the other two humid tropical regions are well advanced. Of particular importance is the accurate determination of the type and history (if possible) of land-use for linkage to the ground-based process studies and observations.

The remote sensing studies should be expanded to include estimates of canopy structure and canopy chemistry when the technology is available.

(v) Modelling

Modelling studies will provide an integrating framework for the experimental and observational studies and for predicting consequences of future land-cover change. For each process, models at the patch and regional scales are required, as well as methodologies for translating between the scales.

Examples of types of models that may be useful include:

- Biogeochemistry (CENTURY, TEM)
- Water/energy exchange (SVATs, BIOME-BGC)
- Forest production models (e.g., MAESTRO, G'DAY)
- Forest succession models (e.g., FORET, ZELIG)
- 2-D atmospheric transport models linked to models of atmospheric chemistry and of trace gas emissions
- Models linking land cover change with biogeochemistry (e.g., the IMAGE system)

Appendix 2
Synopses of Possible Contributions to Collaborative Research from each Core Project

BAHC

Soil-Vegetation-Atmosphere-Transfer (SVAT) Studies and Models

SVAT field studies, an international long-term monitoring network, and development and testing of SVAT models for wider applications are part of current and planned BAHC Focus 1 activities. Parallel efforts for a vegetation classification scheme and SVAT simulations for integrative studies are also under discussion.

Regional-Scale Land-Surface Characterisation

Synthesis of interpretations of patch-scale land-surface processes to describe larger scales (heterogeneous landscapes, regions), the acquisition of a quantitative understanding of important cycles at the land surface at such scales, and improvement of ecohydrological models (considering seasonality, changing canopy structure, feedback to and from the atmosphere, and extreme events) are data processing, modelling, and descriptive tasks that support inter Core Project cooperation. Planning and implementation of land-surface experiments for the development of generalised parameterization schemes for land-surface processes at the regional scale (considering differences between flatlands and mountains and differences in upscaling methods) are key potential contributions under BAHC Focus 2.

Diversity of Biosphere/Hydrosphere interactions

For improved description and modelling of the spatial and temporal variability inherent in biosphere-hydrosphere processes and their interaction with atmospheric processes, BAHC Focus 3 will explore the long term dynamics of relationships between terrestrial ecosystems and water resources in response to incremental forcing. Such forcing results both from natural variability and flexibility (including climatic variations and extreme events such as extended drought, low river flow, and floods), and from direct anthropogenic impacts. Evolution of better models for the transfer-regulation mechanisms of carbon, soil, and nutrients from terrestrial ecosystems to surface and subsurface water, which include feedbacks between the loss of these materials and ecosystem structure, as well as ecosystem function, is another area of joint action. Shared tasks could also include increasing the quality and extent of global data sets necessary for characterisation of biospheric aspects in the hydrological cycle and its connections with biogeochemical cycles and, finally, with Earth's climate.

The Weather Generator Project

BAHC Focus 4 will coordinate the efforts to define the data requirements (the ingredients) of a Weather Generator for ecological and hydrological studies and related management purposes. Further coordination of BAHC Focus 4 will comprise: i) the development of the Weather Generator jointly with contributing WCRP projects, ii) down scaling of coarse information from global models to scales needed for ecosystem and hydrologic research, iii) testing of the down scaling procedure using simulated and empirical data sets of present day climate, and iv) facilitation of access, distribution, and use of the Weather Generator as well as associated data sets.

IGAC

Field Measurements

Six IGAC Activities are conducting, or plan to conduct field research in terrestrial regions: BATGE, BIBEX, DEBITS, HESS, MILOX, TRAGEX. They employ similar measurement techniques to study trace gas and aerosol sources (emissions fluxes), transport and photochemical transformation processes within the atmosphere, and deposition fluxes. Emissions fluxes are measured at "point" scale using chamber methods and at "patch" scale using micrometeorological techniques. Concentration fields on various scales are determined from surface network measurements and from vertical profiles obtained from towers, aircraft and, in some cases, from balloons and kites. Deposition fluxes are estimated by collecting and analysing precipitation (wet deposition) and by exposing surfaces to collect "dry" deposition. In some cases micrometeorological techniques can also be used to estimate dry deposition rates of some gases (e.g., ozone). Several of these Activities have sampling networks in place in various regions and have conducted large intensive studies involving coordination of multiple aircraft and remote sensing capabilities.

Emissions Inventories and Modelling

While each of the Activities named above includes an embedded modelling effort specific to its purposes, a separate Global Integration and Modelling (GIM) Activity is underway specifically to deal with global integration and modelling of fluxes of species significant to global atmospheric chemistry. A related, but distinct Global Emissions Inventory Activity (GEIA) devoted to the development and evaluation of global emissions inventories (databases) of important trace species, incorporating fluxes from both natural and anthropogenic sources, has been underway for several years.

GCTE

IGBP Transects

GCTE has initiated the development of a set of terrestrial transects for IGBP research. The transects are of order 1000 x 200 km in size and are based on a series of study sites along an underlying environmental gradient such as precipitation or temperature. They are

designed to facilitate the scaling-up of processes from local to regional scales. The major themes to be studied along the transects are: a) biogeochemistry and trace gas emission (with IGAC), b) ecosystem dynamics, and c) exchange of energy and water between the land surface and the atmosphere (with BAHC). IGBP transects exist or are under development in three regions, each incorporating a transition between major biome types: a) high-latitude (tundra-boreal forest), b) semi-arid tropical (woodlands-grasslands), and c) mid-latitude (temperate forest-grassland).

Biogeochemistry and Land-Use Change

A proposal for a coordinated IGBP study involving BAHC, IGAC, and GCTE (and potentially Land-Use and Cover Change (LUCC) and LOICZ) has been developed. The major components are: a) intensive process studies based on a "budget-closing" experiment on a small watershed, b) an extensive network of sites sampling varying intensities of land-use change, c) scaling up to a region using aircraft measurements and basin-level hydrological studies, d) remote sensing, and e) modelling. IGBP studies will be undertaken in the three major humid tropical regions starting with the Amazon basin and followed by south-east Asia and equatorial Africa.

Soil Biology and Trace Gas Emissions

GCTE's Task 3.3.3 aims to understand the impact of global change on soil biological processes, including their role in trace gas emissions. Important processes that will be studied include crop management practices, soil microbial processes (micro-organisms, soil fauna, soil organic matter), microbe-vegetation interaction, and atmospheric deposition. The high priority regions for study are tundra/northern wetlands, temperate agriculture, the semi-arid tropics, and the humid tropics (including rice production systems).

Long-Term Ecological Modelling Activity (LEMA)

The LEMA is a network of GCTE modelling groups. Its aim is to facilitate the development of models essential to GCTE through the sharing of model components and data sets, model inter comparisons, and focused modelling projects (e.g., by construction of a dynamic global vegetation model). LEMA provides the links between GCTE and GAIM and DIS, and will facilitate interaction with modelling groups in other Core Projects.

Appendix 3
Opportunities for Bilateral Cooperation between Core Projects

1. Mountain ecosystems studies (BAHC-GCTE; see also Appendix 4)
2. IGAC/RICE Activity and GCTE Task 3.3.3 (rice production network)
3. IGAC/TRAGEX Activity and GCTE Task 3.3.3 (wheat production network)
4. IGAC/MILOX Activity and GCTE Foci 1 and 3 (physiological research)
5. BAHC SVAT modelling and GCTE/BAHC bulk surface conductance project

Appendix 4
Executive Summary of the "IGBP-BAHC/UNEP WORKSHOP on Climate-Hydrology-Ecosystems Interrelations in Mountainous Regions (CHESMO): An International Initiative for Integrative Research", St. Moritz, Switzerland, 2-5 December 1993

The impact of mountainous regions of the earth on the atmospheric circulation, and their role in the global change process, in general, could not be adequately treated in atmospheric global circulation models (GCMs) due to the inherent complexities associated with large topographic variations and the significant challenges posed by incorporating more important first-order processes such as cloud formation and ocean feedbacks into GCMs. The time is right to face the scientific challenges to attain improved understanding of dynamics of land-surface-atmosphere interaction in mountain regions. Although much progress has been made in many aspects of mountain meteorology and hydrology, the geographic and thematic dispersion of mountain specific phenomena and processes has been too broad for the direct improvement of GCMs. Continuing research efforts and large-scale interdisciplinary collaboration between atmospheric scientists, hydrologists, geomorphologists, ecophysiologists, and soil and plant ecologists are needed.

Recognising this situation, IGBP-BAHC and the United Nations Environment Programme (UNEP) agreed to sponsor and organise with the support of the ETH in Zürich a workshop on "Climate-Hydrology-Ecosystem Interrelations in Mountain Areas" in St. Moritz, Switzerland, from 2 to 5 December 1993. The discussions during the workshop covered the full spectrum of problems in mountain research, including impacts of climate and land use change, instrumentation, measurement and data correction techniques, precipitation gradients, snow cover dynamics and glaciology, erosion, sedimentation and geomorphology studies, ecological studies (especially of ecosystem dynamics), up scaling and down scaling problems (in particular in precipitation and runoff modelling), probability of extreme events, and precipitation changes due to extensive irrigation on plains near the mountains. By reviewing the subjects and objectives of ongoing international research programs on global change, it was concluded that important research subjects in mountain environments are not sufficiently addressed.

Recommendations for future research were made in six areas:

1. An intensification, coupling, and focusing of research activities in mountainous regions is urgently needed to achieve required progress in modelling the interrelations between climate, hydrology and ecosystems, as well as the effects of climate changes and other impacts on natural resources (soils, water resources, ecosystems) at different spatial and temporal scales.

2. This research needs to be increasingly integrative and multidisciplinary.

3. Special emphasis should be given to the development of improved measuring techniques adequate for the harsh extreme conditions in mountains (ice, strong winds, heavy rainfall, etc.), and advanced network design, taking into account the distinct gradients in meteorological and hydrological conditions across mountain ranges (dependent on elevation, exposure, etc.).

4. Maximum possible use should be made of remote sensing (from space or on ground, e.g., radar) in order to better assess areal patterns of important characteristics, especially precipitation (rainfall and snow water equivalent).

5. The planning and long-term operation of a few carefully selected multidisciplinary experimental research basins (~ 100 km^2 in area) with embedded smaller, well equipped subbasins, and supersites at critical locations (nested basin approach) is considered as particularly important.

6. Special attention should also be given to the study of human impacts on natural resources (water, soils, vegetation, etc.) and to the delicate balance between ecosystem productivity, applied practices using these resources, and expected climate change.

It was also suggested that after obtaining the approval of the IGBP Scientific Committee (SC) and UNEP, a follow-up expert meeting (workshop) be organised. This meeting would serve to procure more developed, i.e. more specific and focused, plans and proposals which can serve as a basis for an internationally coordinated interdisciplinary action plan for mountain research (CHESMO). Complete documentation for the workshop is available on request from the BAHC Core Project Office.

Appendix 5
IGAC Activity 2.1: Biosphere-Atmosphere Trace Gas Exchange in the Tropics: Influence of Land-Use Change (BATGE)

(excerpted from *IGBP Report No. 32: The IGAC Operational Plan*)

Tropical soils and vegetation represent globally significant sources of a broad range of atmospheric gases, including VOCs, CO, N_2O, NO, and CH_4. Conversion of tropical forests and savannas to agriculture and pasture is presently occurring at very rapid rates, but the impacts of these land-use changes on biogeochemical cycling, trace gas emissions, and atmospheric photochemical and transport processes are not well understood.

Several recent studies of tropical land conversions have suggested the importance of land-use change on trace gas fluxes. Available measurements and modelling results indicate that tropical deforestation in humid areas could lead to increased regional levels of O_3 and of mineral acidity in rainfall. Observations show that these changes may already be occurring in some areas. However, the extent to which these results can be considered representative of tropical land conversion in general is not known.

Forest and savanna conversion to agricultural systems may result in major changes in soil organic matter and soil structure. Soil temperature and moisture regimes may change as a result of reduction in evapotranspiration, altered infiltration, and reduced shading. Management by fertilisation and irrigation greatly influence nutrient and water budgets. These changes will affect microbial populations and nutrient turnover which, in turn, can alter production and consumption of trace gases by micro-organisms. Alterations in soil characteristics, biogeochemical cycling, and trace gas fluxes may be expected to vary over time, depending on the intensity of management, type of cropping system, intensity of grazing, type of soil, time until fallow period, and other factors.

Removal and alteration of vegetation will influence canopy exchange characteristics as well as soil processes. The conversion of forest to pasture or crop results in changes of plant species as well as in vegetation structure and foliar biomass distribution. Plant species differences alone are expected to change emissions of biogenic VOCs and perhaps NH_3. Ozone and NO_X uptake also might be changed as a function both of vegetation species and leaf area. Furthermore, changes in nutrient availability and microclimate characteristics resulting from forest conversion may affect plant physiological processes, possibly leading indirectly to changes in emissions and uptake of trace gases.

Forest conversions result in spatially heterogeneous surface characteristics with vegetation canopies of varying heights and with patchiness of forested and non-forested areas which, in turn, result in varying surface roughness characteristics. The effects of this variation on the measurement of trace gas exchange in the convective boundary layer and transport

into the free troposphere are not well understood, nor is it certain that present knowledge of reaction kinetics is sufficient for atmospheric chemical modelling in heterogeneous environments.

BATGE has been established to address changes in tropical land-atmosphere exchange that result from alterations in soils, canopies, and landscapes in response to land-use change.

Goals

- To determine the fluxes of trace gases between tropical biomes and the atmosphere
- To determine the factors that control these fluxes
- To assess the effects of land-use change, including agricultural expansion and forest harvesting, on the exchange of trace gases
- To develop the ability to predict the impact on these fluxes of both climatic and land-use change by formulating the exchange of trace gases in terms of ecosystem properties

Implementation Strategy

BATGE involves short- and long term studies of ecosystem and atmospheric processes, carried out in areas of active land-use change in both savanna and humid tropical forest regions. Two Tasks have been initiated and are coordinated by Task coordinators; a third Task is in the planning stage.

Task 2.1.1: Measurement Intercomparison

The objectives of the intercomparison are: 1) to provide an intercomparison of trace gas flux measurement techniques, and 2) to identify factors that control the ability to scale from chamber measurements to micrometeorological techniques.

A planning workshop for this Task was organised by R.A. Delmas and J.P. Lacaux and was held at the Lamto Research Station, Ivory Coast in February, 1992. Discussion at the workshop focused on measurement techniques and site selection. A final site decision was made in late 1992 and the intercomparison is planned to take place in October-November, 1994, at the Nylsvley Nature Reserve in South Africa.

Task 2.1.2: Comparative Studies Network

The objectives of this trace gas network are: 1) to identify sites with long term research on trace gas fluxes in response to land-use change and agricultural intensification in the tropics, thereby identifying gaps in knowledge, 2) to facilitate data comparisons and syntheses, and 3) to facilitate interactions among measurement and modelling activities.

This Task seeks to coordinate long term studies within the tropics in order to identify research gaps and improve synthesis and modelling of trace gas fluxes. The emphasis in this task is on sites that are undergoing land-use change or agricultural intensification, such as fertilisation, irrigation, or grazing. It is expected that the network synthesis will provide geographic and ecological perspectives on trace gas emissions and the factors that control them, will foster development of global models of trace gas flux, and will provide a regional and global context for results from intensive, multidisciplinary field campaigns outlined under Task 2.1.3. Currently, 10 sites are included in the network. A workshop is being planned for 1995 to synthesise field data and to compare with simulation outputs from several trace gas models. Task 2.1.2 was initiated in late 1991 and research sites in tropical America, Africa, Australia, and Hawaii have been established. Efforts to identify additional sites and groups are on-going. Preliminary results appear in the book and special issue of *The Journal of Geophysical Research - Atmospheres* devoted to the First IGAC Scientific Conference (see Bibliography). Interested groups should contact BATGE conveners for inclusion in the network.

Task 2.1.3: Multidisciplinary Field Studies

Research on land-use effects on trace gas emissions must address process changes on scales ranging from soil and micro-organism to canopy and ecosystem to boundary layer and free troposphere. Task 3.1.3 proposes coordinated field studies of trace gas exchange, involving measurements of soil gas fluxes, whole ecosystem trace gas exchange, and atmospheric transport and processing. Such studies will be used to test models of trace gas emissions at ecosystem to regional scales, and will allow evaluation of the extent to which landscape heterogeneity controls gas exchange between ecosystems and the troposphere. The field campaigns will include ground, aircraft, and satellite components, and will address questions related to the sources, sinks, and atmospheric transport of a range of trace gases. One of these campaigns, Experiment for Regional Sources and Sinks of Oxidants (EXPRESSO), is being planned jointly with Activity 2.3. Other campaigns are in early planning stages and will be developed in participation with GCTE and other IGBP or national projects.

A. Field Campaigns:

Field campaigns will be carried out in areas subject to rapid land use change. Sites will be selected where some history of management is documented. Ideally, chronosequences of natural environments, managed land, and secondary successive environments will be located on similar substrates. Soil and vegetation emissions will be studied along with canopy exchange, reaction, and transport. This will require techniques that operate at a variety of scales. This research will be coordinated with other long term individual investigator studies in the site network.

Changes in soil emissions (including nitric oxide (NO), N_2O, CH_4, CO, CO_2) and their controlling factors will be studied in replicated managed sites, in control forests, and in fallow systems. Enclosure methods will be used to measure soil trace gas emissions; for the more reactive gases, box measurements will be coupled to tower-based measurements and results interpreted using models of their transformations. In addition to standard soil measurements, *in situ* isotope studies and closed soil incubations will be used to examine

changes in microbial immobilisation and mineralisation of nitrogen. Many of the soil process studies must be carried out through one or more annual cycles in order to understand temporal variability. These studies are expected to precede the tower- and aircraft-based research, and will provide context and constraints for the later phase.

To understand transport of trace gases into and out of a tropical forest canopy, it may be insufficient to monitor only gradients or eddy fluxes. Intermittent large eddies that evacuate deep layers of the canopy may be important and, therefore, make it necessary to observe column concentrations within and above the canopy. In situations where vegetation is short (e.g., pasture, crop, savanna) standard micrometeorological techniques such as Bowen-ratio type gradients and eddy correlation approaches will suffice to make flux estimates.

Trace gas instruments for tower operation exist, or soon will, for CO_2, total hydrocarbons, O_3, CH_4, NO, NO_X, and nitrogen dioxide (NO_2), but are not widely available. Thus, tower-based measurements will be set up for intensive periods during each multi-year study. In addition to the tower-based measurements, leaf chamber measurements of NMHCs, CO_2, NO_X, water, and CO exchange will be carried out, especially in comparisons of cropping and pasture systems. The minimum set should be expanded when possible to include mixing ratios of PAN, organic nitrates, total reactive nitrogen (NO_Y), formaldehyde (HCHO), hydrogen peroxide (H_2O_2), and aerosol composition. These measurements, in conjunction with other process studies, will allow mechanistic understanding of species effects on canopy exchange. Additionally, optical methods will be employed to examine canopy leaf area distribution as a function of vegetation type.

In order to examine the effects of patchy, heterogeneous environments on regional-scale atmospheric dynamics, quantitative estimates of the scale and degree of patchiness will be determined using remote sensing analyses of areal extent of vegetation types, foliar density, and perhaps canopy structure. In addition, intensive micrometeorological data will be acquired through portable tower measurements placed in different sized patches. Other measurements, including gas concentration measurements, will supplement these data. Finally, aircraft-based estimation of eddy fluxes of CO_2, CH_4, and CO, as well as measurements of atmospheric stability and depth of the mixed layer, will be used to integrate over patches and test flux models from other scales.

As noted above, a major field campaign being planned jointly with Activity 2.3 (BIBEX) is the Experiment for Regional Sources and Sinks of Oxidants (EXPRESSO). This investigation of tropical biogeochemistry will take place in the Central African Republic and the Congo with some aircraft missions extending over South Africa. Further information on EXPRESSO is given in the BIBEX section of this Operational Plan. In addition, BATGE scientists are currently involved in planning efforts for biogeochemical studies focused on land-use change in tropical ecosystems in Amazonia in the late 1990s.

B. Models and Extrapolation:

Models of soil and ecosystem dynamics, canopy exchange, and atmospheric chemistry and transport will be developed in concert with the process studies described above. Both

detailed mechanistic models and more highly parameterised models will be undertaken to allow the use of variables acquired from remote sensing and ground-based observations.

Models of soil and ecosystems processes and trace gas fluxes are in early developmental stages. Mechanistic models of factors controlling microbial processes and diffusion of gases through the soil will be developed. At the same time, less detailed models will be developed that can be driven with inputs from soil and climate data bases, from micrometeorological models, and from remote sensing data.

The degree of integration among models at various scales (ecosystem, canopy, atmospheric chemistry, etc.) will depend on the gas of interest. For example, soil process models that estimate N_2O and CH_4 emissions may not require integration with canopy transport models to permit extrapolation to regional and global scales. Model estimates can be tested by comparison with flux estimates from tower and aircraft-based measurements as technological developments permit. For reactive gases such as NO, models of soil emissions can provide inputs for canopy models; canopy models, which include chemistry and biological exchange, then estimate ecosystem-atmosphere exchange, which interact directly with boundary layer models of chemistry.

Sensitivity analyses on models at all levels must be conducted to provide an assessment of which variables need to be measured. There is a need for extensive interactions between the modelling community concerned with trace gas exchange and that concerned with global chemical transport models to ensure that models developed interface with global models.

C. Remote Sensing:

Estimation of the distribution and regional emissions of trace gases in response to tropical land conversions may be done through direct extrapolation approaches (multiplying average fluxes in each land-use by land-use areal extent) and modelling approaches. Either approach requires remote sensing and ground-based data bases. Remote sensing data are also critical for the description of land surface heterogeneity for use in boundary layer mixing studies described earlier. Several remote sensing approaches which may be useful to this study are currently available or are under development. Land-use classification based on thematic mapper or Système Probatoire pour l'Observation de la Terre (SPOT) sensor data are crucial for selection of specific field sites, for description of the heterogeneity or patchiness of regions, and for measurements of areal extent as bases of extrapolation. While these sensors will easily differentiate broad land-use classes, it will be difficult in many instances to detect differences between certain agricultural systems, degree of degradation or condition of these systems, and stage of succession in forest regeneration. Remote sensing studies must be initiated to examine these detection capabilities.

Experimental radar sensors are being applied for measurements of canopy structure, foliar distribution, and vegetation classification. Likewise, high spectral resolution sensors are being tested, and may be used for spectral characterisation of such variables as canopy chemical characteristics and trace gas concentrations. Finally, satellite systems

planned for the late 1990s will include a range of sensors designed for study of both vegetation and atmospheric characteristics, and may be useful for later studies in this project.

Use of these and other sensors may require ground data in addition to those described above. Collaboration with investigators involved in on-going remote sensing projects in the tropics will be sought whenever possible. Remote sensing researchers will be encouraged to consider use of study sites developed for this project.

Timetable

1992	Site selection for intercomparison campaign (Task 2.1.1)
1992-	Network trace gas studies
1994-1995	Planning activities for coordinated field studies (Task 2.1.3)
1994	Instrument/methods intercomparison at Nylsvley Nature Reserve
1996-2000	Coordinated field studies (two intensive campaigns) in humid tropics

Appendix 6
Membership of the BAHC-IGAC-GCTE Science Task Team

A. Becker
Potsdam Institute for Climate Impact Research, Telegrafenberg, Postfach 60 12 03, D-14412 Potsdam, Germany. Tel: (+49) 331 288 2541, Fax: (+49) 331 288 2600,
E-mail: becker@pik-potsdam.de

R.A. Delmas
Laboratoire d'Aerologie, Université Paul Sabatier, 118 Rue de Narbonne, 31062 Toulouse Cedex, France. Tel: (+33) 61 55 64 67, Fax: (+33) 61 55 31 20, E-mail: delr@aero.ups-tlse.fr

M. Keller
Institute of Tropical Forestry, USFS, Call Box 25000, Rio Piedras 00928-2500, Puerto Rico.
Tel: (+1-809) 766 5335, Fax: (+1-809) 766 6392

J.-P. Lacaux
Observatoire Midi-Pyrénées, Centre de Recherches Atmosphériques, Université Paul Sabatier, Campistrous, 65300 Lannmezan, France. Tel: (+33) 62 40 61 08,
Fax: (+33) 62 40 61 01

J.S. Levine
Atmospheric Sciences Division, NASA Langley Research Center, Hampton, VA, 23681-0001, USA. Tel: (+1-804) 864-5692, Fax: (+1-804) 864-6326, E-mail: j.s.levine@larc.nasa.gov

J. Melillo
Marine Biological Laboratory, Woods Hole, MA, 02543, USA.
Tel: (+1-508) 548-3705, Fax: (+1-508) 457-1548, E-mail: jmelillo@lupine.mbl.edu

J.-C. Menaut
Laboratoire d'Ecologie, Ecole Normale Superiure, CNRS-URA 258, 46, Rue d'Ulm, F-75230 Paris Cedex, France. Tel: (+33) 1 32 37 08, Fax: (+33) 1 44 32 38 85,
E-mail: menaut@wotan.ens.fr

H.-U. Neue
Soil and Water Sciences Division, International Rice Research Institute, P.O. Box 933, 1099 Manila, Philippines. Tel: (+63) 2 818 1926, Fax: (+63) 2 817 8470,
E-mail: h.neue@cgnet.com

A.A.P. Pszenny
IGAC Core Project Office, Building 24-409, Massachusetts Institute of Technology, Cambridge, MA 02139-4307, USA. Tel: (+1-617) 253-9887, Fax: (+1-617) 253-9886,
E-mail: pszenny@mit.edu

R.J. Scholes
Ecosystem Management Services Program, CSIR Division of Forest Science and Technology, P.O. Box 395, Pretoria 0001, South Africa. Tel: (+27) 12 841 2045, Fax: (+27) 12 841 2689, E-mail: bscholes@forestek.csir.co.za

W.J. Shuttleworth
Hydrology and Water Resources, University of Arizona, Tuscon, AZ, 85721, USA. Tel: (+1-602) 621-5082, Fax: (+1-602) 621-8787, E-mail: shuttle@hwr.arizona.edu

K.A. Smith
Soil Science Department, The Edinburgh School of Agriculture, West Mains Road, Edinburgh EH9 3JG, United Kingdom. Tel: (+44) 31 667 1041, Fax: (+44) 31 667 2601 E-mail: k.a.smith@ed.ac.uk

W.L. Steffen
GCTE Core Project Office, CSIRO Division of Wildlife and Ecology, P.O. Box 84, Lyneham, ACT 2602, Australia. (+61) 6 242 1755, Fax: (+61) 6 241 2362, E-mail: wls@cbr.dwe.csiro.au

S. Struwe
Department of General Microbiology, University of Copenhagen, Solvgade 83 H, DK-1307 Copenhagen K, Denmark. Tel: (+45) 35 32 20 50, Fax: (+45) 35 32 20 40, E-mail: agm@mermaid.molbio.ku.dk

J. Tenhunen
Department of Plant Ecology, University of Bayreuth, D-8580 Bayreuth, Germany. Tel: (+49) 921 785 71 21, Fax: (+49) 921 785 72 99, E-mail: john.tenhunen@bitoek.uni-bayreuth.d400.de

C. Vörösmarty
Complex Systems Research Center, University of New Hampshire, Durham, NH, 03824-3525, USA. Tel: (+1-603) 862-1792, Fax: (+1-603) 862-0188, E-mail: cv@cycling.unh.edu

Appendix 7
List of Participants at the First Meeting of the BAHC-IGAC-GCTE Science Task Team

A. Becker (Germany)
R.A. Delmas (France)
J.S. Levine (USA)
J.-C. Menaut (France)
H.-U. Neue (Philippines)
R.G. Prinn (USA)
A.A.P. Pszenny (USA)
R.J. Scholes (South Africa)
W.J. Shuttleworth (USA)
K.A. Smith (United Kingdom)
W.L. Steffen (Australia)
S. Struwe (Denmark)
J. Tenhunen (Germany)
C. Vörösmarty (USA)

Unable to attend:

J.-P. Lacaux (France)
J. Melillo (USA)
M. Keller (USA)*

* Appointed to Task Team following meeting

Appendix 8
IGBP Reports

*Reports marked with an * are no longer available.*

No. 12 The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP). The Initial Core Projects. (1990)

No. 13 Terrestrial Biosphere Perspective of the IGAC Project: Companion to the Dookie Report. Edited by P A Matson and D S Ojima. (1990)

No. 14 Coast Ocean Fluxes and Resources. Edited by P M Holligan. (1990)

No. 15 Global Change System for Analysis, Research and Training (START). Report of the Bellagio Meeting. Edited by J A Eddy, T F Malone, J J McCarthy and T Rosswall. (1991)

No. 16 Report of the IGBP Regional Workshop for South America. (1991)

No. 17 Plant-Water Interactions in Large-Scale Hydrological Modelling. (1991)

No. 18.1 Recommendations of the Asian Workshop. Edited by R R Daniel. (1991)

No. 18.2* Proceedings of the Asian Workshop. Edited by R R Daniel and B Babuji. (1992)

No. 19 * The PAGES Project: Proposed Implementation Plans for Research Activities. Edited by J A Eddy. (1992)

No. 20 * Improved Global Data for Land Applications: A Proposal for a New High Resolution Data Set. Report of the Land Cover working Group of IGBP-DIS. Edited by J R G Townshend. (1992)

No. 21 Global Change and Terrestrial Ecosystems: The Operational Plan. Edited by W L Steffen, B H Walker, J S I Ingram and G W Koch. (1992)

No. 22 Report from the START Regional Meeting for Southeast Asia. (1992)

No. 23 Joint Global Ocean Flux Study: Implementation Plan. Published jointly with SCOR. (1992)

No. 24 Relating Land Use and Global Land Cover Change. Edited by B L Turner II, R H Moss and D L Skole. Also HDP/Report No. 5. (1993)

No. 25 Land-Ocean Interactions in the Coastal Zone: Science Plan. Edited by P M Holligan and H de Boois. (1993)

No. 26 Towards a Global Terrestrial Observing System (GTOS): detecting and monitoring change in terrestrial ecosystems. (Report of Fontainbleau Workshop). Edited by O W Heal, J-C Menaut and W L Steffen. Also UNESCO/MAB Digest. (1993)

No. 27 Biospherics Aspects of the Hydrological Cycle: The Operational Plan. (1993)

No. 28 IGBP In Action: Work Plan 1994 - 1998. (1994)

No. 29 Africa and Global Change. Report from a Meeting at Niamey, Niger, 23-27 November, 1992. (1994)

No. 30 IGBP Global Modelling and Data Activities 1994 - 1998. (1994)

No. 31 African Savannas and the Global Atmosphere: Research Agenda. Edited by C Justice, R J Scholes and P G H Frost. (1994)

No. 32 International Global Atmospheric Chemistry (IGAC) Project: The Operational Plan. (1994)

No. 33 Land-Ocean Interactions in the Coastal Zone: Implementation Plan. Edited by J C Pernetta and J D Milliman. (1995)

No. 34 BAHC-IGAC-GCTE Science Task Team: Report of First Meeting. (1995)

Appendix 9
Acronyms and Abbreviations

BAHC	Biospheric Aspects of the Hydrological Cycle (IGBP)
BATGE	Biosphere-Atmosphere Trace Gas Exchange (IGAC)
BIBEX	Biomass Burning Experiment (IGAC)
BIOME-BGC	Global biome model-biogeochemical cycle
BOREAS	Boreal Ecosystems Atmosphere Study (BAHC/GEWEX)
CHESMO	Climate-Hydrology-Ecosystems Interrelation in Mountainous Regions (BAHC/UNEP)
CPO	Core Project Office (IGBP)
DEBITS	Deposition of Biogeochemically Important Trace Species
DECAFE	Dynamique et Chimie Atmospherique en Forêt Equatoriale
DIS	Data and Information System (IGBP)
EC	European Community
ECHIVAL	European Climate and Hydrological Project on Interactions between Vegetation, Atmosphere and Land
EFEDA	ECHIVAL Field Experiment in a Desertification Threatened Area (BAHC)
ETH	Eidgenössische Technische Hochschule Zürich (Swiss Federal Institute of Technology Zürich)
EXPRESSO	Experiment for Regional Sources and Sinks of Oxidants
FIFE	First ISLSCP Field Experiment
FORET	Forests of East Tennessee
GAIM	Global Analysis, Interpretation and Modelling (IGBP)
GCM	General Circulation Model
GCTE	Global Change and Terrestrial Ecosystems (IGBP)
G'DAY	Generic Decomposition And Yield
GEIA	Global Emissions Inventory Activity (IGAC)
GEWEX	Global Energy and Water Cycle Experiment (WCRP)
GIM	Global Integration and Modelling
HAPEX	Hydrologic Atmospheric Pilot Experiment
HESS	High Latitude Ecosystems as Sources and Sinks of Trace Gases (IGAC)
ICSU	International Council of Scientific Unions (ICSU)
IGAC	International Global Atmospheric Chemistry project (IGBP)
IGBP	International Geosphere-Biosphere Programme
IMAGE	Integrated Model for the Assessment of the Greenhouse Effect
IOC	Intergovernmental Oceanographic Commission (UNESCO)
ISLSCP	International Satellite Land Surface Climatology Project (WCRP)
LBA	Large-Scale Biosphere-Atmosphere Experiment in Amazonia
LEMA	Long-Term Ecological Modelling Activity (GCTE)
LOICZ	Land-Ocean Interactions in the Coastal Zone (IGBP)
LUCC	Land-Use and Cover Change (IGBP)
MAESTRO	Multiple-array, Assimilation, Evaporation, Stand, Tree, Radiation Orgy
MILOX	Mid-Latitude Ecosystems as Sources and Sinks for Atmospheric Oxidants (IGAC)

NASA	National Aeronautics and Space Administration (USA)
NATT	Northern Australian Tropical Transect
NMHC	Non-Methane Hydrocarbons
NOPEX	Northern Hemisphere Climate Processes Experiment (IGAC)
PAN	Peroxyacetylnitrate
RICE	Rice Cultivation and Trace Gas Exchange (IGAC)
SAFARI	Southern African Fire Atmosphere Research Initiative (BIBEX)
SALT	Savannas in the Long Term
SC-IGBP	Scientific Committee of the IGBP
SPOT	Système Probatoire de l'Observation de la Terre (a satellite sensor)
SSC	Scientific Steering Committee (IGBP)
STARE	Southern Tropical Atlantic Regional Experiment
START	Global Change System for Analysis, Research and Training (IGBP)
SVAT	Soil-Vegetation Atmosphere Transfer Model(BAHC)
TEM	Terrestrial Ecosystem Model (GAIM)
TIGER	Terrestrial Initiative in Global Environmental Research (UK)
T/LSEs	Transects and large-scale land surface experiments
TRAGEX	Trace Gas Exchange: Mid-Latitude Terrestrial Ecosystems and Atmosphere (IGAC)
TRAGNET	Trace Gas Network (US contribution to IGAC/TRAGEX)
UNEP	United Nations Environment Programme
UNESCO	United Nations Economic, Scientific and Cultural Organisation
VOC	Volatile Organic Compound
WCRP	World Climate Research Programme (ICSU/WMO/IOC)
WMO	World Meteorological Organization