

# Chapter 1

## The International Geosphere-Biosphere Programme

### Introduction

The global environment is currently undergoing change on scales which may, with the benefit of hindsight, be seen to exceed in speed most of those hitherto experienced during human occupancy of the planet. Undoubtedly, some of these changes are natural, reflecting the age-old rhythms of the ecosphere as it makes its evolutionary journey through time. Some changes, however are undoubtedly anthropogenically induced by the increased demands on finite resources which arise from growing population numbers and the greater leverage which can be exerted on crucial points of environmental systems by industrial societies.

### The Background to the IGBP

The International Council for Scientific Unions (ICSU) decided in 1986 that a global perspective on human-induced environmental change was urgently required. Prior to this, various international programmes had tended to focus on individual components such as the oceans, atmosphere, or terrestrial biosphere in a somewhat piecemeal fashion and frequently lacked the holistic perspective which was required to address effectively the growing problems of global change. The unitary nature of the biosphere meant that small scale, compartmentalised, scientific approaches often solved one problem only at the expense of creating another. It was already clear at that time that the complexity of the operation of global environmental systems had not been fully appreciated and that major limitations existed when integration of knowledge concerning parts of the global environmental system was attempted. Above all there was the growing realisation that the pace of global change was accelerating. Public sensitisation to global scale problems, especially relating to atmospheric composition was growing rapidly. It was clear that the consequences of increasing emission of greenhouse gases and the then recently discovered depletion of stratospheric ozone, were inadequately understood. The International Geosphere-Biosphere Programme (IGBP) was there-

fore established to identify disciplinary gaps in the scientific community's approach to global change problems and to co-ordinate and encourage research in such areas. In addition to ICSU, the IGBP was sponsored by the major National Academies of Science and Scientific Unions and the Secretariat was established at the Royal Swedish Academy of Sciences in 1987.

The objective of this, the largest and most ambitious scientific undertaking on a global scale ever made, can be simply stated as follows:

'To describe and understand the interactive physical, chemical and biological processes that regulate the total earth system, the unique environment that it provides for life, the changes that are occurring in this system and the manner in which they are influenced by human activities.'

These objectives are essential prerequisites for the achievement of goals espoused in more recent statements on global environmental well-being, most notably the Brundtland Report with its emphasis on sustainability and inter-generational equity. The attainment of these objectives, however, implies a level of multidisciplinary integration within the sciences not presently in existence, but one which is essential if the problems of global change are to be adequately addressed.

The IGBP thus seeks to develop a global model which will incorporate a fuller understanding of the complex interactions between the physical, chemical and biological processes that regulate the global environmental system. However, it is clear that much fuller information than presently exists is required to perfect such a model and a major co-operative effort involving the scientific community is necessary to address the challenge. Over the past decade many strides have been made towards this end and the IGBP has become a large organisation to which almost all of the world's countries, both in the developed world and in the developing world, have become affiliated. Some 74 National Committees were established by 1996.

### The Scientific Objectives of the IGBP

In order to address the problems of global environmental change, the IGBP seeks to establish pathways of communication between major scientific activities in various disciplines around the world. It seeks to plan in detail an interdisciplinary framework for global change studies. This approach is widely used in national science programmes to assure continuity over time, and over generations of researchers, in addressing particular scientific problems. It also ensures consistency in the methods utilised to address these problems and compatibility in the resulting data produced. The IGBP thus is concerned with co-ordination of research, with integration of results and with the development of a holistic approach to global processes. It is important to stress that IGBP is not a funding body but is recognised by inter-governmental bodies as serving a useful role in providing input to policy formulation and thus IGBP-related activities are fostered by national funding agencies and institutes.

The IGBP science plan was launched in 1990. Because of the disciplinary breadth of global change research, more detailed plans have been developed in a number of critical areas. These have focused on seven key scientific objectives which can be formulated as questions as follows:

- (1) How is the chemistry of the global atmosphere regulated, and what is the role of biological processes in producing and consuming trace gases?
- (2) How will global changes affect terrestrial ecosystems?
- (3) How does vegetation interact with the physical processes of the hydrological cycle?
- (4) How will changes in land use, sea level and climate alter coastal ecosystems, and what are the wider consequences?
- (5) How do ocean biogeochemical processes influence and respond to climate change?
- (6) What significant climatic and environmental changes have occurred in the past, and what were their causes?
- (7) What causes global changes in land use and land cover to occur, and what are the relevant human driving forces of such changes?
- (8) What changes are taking place in the structure and functioning of the marine ecosystem, and how do

these changes alter the capacity of the ocean to absorb some of the greenhouse gases from the atmosphere?

These scientific objectives have formed foci around which research activities are organised in a series of Core Projects.

### Organisation and Funding of the IGBP

To provide answers to the key questions identified above, the IGBP has established individual Core Projects. These have a Core Project Office and executive and act to co-ordinate research in their respective areas. Core Projects are not designed to be permanent features of the IGBP, but are designed to have a useful life after which they will be replaced by new Core Projects which ongoing research suggests as appropriate. Funding for all IGBP-related activities, including Core Projects, is carried out at the national level. At present there are eight Core Projects, the most recent being approved in late 1995, as follows:

#### *International Global Atmospheric Chemistry Project (IGAC)*

Climate, the biosphere and the various components of the atmosphere constitute a closely interlinked system which is as yet imperfectly understood. This system does however act to regulate the concentrations of greenhouse gases such as carbon dioxide, methane, nitrous oxide and ozone, concentrations of which are increasing rapidly as a consequence of human activities. Accordingly, IGAC (which is a joint project with the Commission on Atmospheric Chemistry and Global Pollution of the International Association of Meteorology and Atmospheric Physics (IAMAP) addresses the relationships between atmospheric composition, physical and biospheric processes and climate. A particular focus is on the role of greenhouse gases (such as carbon dioxide, methane, nitrous oxide and other trace gases) in effecting climate change. The project also incorporates the development of emission inventories, the standardisation of measurement techniques and the development of global monitoring networks. IGAC has three main aims:

- To develop a fundamental understanding of the processes that determine the chemical composition of the atmosphere.
- To understand the interactions between atmospheric chemical composition and biospheric and climatic processes.
- To predict the impact of natural and anthropogenic forcings on the chemical composition of the atmosphere.

Globally IGAC is participating in several worldwide monitoring networks and several large scale surveys, such as the Global Atmospheric Gases Experiment (GAGE), and the European Experiment on Transport and Transformation of Environmentally Relevant Trace Constituents in the Troposphere over Europe (EUROTRAC).

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#### *Global Change and Terrestrial Ecosystems (GCTE)*

This Core Project involves examining the role of the terrestrial biosphere in causing and responding to changes in climate, atmospheric composition and land use. Ecosystem responses to global change are investigated under the terms of this Core Project by experimentation (e.g. plants growing in enriched CO<sub>2</sub>) and through long term ecological monitoring. The main foci of GCTE are as follows:

- To predict the effects of climate changes, changes in the composition of the atmosphere, and land use changes on terrestrial ecosystems. This effort is intended to include effects on agriculture, forestry, soils and also to incorporate the impacts of global environmental changes on biodiversity.
- To determine how these effects lead in turn to feedbacks to the atmosphere and to the physical climate system.

GCTE is closely involved with several global ob-

serving and monitoring networks such as the global Climate Observing System (GCOS), the Global Terrestrial Observing System (GTOS) and the Global Atmosphere Watch (GAW). However, most GCTE activities tend to be concerned with field experiments, the development of ecosystem change-response models, landscape change analysis and the development of appropriate databases to further the aims specified above.

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#### *Biospheric Aspects of the Hydrological Cycle (BAHC)*

BAHC deals mainly with the role of the Biosphere in and its interaction with the terrestrial component of the hydrological cycle. These aspects are as yet poorly represented on global climate models and there is a pressing need to improve the parameterization of land-surface processes on such models in order to enable downscaling of GCMs. To achieve this requires considerable interdisciplinary collaboration involving not just hydrologists but also soil scientists, meteorologists/climatologists and ecologists. The main research foci are:

- To determine the biospheric controls on the hydrological cycle through field experiments with the aim of constructing models of the flux of energy and water in the soil-vegetation system. This is important at various temporal scales, including those appropriate for general circulation model input.
- To develop appropriate databases which can be used to quantify the relationship between the biosphere and the physical environmental systems and which can thus be used to construct models which investigate this relationship.

As one of the oldest, and largest, Core Projects BAHC has many international links, such as with the United Nations Environment Programme (UNEP), the Global Energy and Water Cycle Experiment (GEWEX) and the International Hydrological Programme (IHP).

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#### *Land-Ocean Interactions in the Coastal Zone (LOICZ)*

The coastal zone is one of the most heavily exploited and heavily populated regions of the globe and has been subjected to growing pressures in recent decades. It is, however, one of the environmental niches which is most vulnerable to global change - both in terms of short term events such as storm surges or longer term events such as sea level changes. These changes have the potential to seriously destabilise some coastal zones, inducing major morphological changes in the coast as well as altering the terrestrial systems on-shore. LOICZ aims to better understand the behaviour of the land-ocean interface and hence anticipate the responses of coastal systems to global change. Four main research areas can be identified:

- The effects of changes in external forcing on coastal fluxes of material between land sea and atmosphere. This includes carbon fluxes and trace gas emissions.
- The capacity of coastal systems to transform and store sediments and dissolved matter
- Coastal geomorphology and sea level rise
- Economic and social impacts of global change on coastal systems.

LOICZ interacts strongly with the World Climate Programme (WCP), the Scientific Commission on Oceanic Research (SCOR) and the Intergovernmental Oceanic Commission (IOC) as well as various other IGBP Core Projects and the International Human Dimensions Programme (IHDP).

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#### *Joint Global Ocean Flux Study (JGOFS)*

Although the atmospheric concentration of greenhouse gases is the primary cause of concern for climate change in the immediate future, it is important to realise that the store of carbon in the atmosphere is much less than in the oceans. Indeed the storage capacity of the oceans for carbon is approximately 50 times that of the atmosphere, and the response of the oceans to changes in the atmosphere is thus going to be of great importance for the future course of global climate. JGOFS is concerned with examining the fluxes of various elements and compounds through the oceans - some of which are currently only partly understood - and thus enabling better anticipation of the magnitude of climate change. Two broad approaches are employed:

- *Analysis:* Solving the problems associated with understanding the processes controlling the fluxes of carbon and other biogenic elements in the oceans, and quantifying the exchanges which occur involving the ocean and other global stores.
- *Prediction:* Improving forecasting capabilities involving the response of oceanic biogeochemical processes to human disturbances, particularly insofar as they relate to present and possible future climate change.

JGOFS employs a number of different sensing techniques to monitor oceanic processes. These include satellite-borne and ship-borne sensors. JGOFS has also been actively involved in the implementation of the Global Ocean Observing System (GOOS), launched in 1992, and in a number of projects in collaboration with the World Ocean Circulation Experiment (WOCE) and Scientific Committee on Antarctic Research (SCAR).

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## Past Global Changes (PAGES)

Instrumental observations of weather and climate extend only to the mid seventeenth century and then mainly for locations in western Europe. For most of the world records commence in the twentieth century and do not provide a long enough time span for reliable characterisation of climate. Accordingly, a number of techniques of climatic reconstruction using proxy sources such as ice cores, sediments, corals, tree rings or pollen grains have been developed to provide a perspective on the vagaries of climate before human numbers reached a point at which they began to alter significantly the composition of the atmosphere. PAGES is the core program which attempts to examine climate change both in the distant past and in more recent times. A two strand approach is employed:

- *Stream 1:* To reconstruct the detailed history of climate and environmental change for the entire globe over the last 2000 years. A temporal resolution of decadal, or ideally annual, or less is sought. This is the period in which human influence on climate has become increasing significant.

- *Stream 2:* A full glacial-interglacial cycle. This encompasses the past 150,000 years in order to improve understanding of natural processes of climate change. Reconstructions of climate over this long period are necessarily dependent on various natural records, such as sediments and ice cores.

The multiplicity of approaches involved in palaeoclimatic reconstructions mean considerable co-operative links with other programmes are inevitable. PAGES has established close working relationships with the International Union for Quaternary Research (INQUA) and the World Climate Research Programme (WCRP). The huge data requirements of PAGES research are facilitated also by co-operation with the World Data Centre at the U.S. National Geophysical Center in Boulder, Colorado.

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## Land-Use/Cover Change (LUCC)

Land-use and land cover change is significant to a wide range of issues central to global environmental change. Alterations in land use have major implications for sustainable development and for the operation of biogeochemical cycles. Despite this, there is at present neither an accurate map of global agricultural activities, nor good measurements of current land use changes. Furthermore, to understand the global land use mosaic demands the joint efforts of natural and social science. Land cover is determined by both the physical environment and human activities. The Land-Use/Cover Change core project is therefore unique in the IGBP stable in that it is a joint project with the recently established International Human Dimensions of Global Environmental Change Programme (IHDP). It focuses primarily on how land use/land cover and surface characteristics are influenced by socio-economic factors. The ultimate objective is to integrate the factors which induce land-use/land cover changes into a global model. LUCC therefore seeks to:

- Develop the fundamental understanding of the human and biophysical dynamics of land-use changes and of the impact of these changes on land cover.
- Develop robust and regionally sensitive global models of land-use/land cover change with improved capacities to predict and project future changes.
- Develop an understanding of the dynamics of land-use/land cover changes through a systematic and integrated set of studies.
- Help in the development of a global land-use classification scheme.

LUCC is one of the two most recently established Core Projects and also represents the first time the IGBP and IHDP have mounted a combined initiative. The Science Plan for LUCC was published in late 1995 and discussed in an open meeting in 1996.

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## Global Ocean Euphotic Zone Study (GLOBEC)

GLBEC is the newest IGBP Core Project and has as its principal objective the advancement of the science of the global ocean ecosystem. Three significant gaps in the understanding of marine ecosystems exist:

- (1) Details of the food chain relationships between zooplankton and phytoplankton and the interaction which both have with predators.

- (2) The role of mesoscale physical factors in forcing changes in zooplankton populations.

- (3) Biophysical factors which control the population balance between different types of plankton.

GLOBEC is already operational, having been developed and sponsored originally by the Scientific Committee for Oceanic Research (SCOR) and a number of other organisations. In 1994 these bodies requested that GLOBEC become formally affiliated to the IGBP. This was approved in October 1995.

CLOBEC Office: Not Yet Established

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IGBP core projects are not designed to have an indefinite lifetime. As the major work is completed, new foci become apparent, and new generations of core projects are envisaged. Thus while at present eight core projects exist, these are likely to change in the future, particularly as the first generation mature.

In addition to core projects, the IGBP have three further over-arching activities designed to build capacity in critical areas. These involve modelling, data provision and the fostering of regional research networks in parts of the world where stronger links among scientists would be beneficial to the overall programme.

Global Analysis, Interpretation and Modelling (GAIM)

The long term aim of the GAIM task force is to enable the development of comprehensive predictive models of the global biogeochemical systems. These can then be coupled to the general circulation models

to integrate the various parts of the IGBP programme into a more coherent understanding of how the planet functions.

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IGBP Data and Information Systems (IGBP-DIS)

The role of IGBP-DIS is mainly to assist core projects in the development of their particular data needs. IGBP-DIS also strives to furnish an overall data plan for IGBP and to carry out activities which produce useful datasets for the study of global change. It also has a brief to ensure that the data needs of IGBP are where possible facilitated by the activities of national and international data gathering bodies.

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

START is a framework activity of the IGBP which fosters a world-wide system of regional research networks. The main purpose of a regional research network is to coordinate research on the specific regional origins and impacts of global environmental change. START is essentially a capacity building activity which aims to encourage collaborative research in areas of the world where co-operative activities between scientists are weak

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### **Ireland and the IGBP**

Ireland will be intimately affected by the global environmental changes projected for the next few decades and there is a pressing need to consider these impacts in as much detail as possible. By the year 2030, average annual temperature may have increased by approximately 1°C. Summer precipitation may have decreased by 5-10%, with comparable increases for winter precipitation. Sea level may rise by approximately 18cms.

Only by anticipating where and to what extent these changes will necessitate adjustments can the necessary forward planning be put in place to enable Ireland to retain its comparative economic advantages in key areas such as agriculture and environmental quality. In some respects the relatively unique geographical and environmental position of Ireland makes it also an important sentry post for global change for other parts of Europe.

First, the location of Ireland at the interface where the North Atlantic Drift reaches the European landmass means it enjoys a complex mix of flora and fauna, with Arctic and Alpine, Lusitanian and Continental species existing sometimes side by side. For a relatively small island, a very wide range of microhabitats and microclimates exists. However, as well as exhibiting great habitat diversity, it could be suggested that some Irish plant species, as well as some agricultural crops, are close to the edge of their ranges and thus can be expected to be very sensitive to environmental change. Which crops, which vegetation types can be expected to be winners and losers in this situation?

Secondly, the relatively unspoilt environment of Ireland makes it an ideal laboratory for research work in many fields related to the IGBP, such as the monitoring of background air pollutants or long term ecological monitoring of various kinds. A great variety of research questions need to be answered. How will Ireland's green mantle adapt to the climate changes projected? What do they mean for hydrology and freshwater resources, or for peatlands or sand dune environments?

Thirdly, there is a pressing need to understand how the Irish coast will respond to changing sea levels. Will coastal sediment be remobilised? Will storm surges

pose a significantly increased risk for urban populations? Will aquaculture and fisheries be affected?

The Irish Committee for IGBP was established by the Royal Irish Academy in October 1988 to assist in the task of fostering global change research. Since that time the Irish Committee for IGBP have seen their brief as primarily to apprise researchers in Ireland of current developments in global change studies and to facilitate national research in pursuit of the IGBP goals. This latter role has of necessity been limited by the absence of national funding agencies such as exist in most other countries. The abilities of the Irish IGBP Committee to influence the direction of research has thus been limited. Information dissemination regarding the IGBP has however been facilitated by a small grant from the Department of the Environment and most third level institutions active in global environmental research, as well as semi state organisations such as the Met Éireann and Forbairt, have representation on the IGBP Committee.

The primary purpose of the Irish Committee for IGBP is thus to provide information for researchers throughout Ireland on the various international programmes and to highlight areas where an Irish contribution to global environmental change research could be made. Such opportunities for collaboration have also been fostered by the recent publication of a national research register in global change. The Committee has also been able to offer some financial support to young researchers to facilitate their attendance at global change-related conferences.

At a national level, one major conference has been organised thus far with a view to highlighting the quality and range of global change research currently existing within Ireland. This has indicated that a reservoir of high quality work in global environmental change related areas exists within Ireland, and that Irish researchers are actively involved in many areas which the IGBP Core Projects address, often as coordinators or partners in European Union-funded programmes such as the Environment and Climate Programme. This publication represents the proceedings of this first national IGBP symposium which was held from 22nd-23rd September 1995 at the National University of Ireland, Maynooth.