Report 1993:1

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ISSN: 0804-4562

CICERO
Center for International Climate
and Energy Research - Oslo

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February 1993

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INTRODUCTION

Country studies are important instruments for determining national climate policies and adding to the global knowledge on climate issues. They are, however, also the basis for examining the obligations of the Parties under the United Nations Framework Convention on Climate Change (FCCC), and for developing and assessing projects eligible for financing by the Global Environmental Facility (GEF). It is important that these country studies are comparable, in order to make the GEF efficient and able to compare and choose between projects built on country studies, in terms of their ecological and economic efficiency.

The term "country study" should in our context be understood as an official national study on climate change which could include parts or all of the following areas: inventories of sources and sinks; impacts and vulnerability assessments; and response strategies and options, both on adaptation and greenhouse gas (GHG) abatement..

This report is prepared for the Administrator of the Global Environmental Facility (GEF), as a basis for discussion at a workshop organized by TERI in New Delhi in February 1993 on improving current approaches to country studies on climate change. It is also a contribution to the discussion within the Program for Measuring Incremental Costs in the Environment (PRINCE). The GEF commissioned CICERO on November 20, 1992, to study experience to date, drawing explicitly upon those studies funded under GEF as well as experiences from other studies.

As many of the studies are not yet completed, the focus of this review is on work plans, terms of reference and underlying assumptions and parameters used in their development. Ideally this work should also include interviews with the institutions involved in the preparation of such studies. The time available has, however, not permitted us to meet this objective.

The terms of reference of the review states that the following elements should be considered, of which the area of costing exercises was highlighted:

(i) an assessment of the level of activity currently and projected in the field of country studies on climate change, including an inventory of studies underway or planned;

(ii) a review of the terms of reference for such studies including a review and assessment of:
-their objectives;
-methodological approaches;
-parameters and assumptions used, including treatment of discount rate, costing assumptions, abatement targets etc.;
-range of policy and investment/expenditure options to be reviewed and assessed; and
-the extent to which local staff were involved in design and implementation of these studies;

(iii) a review of the costs and staffing patterns of such studies including the expertise required to undertake specific studies; and

(iv) for those studies completed or underway, an assessment of their usefulness for government policy makers, especially in terms of providing a clear strategy for future activities including provisions and "expectations" laid down in the climate convention.

The availability of completed studies and terms of reference for such studies was meager. This review and assessment is, therefore, built on a very limited number of studies and terms of references, as listed in Annex 1. The time available for the preparation of this first draft has also limited our ability to study in depth all the issues mentioned above. We trust, however, that this exercise is a valuable start and may assist in the discussions and the development of more comparable methodologies for country studies.

CICERO has benefitted from the assistance of by Audun Rosland, Norwegian State Pollution Authority and Kristin Rypdal, Central Bureau of Statistics of Norway, as well as Peter Usher, United Nations Environment Program.

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CHAPTER 1
ACTIVITY IN THE FIELD OF COUNTRY STUDIES

1.1 The legal and financial basis

The Framework Convention on Climate Change (FCCC) commits all Parties from the entry into force of the Convention to develop and periodically update national inventories of sources and sinks of GHGs, using comparable methodologies. It also commits the Parties to formulate and implement programs for mitigation and adaptation. A general obligation for all Parties also exists to take climatic change considerations into account in their social, economic and environmental policies and actions. National inventories are to be published and communicated to the Conference of the Parties of the FCCC.

Developed country Parties included in Annex I have demanding commitments such as adoption of national policies and corresponding measures, demonstrating that they are taking the lead. They are also obliged to communicate this information within six months of the entry into force of the Convention, while developing country Parties are obliged to respond within three years and least developed country Parties at their own discretion.

Whether a great number of developing country Parties will be able to present information on inventories of sources and sinks of GHGs and programs for mitigation and adaptation prior to the first Conference of the Parties, expected by late 1994, depends largely on the availability of bilateral and/or multilateral funding as laid down in the convention, as well as on the availability of basic national data and on human, technological and institutional resources.

1.2 The data and methodological basis

Much of the data relevant and necessary for making a fruitful country study is difficult to obtain in some countries. As yet, a comprehensive and authoritative methodology for full-fledged country studies has not been developed.

Much work has, however, been done regarding methodological elements of such studies. IPCC's Working Group (WG) I has together with OECD, provided a draft methodology for developing national inventories of emissions and sinks. A revised version will be presented by mid 1993. WG II has prepared a report on "Preliminary Guidelines for Assessing Impacts of Climate Change". A subgroup of the earlier WG III has developed "A Common Methodology for Assessing Vulnerability to Sea-Level Rise." UNEP has, through Risø National Laboratory, initiated a project to work on a methodological framework for undertaking cost assessments of GHG abatement. GEF has commissioned a study on Economic Costs of Carbon Dioxide Reduction Measures. Draft guidelines for a comprehensive set of country studies have also been submitted by Finland and the United States.

1.3 Reported ongoing and planned activities

The main thrust of information on the planned and existing activity on country studies stems from the work of UNEP and their second Country Study Report dated November 5, 1992. The recent VIII. session of the IPCC in Harare hailed UNEP for its work in this sector, and appealed to all countries to assist UNEP in its biannual updating of this activity report. A country study summary from this report is enclosed as Annex 2 for easy reference.

As of October 1992, 65 countries had undertaken, or planned to undertake, some form of country study. Several other countries have indicated their interest in this activity, but have lacked the financial and/or technical resources to participate. The activity on country studies are reported to have a fairly even split among emission inventories, impact assessments and mitigation analyses.

Table 1 Reported activity on country studies or elements of such studies.

Region	Studies on Inventories	Studies on Effects	Studies on Mitigation
OECD-region. Information from 19 out of 24 countries	15	16	19
Countries with economies in transition. Information from 7 out of 14 countries	4	2	3
Asia and the Pacific. Information from 22 out of 47 countries	6	15	17
Latin America Information from 18 out of 32 countries	4	6	3
Africa Information from 26 out of 50 countries	10	9	6

Table based on information from UNEP's 2nd Country Study Report, Nov. 1992

On the multilateral scene, the main actors are:
- The United Nations Development Program (UNDP) has a country study program involving 14 developing Asian countries. The program will deal with inventories of emissions and sinks; identify measures to reduce emissions or enhance sinks and estimate the costs and effectiveness of these measures; develop scenarios of emissions from different sources; and prepare policy responses.
- The United Nations Environment Program (UNEP) is involved in projects on emission inventories, impact assessments and response options and economic assessments of limiting GHG. Ongoing is a country study program on sources and sinks of GHG in 11 countries. UNEP has supported three studies on the potential socio-economic effects of climate change in 5 developing countries. UNEP has also assisted in the development of a methodology for assessing vulnerability to sea level rise, and initiated a program on methodology to undertake GHG abatement costing studies.
-The Asian Development Bank (ADB) has a country study program for 8 developing Asian countries. The program will establish a common framework for country studies; assess the socio-economic impacts of climate change; identify policy options for limiting net emissions; adapting to climate change; and develop national and regional strategies. ADB also provides assistance to China and Thailand.

The United States has supported studies on patterns of GHG emissions and mitigation options in China, India, Indonesia, The Republic of Korea, Nigeria, Argentina, Brazil, Mexico, Venezuela, Sierra Leone and countries of the Gulf Council.

Major international programs which include studies related to potential biological effects of climate change are presented in Annex 4. The Berkeley workshop, ref. IPCC (1992c), identified considerable information on technological options.

CHAPTER 2
INVENTORIES OF SOURCES AND SINKS OF GREENHOUSE GASES[1]

2.1 The objectives of GHG inventories

Inventories of sources and sinks of GHGs are a prerequisite for identifying the most important sectors as well as for the implementation of cost-effective measures to limit/mitigate climate change. They also form starting points for projections of emissions, and provide a necessary basis for further negotiations on GHG limitations. If comprehensive national inventories are made worldwide, they will help to understand changes in the composition of the atmosphere initiated by human activity, and to further develop methods for making source and sink inventories. They may also form the start of a more permanent network for exchange of data and information regarding climate change. The emphasis given to these objectives of inventories may differ between the various countries. To assure that we make inventories for the gases that are of relevance for climatic change it is crucial to have a good understanding of the mechanisms and importance of the individual gases for the radiative forcing of the climate.

2.2 Gases affecting the climate

The source gases that affect climate can be divided into two groups: Firstly, we have the GHGs that have a direct effect on climate. Such gases are CO_2, CH_4, N_2O and the CFCs, HCFCs, HFCs and other chlorine compounds. Their relative impact on the climate is rather well established through the calculated GWPs (Global Warming Potentials) which were performed as part of the IPCC assessment.

The three first compounds given above have important natural as well as anthropogenic sources. In order to understand the significance of anthropogenic emissions it is important to know their natural cycles, which are not well known. Major efforts should therefore be made to estimate the contribution of different countries to the natural cycles of the GHGs. The significance of the different biogenic sources may vary, and such differences between different regions and countries should be recognized. It is also important to clarify to what extent human activity has modified the strength of the natural sources and sinks.

Most of the chlorine-containing compounds which have a greenhouse effect are of anthropogenic origin, and their sources are well established. Furthermore, the CFCs, HCFCs and the chlorine compounds methyl bromide and carbon tetrachloride are regulated under the Montreal Protocol due to their impact on the ozone layer, and therefore need not be considered in this context. The HFCs (particularly HFC-134a) have no ozone effect and are therefore not regulated through the Montreal Protocol but could have a noticeable GWP and should be included in the inventory list. The same is true for carbon tetra fluoride (CF_4) which has a high GWP and therefore should be included in the inventories. Although globally CF_4 is not a major greenhouse gas, it may be an important gas for certain countries (e.g. countries with production of aluminum).

Secondly, there are emissions of gases which have a negligible direct greenhouse effect, but are *indirectly* affecting climate through their impact on chemical and physical processes in the atmosphere, and thereby on the GHGs which are affected by chemistry. Source gases which belong to this group are NOx, CO and hydrocarbons. GHGs which will be affected by emission of these gases are methane and ozone. Ozone (O_3) is not emitted but is formed in the atmosphere. It affects climate through interaction with both longwave radiation and solar (shortwave) radiation. Emissions of SO_2 may also, through the formation of sulphate aerosols, affect climate. These aerosols reflect solar radiation, and may also affect the radiation budget through changes in cloud optical properties. The climate impact of this second group of gases cannot be assessed with satisfactory accuracy at present as it has been recognized through the recent IPCC assessment that

[1] We use the term greenhouse gas for all the gases mentioned below, although SO_2 affects climate through reflection of solar radiation.

we know too little about their impact on the greenhouse gases and the aerosols in the atmosphere. Nevertheless, it is believed that the indirect effect on climate can be important. Studies indicate that the increased reflection caused by increased aerosol formation from SO_2 has a cooling influence on the Northern Hemisphere. There is now a large effort to study the indirect greenhouse effects from anthropogenic emissions, and science should soon be in the position to give more reliable values for the climate impact of this second group of gases.

2.3 Sinks

Large amounts of carbon are continuously transferred between the atmosphere, the ocean and the terrestrial biosphere. In our current understanding of the carbon cycle there is an apparent imbalance; often referred to as "the missing sink" of CO_2. It is suggested that the terrestrial biomass (including soils) may account for this. The management of sinks to control atmospheric concentrations of GHGs should be oriented towards reforestation/afforestation, which will reduce atmospheric abundances of CO_2 and help control the buildup of this GHG. The ocean is a net sink for "excess CO_2" introduced to the atmosphere by human activities. The possibility of injection of CO_2 into the ocean is under investigation. It is however, of great importance to have a thorough understanding of the circulation and chemistry in the oceans before such measures are implemented.

For the other GHGs the dominant sink is provided by atmospheric oxidation, which is not easily controlled and is linked to other environmental problems.

2.4 Sources

There are now adequate methods for developing national inventories of the sources and sinks of the major GHGs. A major obstacle is that current estimates of sources and sinks are connected with large uncertainties. The different source categories are, however, identified. The main effort should be to estimate emissions within the categories that are important for the individual countries.

The main reason for the increase in atmospheric CO_2 is the use of fossil fuels in energy combustion. Another source is change in land use pattern. A small source which is relatively well known is cement production. There are other sources which have been identified, where the source strengths are uncertain, and where the contribution from individual countries can be important, like production and use of lime, gas wells, landfills, etc. Methane is known to come from a large number of sources, and significant uncertainties are still connected to the contribution from the different sources. A large fraction is anthropogenic, like the emissions from livestock, animal waste, coal bed releases, oil and gas production and transportation, wet rice cultivation, biomass burning, landfill and other human waste. The sources of nitrous oxide are poorly known; both the natural production and anthropogenic releases are connected with large uncertainties. Anthropogenic impact is due to the use of fertilizer, fossil fuel combustion, and processes associated with nylon manufacturing.

Due to the difficulties in assessing emissions of some of the major GHGs, a network to monitor atmospheric distribution of the gases may prove helpful in estimating sources, as well as controlling how control measures affect the atmospheric distribution of the GHGs. Such a network is already in operation through The World Meteorological Organization (WMO) and could play an important role in the long term process of climate change mitigation.

2.5 Review and assessment of source and sink inventories

Inventories of sources and sinks for the gases that affect climate are parts of most of the planned or ongoing country studies. IPCC established, in 1991, a work program to develop an approved methodology for preparing national inventories of greenhouse gas emissions and sinks. The objective of this program is to improve the quality and the comparability of national inventories. This methodology is described in OECD (1991). The IPCC default methodology is not meant to be obligatory. The countries could use other methods when better data and measurements are available. The common reporting framework given by the IPCC (OECD (1991), Annex C) was recommended however, to be used by all countries to allow for comparison of these inventories.

The Conference of the Parties is later expected to decide on format and/or guidelines for reporting. To assure comparability, the inventories should be transparent in approach, definitions and assumptions. An inventory is transparent when the methods are fully described and assumptions are documented and the GHG data are reported in a common framework. This means that national methodologies are acceptable, provided assumptions are clearly set out and scientifically defensible, and reporting categories consistent with the IPCC methodology are used (IPCC (1992c)). The IPCC methodology is still under improvement, and output from the country studies is important in this process. It is therefore essential that this work is strongly coupled to the activity of the IPCC.

In this section we will review and assess the terms of reference for studies that are not completed (ADB (1992); UNDP (1992); UNEP (1992a)) and the reports from the completed studies (SFT (1992); Jaques (1992); FEWE (1992)). The specific criteria that have been applied as a basis for the review and assessment are given in Annex 3. They are based on the recommendations given in OECD (1991), Leggett (1992), and what we consider important for assuring adequate preparation of the inventories.

2.6.1 Methodology

The methods prepared by the IPCC represent bottom-up approaches for CH_4, N_2O, NOx, CO and non-methane hydrocarbons. This means that several activity data are used on a quite detailed level together with source specific emission factors.

For CO_2, on the other hand, a top-down approach is given by the IPCC. This is based mainly on the supply of primary fuels and requires a complete balance of primary fuels produced, plus imports minus exports and net increase in stocks. If countries choose to use their own method, it will be useful if they also make an estimate in a manner consistent with this default method thereby allowing for comparison.

Testing of the IPCC methodology is the main objective of UNEP (1992a). It is not explicitly recommended in UNDP (1992). In ADB (1992), an examination of accepted methodologies and proposal of modified methods are required. Contributions to refinements of making inventories will be done in UNEP (1992a), and UNDP (1992). Regional studies to obtain better knowledge is promoted and the importance of the distinctive characteristics of the regions/countries is addressed in all three. Methodological requirements are however, given in only very broad and unspecified terms. The roles of the sources and sinks in the natural cycles are given some attention. A project that deals with this issue is the Amazonian sub project in UNEP (1992a). The objective of this study is to gain a better understanding of the capacity of the Amazonian rainforest as a net sink of CO_2 and the effects of deforestation on this capacity.

Disaggregated approaches have been applied in the studies from Poland, Norway and Canada (bottom-up methods). The methods applied are easy to update and time series easy to make if sufficient activity data are available. Attention has been given to sources that are important for these countries and results from national studies have been applied. The use of total amount of carbon for calculations of CO_2 emissions varies. In the IPCC method it is recommended that all carbon should be included in the CO_2 emission estimate (OECD (1991), summary). This means that carbon in hydrocarbons and carbonmonoxide should be accounted as CO_2. However, it may be argued that carbon sequestered in products for more than 20-50 years should be subtracted (e.g. production of silicon carbide).

These three countries have tested the IPCC method and compared it with national methods. For Norway and Canada this is done as the first step in a transparency study initiated by the IPCC (SFT (1992); Graham Associates (1992)). None of these three studies have used the same year as basis. Lack of data is hampering the use of the IPCC methodology for the Polish study, and recommendations are made to determine the necessary data sets for using this method. Recommendations are also given for initiating further activity to adapt the method to Polish conditions. This experience might be valuable also for other countries with economies in transition.

Estimates of natural sources and sinks and discussions of their roles in the natural cycles is to a large extent missing. Canada however, has estimated natural emissions of N_2O and CH_4. In addition, a carbon budget, although incomplete, has been developed. CO_2 emissions from the burning of wood are calculated in all three studies. These emissions are, in accordance with the guidelines from IPCC, not included in the total CO_2 emissions reported. In Norway, work is being initiated to quantify the strengths of the natural sources and sinks.

2.6.2 Documentation

Little attention is given to the transparency of the methods and results in the terms of reference for the three uncompleted studies. Descriptions and references sufficient for a reconstruction are not asked for. No direct requirements are given for reporting emission factors, activity data and essential assumptions. Analyses and explanation for any deviations between data sets, emission factors and results are not among the terms of reference. In ADB (1992), however, a review of emission factors for methane emissions from rice fields and CO_2 from coal mines and coal-fired devices are asked for. In addition, socioeconomic indicators should, according to the terms of references, be collected and compared, and the results should be compared to preliminary estimates conducted. The documentation is clear and thorough in the studies on Canada, Norway, and Poland. However, there is limited documentation of what is included in the activity data for marine and air transport in the Canadian study.

2.6.3 Reporting

Different methods may be used, but it is of great importance that the results are reported in a way which makes it possible to compare the studies and find the reasons for any deviations.

In ADB (1992), the terms of reference only address GHGs without stating explicitly whether the gases with indirect effects on climate should be included. Neither reference year, time intervals nor units of emissions are specified. No direct requirements for a common set of source and sink categories are given, and no definitions are wanted. However, since gaining experience with the IPCC method is the main objective of UNEP (1992a), several reporting requirements are given indirectly.

The reporting of the results from the completed studies are well arranged. Full molecular mass units are used. Such requirements are not given in the terms of reference for the uncompleted studies. Assessments of uncertainty are generally absent, but they are treated to some extent in the Polish study where results obtained with different assumptions and parameter values are compared.

HFCs and CF_4 have, due to recent findings on their climate impact, only received limited attention. A preliminary estimate for CF_4 is, however, made for Canada. In Norway, work is initiated to estimate the emission of this gas.

2.7 Possible improvements of current approaches

For the uncompleted studies it may be concluded that the terms of references are given on a far less detailed level than the requirements set up in Annex 3. The completed studies, on the other hand, are much more in accordance with the criteria set up in the annex. An explanation for the difference between the two groups may be that the completed studies on inventories are from developed countries or are conducted with assistance from a developed country. In addition, to be able to carry out an estimation of the strength of sources and sinks, one has to apply a rather detailed and well structured approach. When the planned studies are completed, the reports may therefore be more in accordance with the criteria that have been applied in this review and assessment.

Based on the review of the terms of reference and the completed studies, the following remarks can be made:

1) As long as the IPCC methodology is recommended in terms of reference, several documentation and reporting requirements are given indirectly. Stating requirements for documentation and reporting in more explicit terms, would, however, help to ensure that the projects are carried out

within a common framework and in accordance with the overall aim of the country studies. A standard summary of results for easy and quick overview and comparison should be made.
2) Countries should clearly account for any deviations from the IPCC default methodology.
3) Comparison between results obtained with different assumptions and methods is useful and should be performed if resources are available. This will elucidate the sensitivity of the results for the various elements in the approach.
4) Promote the use of a method with disaggregation on a level of detail that is necessary for national policy making and the implementation of measures to reduce emissions/enhance sinks.
5) The country studies represent a good opportunity to collect data and information that have been missing in international and national statistics so far. E.g. data for non-commercial energy could be made available if this was specified clearly in the terms of references.
6) Emphasize the difference between countries with respect to the importance of the sources and sinks, and promote national or regional studies to gain better understanding of important processes. Focus on and take into account that emission factors, assumptions, etc. that are valid in some countries/regions, may not be applicable in other countries/regions, e.g. due to differences in climate.
7) The natural cycles could be given more attention, thereby contributing to the understanding of the full cycles of the GHGs. It would also be useful to study to which extent human activities have modified the strengths of the natural sources and sinks.
8) The need for inclusion of gases which have an indirect effect on climate should be recognized.
9) The issue of uncertainty should be given higher priority. Preferably, uncertainty ranges for the estimates should be given.

CHAPTER 3
IMPACT AND VULNERABILITY ASSESSMENT

National assessments of climate impact and vulnerability are necessary building blocks in making damage cost projections, and, furthermore, they are needed to develop efficient national response strategies. *Vulnerability* to climate change may be defined as a nation's ability to cope with the consequences of the range of impacts of climatic changes that may follow from further increases in GHG concentrations in the atmosphere. Human activities and natural systems show different degrees of sensitivity to climate change. Thus the ability to cope with a changing climate depends on political and socio-economical conditions and on the natural ecosystems. *Impacts* of climate change can be defined as the (biological, physical and economic) consequences of a particular scenario with respect to the path of future global GHG emissions and given the resulting estimated climate changes.

3.1 Regional climate change

A first step in a country study of the probable impacts of climate change is to establish the basis upon which national impacts can be estimated. Confidence in the prediction of regional changes based directly on the Global Circulation Models (GCMs) is low, according to Houghton et al. (1992). Even if some progress in the simulation of regional climate has been made, this basis remains uncertain. The IPCC decided in their November meeting that the issue of regional scenarios should receive high priority in the program of WG I.

An alternative to projections from GCMs is the use of analogue data from past climate events. These are related either to present-day climatic variations, like droughts or floods, or to paleoclimateological analysis. Based on such vulnerability studies of climate variations, possible climate impacts from anthropogenic climate change may be projected and assessed. One problem of this methodology is the uncertain projective power of past climate events to study long-term climate change caused by anthropogenic GHG emissions.

3.2 Review of climate impact in physical and biological terms

Physical and biological climate impacts can be divided into three groups. The first consists of physical impacts, like sea level rise and loss of land, and damages to infrastructure due to hurricanes and floods, etc. The second group are biological impacts on agriculture, forestry, fishing and aquaculture related to changes in precipitation, water supply, soil moisture, and hurricanes, etc. The third is made up of biological impacts on natural ecosystems.

There are many types of uncertainty in this area, but the IPCC WG II recommends that the linkages between physical and socio-economic impacts should be further explored and that the methodologies for quantifying these impacts should be improved.

The impacts from climate change depend on the species of plants and animal in the ecosystem under consideration, and the interrelations between these (Kristiansen (1992)). The ultimate outcome of climate changes at the ecosystem level depends upon the system's ability to adapt and species' dispersal ability. Most studies suggest that time and genetic variability is insufficient for evolution to occur, and that the major response will be migration. It is likely that the rate of extinction will be increased. Whereas some factors tend to increase biomass accumulation, others work in the opposite direction, which will affect the carbon-cycle. There are indications that the terrestrial biosphere may act as a net sink for carbon. This is still a controversy, however. The major international programs which include studies related to potential biological effects of climate changes are presented in Annex 4.

According to Houghton et al. (1990) the human settlements, most vulnerable to climate change are found in developing countries: low-income groups, residents of coastal lowlands and islands, populations in semi-arid grasslands, and urban poor in squatter settlements.

There is considerable variation in the methodological approach taken in the country studies that have been reviewed. About half of the studies mostly employ GCMs combined with impact models to estimate losses to agricultural production and soil erosion, whereas the other half are vulnerability studies based on analogue data from present-day climatic variations. A majority of the studies consider both physical impacts from sea level rise and biological impacts such as crop losses in agriculture and forestry, but some are concerned only with sea level rise and related loss of land. Much less is done in the area of biological impacts on natural ecosystems.

3.3 Review of climate impact and vulnerability in economic terms

The economic costs of climate change can be divided into two parts, namely i) costs of adapting to climate change, and ii) economic losses resulting after efficient adaptation has taken place. Efficient adaptation on a global scale implies that net marginal adaptation cost is equal for all adaptation measures, and is equal to net marginal reduction in economic loss. Most practical cost calculations will probably be made at the national level, eventually for groups of countries. With no external effects between countries resulting from adaptation measures, the same basic principle can be applied to the national level. Possible external effects ought to be accounted for, but they are likely to be small for national adaptation measures.

The principle of efficient adaptation implies that the total economic costs (to the world community, and/or each region and individual country) of a given climate change are minimized. An important aim of the country studies is, therefore, to try to identify efficient adaptation measures, both for each country, and with respect to their potential for reducing other countries' costs, and for groups of countries.

Adaptation measures are of three main types: i) investments in infrastructure; ii) relocation of structures in response to climatic change or sea level rise; and iii) increased costs borne by businesses and households, which are necessary to optimize the response to temperature rise. Post-adaptation economic losses due to climate change consists of two main parts: i) production losses (in agriculture, forestry, industry etc.); and ii) direct welfare impacts on the general population from the change in climate.

Both groups of costs are difficult to assess on a prior basis. At least three main problems are involved in their calculation: i) the choice of an appropriate rate of discount; ii) general uncertainty of impacts, valuations, technological change, and preferences; and iii) ethical issues related to intergenerational welfare comparisons. Point i), while of crucial importance for cost-benefit analyses of adaptation measures, is discussed further in Chapter 4. Point ii) is also of major importance, given the long time horizon involved. In general, the greater the uncertainty of impacts, the more serious should be an adverse impact with a given expected cost (to the world or national community), provided a reasonable assumption of risk aversion with respect to major welfare changes. Particularly great problems are involved in valuing the direct welfare impacts. Here, special methods for valuation of environmental goods should be applied, and user, option and existence values related to the environmental changes included. An increased rate of technological change is important since adaptation costs and post-adaptation economic losses can be reduced. Obviously the direct welfare impacts on the general population may change if the preferences of the population change. Problems of intergenerational welfare comparisons are also crucial, but cannot be discussed adequately here. Note that the lower the rate of discount chosen, the greater weight is generally put, today, on future generations when calculating economic impacts of climate change.

The following additional points should be noted:
- The issue of efficient adaptation has so far been discussed independent of efficient abatement, taken up in section 4.1. In principle, the two should be determined simultaneously, and together make up an optimal overall strategy to deal with climate change. This would also involve taking into consideration interrelations between the two, whenever they are present. At the national level it should be legitimate to take the climate effect as exogenous when deciding on adaptation.
- The more remote and gradual the occurrence of climate change, and the shorter the lifetime of investments, the lower adaptation costs are likely to be, and the greater degree of adaptation is likely to be optimal. This is because future investments and technological developments are likely to accommodate the climate change and be structured in such a way as to further reduce impacts, and because a more gradual climate change allows for ecosystem adaptation.
- Adaptation measures indicated in national plans may not be optimal, due to the inability to identify such measures for all relevant sectors, to institutional and political constraints, and to the inherent uncertainty involved in calculating the net benefits of the measures. While we do not provide a complete guide on how to deal with the various issues, the national plans should at least discuss the problems of cost calculation mentioned above, and how these are considered in the plans.

The country studies reviewed commonly assess climate impact in economic terms as production losses in agriculture and other economic sectors, and as loss of land which may be habitated, used for production activities or occupied by natural ecosystems. These impacts are experienced as droughts, sea level rise, saltwater intrusion into freshwater aquifers, floods, increased erosion, etc. Production losses are often expressed as percentage losses in sectoral GDP, and may therefore be relatively easily expressed in money terms. Very few efforts have been made to value changes to environmental goods.

Most of the studies consider adaptation measures in agriculture, forestry, water resource management, and coastal zone protection and management, etc., but very few cost calculations for these measures are reported. Calculations of costs and effects are necessary in order to identify efficient adaptation measures. These calculations are also necessary to compare the costs of adaptation measures and the costs of remaining impacts, which are both necessary components to develop a cost-efficient national response strategy. One example of cost calculations is found in the case studies of sea level rise reported in IPCC (1992a), but the calculations are limited to a fixed capital value of infrastructure (no depreciation or growth), and they are based on the current capital cost of adaptation measures (no discounting).

IPCC (1992a) discusses the robustness of adaptation strategies with respect to uncertain sea level rise. For this purpose probability distributions of sea level rise are generated.

3.4 Possible improvements of current approaches

Based on the review of the terms of reference and the completed studies, the following remarks can be made:

1. The country studies should include both physical vulnerability/impacts, biological vulnerability/impacts related to agriculture and forestry, etc., and biological vulnerability/impacts related to natural ecosystems.
2. More emphasis might be put on climate vulnerability analyses of local ecosystems.
3. The country studies should, to a larger extent, reflect the uncertainty of national/regional climate change on one hand, and the uncertainty of vulnerability and impacts on the other hand. With respect to climate impact uncertainty scenarios of high, medium, and low vulnerability could be analyzed. Moreover, the different components of climate change should, when appropriate, be considered separately. This includes temperature rise, changes in precipitation patterns, and changes in wind patterns (e.g. frequency of hurricanes).
4. More emphasis should be put on calculating likely sectoral production losses in money terms, and on estimating the money costs of other types of climate impacts, e.g. loss of land.
5. Biological and physical impacts of climate change should, whenever possible, be valued, preferably in economic terms, even if there are particular problems associated with this.
6. The costs should be expressed in the same currency, possibly in 1992 USD.
7. The costs of adaptation measures should be clearly identified and evaluated in terms of cost-benefit analyses whereby the adaptation cost is compared to the expected benefit in terms of reduced damage from climate change.
8. A cost-efficient curve of adaptation measures should be constructed, where projects/measures are ranked according to increasing net expected cost (total cost minus expected benefit).
9. For evaluation of impacts and adaptation measures, assumptions on time horizon, discount rate, and uncertain impacts and valuations should be harmonized in the country studies. In particular all country studies should include one common set of parameter values, whereas additional sets could be based on national conditions.

CHAPTER 4
COST EFFECTIVE INTERVENTIONS

The third main component of country studies in addition to emission inventories, and impact and vulnerability assessments, is cost-effective interventions. A discussion of cost-effective interventions should be based on the general framework of cost-benefit analysis.

4.1. Theoretical basis for cost-benefit analyses related to climate change

We will sketch three different successive levels of aggregation at which such analyses can be conducted.

The global optimum. This is basically a theoretical concept, where global net marginal cost of reducing GHG emissions equals the marginal gain to the world community from reducing these emissions. In particular, this implies i) determining optimally the global target for GHG emissions, ii) always implementing the most cost-effective measures for reducing emissions on a global scale, and iii) implementing abatement measures and adaptation measures until the marginal cost is equal for the two groups of measures. *Net marginal cost* should here be defined as gross marginal cost (output losses and the like) minus net marginal external benefits beyond those due to the reduced greenhouse effect (such as reduced pollution and technological spillovers), resulting from the efforts to reduce GHG emissions.

Global cost minimization given a global GHGs emission target. This implies that any given global emission target for GHGs (e.g. measured in carbon equivalents in terms of their global warming potential) should be implemented with a minimum net total abatement cost to the world

community. In particular, this implies that there does not exist an unimplemented abatement measure with a lower net cost than those already implemented. It also implies that abatement projects are realized in each country until the net marginal abatement cost is the same for all countries.

National cost minimization. The objective here is basically the same as at the international level: For all sectors, the net marginal abatement cost is to be equal, and there must not exist sectors where unimplemented efforts imply lower net marginal cost. A particular problem at the national level is that national efforts to reduce emissions may have external effects for other countries, e.g., reduced coal consumption in one country may imply less air pollution for the neighbor. Such neighbor effects should generally be counted when calculating the net costs of abatement in any one given country. If such external effects are important, it may be an argument in favor of treating countries not individually but by groups according to such effects.

The following comments are warranted.

i) Some abatement measures may imply technological improvements that may reduce costs in other sectors and countries than those directly affected by the measures. Such cost savings should in principle be counted in calculating the relevant cost concepts, although this often may be difficult in practice.

ii) There may be problems of comparing marginal costs across nations (or even within countries), due to missing markets, widely differing relative prices among nations, and to the use of local currencies whose official values deviate from market values. A related problem is that for some products which contribute to emissions, e.g., energy commodities such as coal and oil, prices are distorted due to subsidies. Furthermore, ordinary markets may be thin or nonexistent (e.g. for fuel wood and charcoal), and any possible observable market prices are unreliable. If this problem is serious for some countries, it is an argument in favor of only considering national-level plans, and not attempting to incorporate these into a global optimizing framework.

iii) Other externalities related to GHG emissions are notoriously difficult to quantify and value. Although valuation methods do exist, there are very few examples of national plans (e.g. with respect to energy use) that incorporate such valuation in a consistent way.

iv) In the above we have taken the marginal damage curve related to GHG emissions as exogenous. Some of the relevant national and international efforts to reduce emissions may, however, affect the economic cost resulting from a given rise in temperature. With a given global emission target, this should generally be treated as an externality contributing to a modification of net marginal abatement cost (upward or downward depending on whether cost is increased or decreased).

v) The procedure of ordering projects according to rising net total marginal cost is far from trivial, in practice and in principle. For one thing, different projects may have different time profiles for costs and benefits, and a proper choice of the rate of discount, a difficult issue to be discussed more in section 4.2, is then often necessary for ranking. Secondly, project externalities may make the computation of the optimal project sequence extremely hard, even under certainty. For each project, one has to calculate the externalities for all remaining projects that will be implemented in the future in the appropriate sequence of development. Note that such externalities may lead to a net marginal abatement cost curve for the individual projects that is not necessarily uniformly upward sloping if the implementation of some abatement cost measures significantly lowers the costs of carrying out other measures. Uncertainty will further complicate the computational problem, since it means that the expected path of future costs will depend on uncertain state variables and on other intrinsic uncertainty revealed over time.

vi) In the discussion of abatement measures it is useful to distinguish between the "bottom-up" approach, where projects are considered on an individual basis, and the "top-down" approach, where more general policy measures (largely directed toward the private sector) are being valued.

The discussion has so far been based on a bottom-up approach. The basic principles of optimal project selection and sequencing should, however, in principle, apply also when more general measures (such as taxes and subsidies) are used. This distinction will be elaborated in the next section.

4.2 A practical approach to cost-benefit analyses related to climate change

The main focus of abatement efforts is at the national level, but extra cost savings for a given abatement target are possible for collaborating countries as long as there are structural differences between them, i.e. different national abatement costs. Through cooperation between nations these cost savings can be realized. There are provisions for abatement collaboration between nations under FCCC, confer "joint implementation" (FCCC, Art. 4, §2.(a)), even if the criteria of joint implementation have to be negotiated. Even if nations cooperate, abatement costs should be minimized in each country.

To minimize national abatement costs related to some national abatement target we should evaluate all possible measures to reduce net GHG emissions and choose the least expensive set of measures for each given level of abatement. Measures can be project investments, direct regulation, or economic policy instruments like taxes and tradeable emission allowances. The measures can be ranked according to net total costs relative to net reduction of GHG emissions, e.g., expressed in 1992 USD per ton of carbon dioxide, where other GHGs than carbon dioxide are expressed in tons of carbon dioxide by using global warming potentials (Houghton et al. (1990), (1992)). Instead of reducing gross GHG emissions, net emissions can be reduced by the sequestering of carbon through afforestation. Abatement measures are often not selective, i.e. they might reduce pollution or lead to technological spillovers. These externalities should be accounted for by subtracting the benefits from the cost of the measure. To make the country studies comparable, sectoral and activity definitions and reporting units should be standardized.

National abatement costs should be minimized over economic sectors, different GHGs, projects, technologies, and policy measures. A cost curve can be calculated by ranking all possible projects to reduce net GHG emissions according to increasing cost. Total costs are minimized if the cheapest project is chosen first, and then more projects chosen according to increasing cost. The costs and ranking of remaining projects may be influenced by the realization of projects. To correct for externalities of this type the costs of the remaining projects should be recalculated successively for each realization of the cheapest project. These calculations require a project overview where policy and expenditure measures are listed with cost and emission impact data. To account for externalities among projects relevant data for these should be supplied.

Projects and measures can be divided into two main groups according to methodological approach. In the *bottom-up* approach the projects are well-defined investment objects with a specific investment profile, e.g., replacing an existing technology in a production process with the most energy efficient new technology. This approach is well suited for studying the choice between different technologies, which is particularly relevant for valuing public GHGs abatement projects. A disadvantage is that accounting for interdependencies between the projects is difficult with this approach. However, some interdependencies between, e.g., energy technologies or projects can be accounted for in energy-system models. In the *top-down* approach a macroeconomic model is employed to analyze the effects of more general policy measures and programs, e.g., a carbon tax. The interdependencies between the different markets and sectors are here modelled explicitly. The relation to specific technologies and investment projects is weak, and the cost of an abatement measure must be expressed in terms of reduced economic growth or implicitly calculated the efficiency losses. With this approach, explicit assumptions must be made about market structure and the economic behavior of individual agents. In particular, the degree of competition in the sector contributing the GHG emissions is of importance for the efficiency of policy measures. For economies in transition there are specific problems related to the instability of institutions and market structure, as in the situation in Eastern Europe.

In a long-term climate policy of cost-benefit analyses featuring abatement costs and benefits the

discount rate could be based on pure time preference, expected growth of per capita income, and the elasticity of the marginal utility of consumption, see Cline (1992a), (1992b) and Pearce (1991). In our context, however, a common discount rate is only required to compare projects with different cost profiles and eventually with different benefit profiles with respect to local and regional pollution and other externalities. If the projects are publicly financed the relevant discount rate is the average return to public investments, or, more precisely, the return to the best alternative public investment project. To the extent that direct regulations of private firms and market measures such as taxes are employed to induce abatement efforts, the regulation and taxing levels should be based on national cost-benefit analyses where the appropriate discount rate is applied. Also, in this case, the appropriate discount rate required to compare projects and measures of different time profiles is the average return to public investments.

The average return to public investments may vary between countries due to different political systems and priorities and to capital market imperfections in general. Consequently, the appropriate discount rate for abatement project calculations may also vary between countries. In a joint implementation perspective a higher return to public investments in a country, reflected through a higher discount rate applied in that country, could then be taken as a signal that abatement projects should be realized in this country before projects in other countries.

There are many uncertainties regarding future climate change which complicate a long-term cost-benefit analysis, i.a. making discount rate calculations more complicated. The effects of a project on GHG emissions and on many externalities may not be known. Furthermore, there are uncertainties with respect to future available abatement technologies and projects, commodity prices, economic growth, and the global situation in general. Part of the first type of uncertainties can be resolved through data collection and research, whereas the simplest way to handle the latter type of uncertainty is to update the list of projects and measures constantly with respect to items, costs and emission data.

Minimization of national abatement costs is based on assumptions about the global situation, international markets and abatement policies of other countries, e.g., economic growth, population growth, oil price development, exchange rates, interest rate levels, and future technological options. National measures may influence international markets and prices. One example is a carbon tax in some countries that reduces demand in these countries, but decreases the world market oil price and thereby increases demand in other countries. Assumptions on these global parameters should be coordinated between country studies to make them comparable and consistent. This would also require the coordination and harmonization of baseline scenarios to which the abatement scenarios are compared.

4.3 Review of country studies

In this section we review terms of reference for country studies that are completed, underway or planned based on the discussion above. Ten features of the studies are considered.

Objectives

The objective of most of the country studies is to identify policy options to reduce GHG emissions as part of a national response strategy. In ADB (1991 and 1992) and UNDP (1992) there is an additional regional (eight to fourteen Asian countries) response strategy perspective. In some studies there is an additional focus on cost effective opportunities, and both abatement and adaptation measures are considered. The scope of other studies is limited to a review of existing policies with a view to minimizing conflicts with climate policy, to the industrial sector, or to macroeconomic impacts of GHGs abatement.

Methodological approach

The main focus is on bottom-up models and cost-benefit calculations for projects and technological options. In six of the studies both bottom-up and top-down models are considered. Macroeconomic models are available largely only for developed countries (Denmark, the Netherlands, and Japan). In the ADB studies for eight Asian countries (ADB (1991)) and the Zimbabwe study (SCEE et al.

(1992)) macroeconomic implications are discussed. In most of the other nine studies the scope is limited to identifying technological options and potential energy saving and GHG emissions reduction, eventually including investment costs, operation and maintenance costs, and fuel costs. In a few of the studies in this group a cost efficient curve of abatement projects is constructed.

Externalities between projects and economic sectors are accounted for in the top-down studies. In ADB (1991) and (1992) other benefits than those relating to climate change will be accounted for. To some degree, externalities between countries are included in the ADB studies for eight Asian countries (ADB (1991)) since a regional strategy is considered. The effects of the projects for environmental externalities are generally not discussed in any of the studies, nor how such externalities should be included and valued.

Units of measurement
An explicit documentation of units of measurement is to a large extent missing in the country studies.

Range of projects, options and measures considered
The coverage of options to reduce net GHG emissions is one of the strengths of the studies. Most studies consider different technological options to improve energy efficiency; fuel switching to gas, oil or renewable energy sources (including agricultural and other waste). Fewer studies consider afforestation and change in agriculture and other land use practices. The transport sector and the potential for public transportation is also included in many studies. In some of the studies for Asian countries, adaptation measures in agriculture, forestry, water management, the residential sector, etc., are included. Taxes, subsidies and direct regulations are policy measures considered in half of the studies.

Range of economic sectors considered
Most economic sectors are covered in around two thirds of the studies, whereas clear documentation is missing for the rest. A few sectors, e.g., agriculture, are missing in a few of the studies. In the Italian study (Contaldi (1992)) the only sector considered is industry.

Definition of GHGs abatement costs
Documentation of definitions of abatement costs is scarce in many studies. In the bottom-up studies the common approach is to calculate the investment cost of a project, eventually including operating and maintenance and fuel costs. In the top-down studies the cost is usually reported as GNP loss. In the Brazilian study reported in UNEP Collaborating Centre on Energy and Environment (1992) the cost is calculated from the consumers' perspective as net project investment plus the value of energy expenses saved through the project.

Discount rate
The documentation on discount rates is scarce. A discount rate of 12% is reported in the Brazilian study as reported in UNEP Collaborating Centre on Energy and Environment (1992a) and a discount rate of 5% is reported in Burg, Harmelen and Ybema (1992).

Uncertainty
In a few studies, uncertainty related to model specifications and assumptions is handled by comparing the results of different models and studies. Another option considered is the inclusion of more than one baseline scenario. Besides this, little attention is generally paid to uncertainty.

Baseline scenarios: Assumptions on international markets and the global situation
A business-as-usual baseline scenario is mentioned in many of the studies. The assumptions with respect to fuel price, economic growth and other factors are stated in only a few of the studies.

Realism: Political and social constraints
In a few of the studies some evaluations of political and social constraints for implementing abatement measures are given.

4.4 Possible improvements of current approaches

Based on the review of the terms of reference and the completed studies, the following remarks can be made:

1. The objective of all studies should be expanded to identify cost-effective abatement projects and options, given a national abatement target and the necessary policy measures at the national level.
2. In the bottom-up models, more efforts should be put into finding an optimal sequence of projects and thus a cost efficient curve accounting for externalities between them, as well as accounting for other positive externalities such as reduced pollution and technological spillovers, which may be considerable. Investment, fuel and operation and maintenance costs should be included.
3. The cost efficient curves of abatement projects should be comparable between countries to identify the project sequence minimizing abatement costs across countries in order to develop joint implementation programs.
4. Top-down analyses based on macroeconomic models, if available, should be employed to supplement the bottom-up analyses and to account for interdependencies and externalities between sectors. In particular, more attention should be paid to the inclusion of environmental externalities in the studies (both within countries and possible externalities across country borders).
5. In the bottom-up analyses, costs should be reported as 1992 USD per ton of carbon dioxide equivalent. In the top-down analyses, costs should be reported as GNP loss in per cent and 1992 USD. Other reporting units should also be standardized and clearly documented.
6. Some country studies need to expand the range of projects, options and policy measures considered. Similarly, the range of economic sectors considered should be expanded in some studies.
7. The discount rate employed should be clearly documented. The discount rate should be the same as the discount rate applied for calculating the returns to public investments in each particular country. Supplementary calculations based on a low and high level may strengthen the analysis, however. This low and high rate should preferably be the same for all countries.
8. Since there is intrinsic uncertainty with respect to assumptions about the future and thus baseline scenarios, two or more baseline scenarios should be considered. More might preferably be done to identify the likely main sources of uncertainty, e.g., related to future parameter values, technological factors and valuation issues.
9. The baseline scenarios should be harmonized to make the country studies consistent and comparable, e.g., with respect to time horizons, economic growth, population growth, interest rates, and fuel price growth rates. In particular all country studies should include one common set of parameter values, whereas additional sets could be based on national conditions.
10. More emphasis should be put on discussing political and social constraints to abatement policy measures. While we do not recommend that such constraints should be viewed as absolute obstacles to policy changes when warranted, realistic national plans should not include measures that are politically impossible to implement. The studies will be further strengthened if an analysis of the cost-effectiveness of such possible measures is included.

CHAPTER 5
COSTS AND STAFFING PATTERNS

5.1 Costs and staffing

The cost of full-fledged country studies will vary with the size and complexity of the study. The US is offering support to developing countries and countries with economies in transition to carry out climate change studies. They are considering funding in the range of 100,000 to 500,000 USD per country (Morgenstern (1992)).

Looking at country studies financed through multilateral sources, we can see that:
The ADB study had 3 main components: (i) establishment of a common framework for country studies; (ii) execution of 8 country studies; and (iii) preparation of a regional strategy. The country studies had 3 components: Socio-economic impacts; policy options; and national response strategies.

The full study had a budget of 1,690,000 USD, giving an average cost of 211,250 USD per country.
The UNEP study on sources and sinks only, for 11 countries, had a cost of 6,416,975 USD, which gives an average cost of 583,361 USD per country.
The UNEP supported Brazilian study on impacts had a funding of 50,000 USD, while the UNEP supported impact studies in 5 countries had a funding of approximately 150,000 USD per country, (Peter Usher, UNEP).
The UNDP study made a budget for its study. Added to the figures quoted below are also the expenses for project execution estimated at 1,300,000 USD.

Table 2 Indicative budget for the UNDP study for 14 countries in Asia

Component	Approximate Costs per country
Emissions Inventory for 14 countries	72,000 USD
Emissions Measurement for 6 countries	250,000 USD
Cost Emissions Reduction Technology Curves for 4 countries	250,000 USD
GHG Emission Scenarios/Impact Evaluation for 4 countries	250,000 USD
National Response Strategy, 14 countries	65,000 USD
Training programs, Expert Consultants, Study tours, etc.	25% of budget

Source: UNDP project document RAS/92/G31

There are several viable initiatives for obtaining a better cost effectiveness and rationalization in the overall execution of country study activities.

Many country studies have an extremely wide scope and range (assessments in the fields of climatology, agriculture, forestry, water resources, costal management, energy, industry, transport, health, socio-economic and institutional aspects etc.). Assignments by multilateral organizations for international consultants to assist in the country study activity are often for "all-round" experts in addition to a project coordinator, ADB (1991), where one team leader/resource economist, one impact specialist and one strategy specialist were requested. Even if local teams are supposed to do most of the substantial work, these consultants are expected to be "back-up" experts for all the issues covered in the terms of reference.

5.2 Possible improvements of current approaches

Based on the review of the terms of reference and the completed studies, the following remarks can be made:
1. In-depth studies of specific elements like the building of regional climate change scenarios should be performed as a joint activity between countries and organizations. This task under the mandate of the IPCC should receive high priority.
2. Many countries share important ecological and socio-economic characteristics, and thus also probable impacts and vulnerability to climate change. These countries and relevant funding institutions should increase their efforts in coordination of their climate study activities.
3. Interagency coordination should be improved. There seems, especially in the South-East Asian region, to be overlapping activities, ref. the studies of ADB (1991), IPCC (1991) and UNEP (1992A).
4. One might consider giving more attention to the building of local teams well connected to the relevant policy- and decision-making authorities, and to concentrate more on the supply of relevant data, and, where necessary, special expertise to assist in performing certain analyses.
5. Terms of reference might be more country specific and take into account differences in research capabilities.
6. Country workshops to set priorities like ADB (1991) and the planned series of INC/FCCC-UNITAR workshops are recommended.

CHAPTER 6
THE USEFULNESS OF COUNTRY STUDIES TO GOVERNMENT POLICY MAKERS

6.1 Governments interest in country studies

There are many reasons for countries to take an interest in country studies.
- Country studies provide data relevant to the sum of information that governments are committed to provide according to the FCCC.
- Country studies form a necessary basis for cost effective and national response strategies.
- Country studies form a basis for developing projects eligible to GEF funding.
- All governments share an interest in improving the input of data to the IPCC and thereby improving the panel's ability to assess the long term risks of climate change.

The degree of interest for information from country studies will vary with the degree to which governments feel exposed to the risks of damages and heavy abatement costs assessed in chapters 3-4.

Governments in developed countries who may have to implement rather expensive measures to reduce emissions of GHGs in this decade, have a clear interest in a comprehensive inventory of the sources and sinks of these gases. At the same time there should be a strong interest in studies of relative abatement costs and "no regret" or low cost options. Country studies are also necessary for the development of joint implementation projects with other countries.

On the other hand, governments in developing countries may have a particular interest in information about vulnerability of their country, i. a. because the standard of living generally is low and their capacity to implement large-scale adaptation measures, like introducing drought resistant species or making coastal zone infrastructure investments, may be limited.

All governments have a common and less differentiated interest in country studies because the panel will need better information on actual sources of emissions. Such information again, is important as input to the global scientific effort on modelling climate changes organized by or interlinked with the IPCC. All the scientific progress in this respect is a contribution to improving the risk assessment of climate change.

There is a long tradition for international cooperation with regard to scientific information about the global climate system through the World Meteorological Organization (WMO). In other fields of research relevant to the country study process such a tradition is less prevalent and may have to be established through experiencing mutual confidence. In this respect one may have to recognize that some issues are sensitive, particularly energy-related information.

6.2 The organizational setup for country studies

The usefulness of country studies to government policy makers will to a large extent depend on internalization of the process and on governments trust in experts performing it. In most developed countries country studies or elements thereof have been organized through relevant government institutions, and research institutions, very often with the use of inter-ministry/agency working groups. Through such participatory processes, where reports and studies are open to comments by the research community, NGOs and economic interest groups, the process and recommendations are likely to gain confidence, authority and support in political spheres.

A number of developing countries have carried out similar processes as part of the preparation and participation in the INC/FCCC and the IPCC. In particular such integrating efforts have been successful in Malaysia, Indonesia, China, India and Brazil.

In countries with less national governmental preparation, international agencies such as UNEP,

UNDP and ADB have organized country studies. In these processes, it is our impression that external consultants often start with limited experience and time for coordination with national governments, and that they have to fight with rather short timetables, and too ambitious plans for investigation and assessment. In such situations there is always a danger that the country studies fail to achieve the necessary links to national governments, important decision makers and interest groups. Local consultants may sometimes have been chosen without necessary information about the best available scientific experts. Overall, it may be argued that the country study process is not well suited for being organized as a set of consultancy contracts used for technical and engineering projects carried out by development banks or similar agencies.

6.3. Linking country studies to the Convention and its machinery

It is important to note that most of the country studies reviewed in this report were initiated before the FCCC was actually ready for signature and in many cases before it was negotiated. Some of the institutional and organizational weaknesses may therefore be attributed to the fact that studies have been planned as a contribution to a preparatory process for the negotiations by INC rather than for the implementation of the FCCC.

When moving into further studies and supplementing those already in process or available there is a much better chance that studies could feed directly into the preparation of governments inputs to the other Parties to the FCCC.

The secretariat of the INC, which is the intermediary secretariat of the FCCC, and the GEF as financial mechanism could improve these chances by clarifying the division of labor between them with regard to country studies. At the same time they should link this up to the needs of IPCC and use the expertise of the panel and its working groups.

Even if country studies should have a general and wide scope, one could at a later stage of more detailed research consider giving more attention to the most important and feasible measures and less attention to others, and even to omit some of the elements in the terms of reference. If the studies are constrained by a limited research capacity the best use of available resources is to give priority to the most important and feasible measures. Furthermore, country studies should be coordinated with national development planning to make the best use of total resources. Thus some of the relevant components of a country study might already be covered by national planning studies. Countries with large research resources can carry out detailed research in all fields of a country study, whereas other countries might need to restrict the detailed research to fewer fields and the most important measures. At least for the latter group of countries there is a likely gain from cooperation between countries and division of labor on country studies.

Measures for agricultural adaptation, adaptation measures for water resources, and coastal protection measures, etc., are examples of important and feasible measures. Taking into account that the focus under the work of the GEF is very much directed towards the energy, transport and forestry sectors, we feel that country studies should put emphasis on the assessment of policy options likely to be discussed by governments and international agencies during the next two decades. After a decade, most country studies are likely to be outdated.

One might, on the other hand, consider limiting the study of health risks. This is not suggested because the issue is not important, but because other factors in the foreseeable future will be more important for health risks than those related to global climate change.

One might also consider omitting, from national studies, the appraisal of the potential of reduction of methane and nitrous oxides emissions from agricultural practices. Such difficult studies should ideally be initiated as joint ventures through the IPCC network. Even recognizing that methane emissions from livestock is substantial, it is highly unlikely that measures to change feeding practices will be given priority for global environmental reasons. Reduced use of fertilizers may be important for economic and local environmental reasons, but hardly because of climate change.

6.4 Possible improvements of current approaches

Based on the review of the terms of reference and the completed studies, the following remarks can be made:

1. Further country studies should be linked directly to the fact that governments have signed, and intend to ratify the FCCC.
2. Before giving further support to country studies, multinational and bilateral donors should consult closely with national governments and link the studies to a national study board or committee, set up by the government.
3. Country studies should not only contribute to, but be an integral part of national capacity building.
4. One should not preclude the use of international consultants. Preferably, one should choose consultants with proven experience in policy formation, and not only in technical and economic assessment of investment projects.
5. Efforts should be made by governments and donor agencies in cooperation with international institutions working in the field of climate change to achieve cooperation and division of labor on country studies, so that in depth studies of particular fields could be carried out more effectively. Through such arrangements, specialized information may be exchanged for mutual benefit. The sixth meeting of the INC gave a mandate to the Executive Secretary of INC/FCCC to explore the possibility of organizing a "clearing house" for the exchange of information and experience on relevant technical and financial cooperation activities, including GHG inventories and country studies. This is a valuable recommendation.
6. By their design, country studies should take into account the need for continuous or regular reassessment of findings and adaptation and integration of new scientific evidence.
7. The need for continuous exchange of information, presentation of needs for information and harmonization of methodology could be met by the establishment of an Advisory Panel on Climate Change Country Studies. The secretariat of INC, GEF, IPCC, UNEP, UNDP and important donors should be represented on such a panel.

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ANNEX 1
STUDIES, TERMS OF REFERENCE AND PAPERS ASSESSED

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Tata Energy Research Institute (TERI) (1992), *UNEP Greenhouse Gas Abatement Costing Studies, India Country Study*, part of the UNEP/Risø project Greenhouse Gas Abatement Costing Studies, Phase 1.

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UNEP (1992a), *Terms of Reference for Country Case Studies on Sources and Sinks of Greenhouse Gases*, Project number G/4102-92-01 (PP/3011), (China, Costa Rica, Gambia, Mexico, Morocco, Nigeria, Poland, Senegal, Tanzania, Uganda and Venezuela).

UNEP (1991), *The Potential Socio-Economic Effects of Climate Change*, Three regional assessments (Brazil; Indonesia, Malaysia and Thailand; Viet Nam).

UNEP Collaborating Centre on Energy and Environment (1992a), *Greenhouse Gas Abatement Costing Studies, Phase 1 Report*, Risø National Laboratory, Roskilde.

ANNEX 2
COUNTRY STUDY SUMMARY
(from the UNEP Country Study Report, November 5th. 1992)

COUNTRY	STUDIES	
Algeria	No studies	
Argentina	Internal:	1)Potential participant in impacts and mitigation study under Swiss Proclim-Ecosphere Greenhouse Gases Reduction Program through financing from GEF
Australia	Internal:	1)Draft cost/benefit study of emissions reduction
	External:	1)Provided partial funding of sea level rise studies in the South Pacific through the SPREP (Kiribati study complete) 2)Initiated and is funding the South Pacific Sea Level and Climate Monitoring Project (participating countries: Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, Papua New Guinea, the Solomon Islands, Tonga, Tuvalu, Vanuatu, and Western Samoa) 3)Funded WMO to assess climate monitoring capacity in the Pacific and identify critical impacts issues 4)Provides training assistance to Commonwealth developing countries to assist assessments of the effects of climate change on agriculture 5)Provided financial assistance to UNEP GEMS to support an Australian sea level rise expert for UNEP's Southeast Asian Regional Climate Impacts Project
Austria	Internal:	1)Completed inventory of greenhouse gas sources and sinks 2)Completed impacts study 3)Analysis of emissions reduction technologies and development of a national response strategy are in progress
Bangladesh	Internal:	1)Participating in ADB project to develop regional strategy to address the effects of climate change (includes country studies on potential effects, possible policy options to reduce net emissions and to adapt to climate change, and national response strategies) 2)Participant country in proposed UNDP/GEF project on least cost emissions reduction 3)Possible study on sea level rise vulnerability to be undertaken with assistance from the Netherlands
Barbados	No studies	
Belgium	Internal:	1)Compiled a national emissions and sinks inventory 2)Performing an optimization exercise of greenhouse gas reduction strategies in conjunction with ETSAP 3)Funding a number of research projects related to climate change impacts through the Global Change Impulse Programme

Bolivia	Internal:	1)Effects study completed
Brazil	Internal:	1)Completed cooperative study with UNEP on potential socio-economic effects of climate change in Brazil 2)Completed cooperative emissions inventory study with the U.S. 3)Study in progress on greenhouse gas emissions inventory and costs of abatement strategies, coordinated and funded by France (with possible further funding from UNEP under the coordination of Risø National Laboratory) and carried out by the Universidade Federal do Rio de Janeiro
Brunei	No studies	
Bulgaria	Internal:	1)Preliminary assessment of greenhouse gas emissions and sinks underway
Burkina Faso	No studies	
Burundi	No studies	
Canada	Internal:	1)Prepared "National Action Strategy on Global Warming" 2)Developing a national emissions inventory and reporting system 3)Assessment of proposed or implemented emissions reductions actions underway 4)Regional climate change effects studies underway 5)National Report to the Conference of the Parties of the UN Framework Convention on Climate Change expected by June 1993 6)National study underway on the economic effects of emissions control measures 7)Additional related climate change activities have been undertaken, including preparing research monographs; producing a report for UNCED that reviews the potential impacts of climate change on Canada, Canada's National Action Strategy, and initial response strategies; producing a discussion paper on the use of economic instruments to achieve environmental objectives; launching a research program to reduce the uncertainties associated with climate change; preliminary carbon budget modelling to assess forest vulnerability and to facilitate forest management; producing a series of reports on the state of Canada's climate; beginning a series of environmental programs for citizens; and preparing regional climate change reports.
	External:	1)Undertaking pilot study on emissions and control strategy in China

		2)Assisting Mexico in development of emissions inventory 3)Assisting Tanzania and Zimbabwe in joint study on emissions and emissions reductions options 4)Exploring possibilities for assisting one country with an economy in transition
Cape Verde	No studies	
Chile	Internal:	1)Potential ecosystem and socio-economic effects of climate change on coastal regions were assessed
China	Internal:	1)Participant country in UNEP/GEF project on greenhouse gas sources and sinks 2)Completed a paper assessing the impacts of climate change on China using Global Circulation Model results 3)Assistance from the ADB is expected for a detailed effects study 4)Pilot study on emissions and control strategy underway with Canada 5)Participant country in proposed UNDP/GEF project on least cost emissions reduction 6)Potential participant in separate GEF Regional Asia least cost emissions reduction project
Colombia	No studies	
Congo	No studies	
Costa Rica	Internal:	1)Participant country in UNEP/GEF project on greenhouse gas sources and sinks
Côte d'Ivoire	Internal:	1)Study on inventory of greenhouse gas emissions sources undertaken, coordinated, and funded by France
Cyprus	No studies	
Czechoslovakia	Internal:	1)Joint project with Austria on possibilities for enhancing efficiency in energy sector
Denmark	Internal:	1)National inventory of sources and sinks of greenhouse gases is completed 2)National impacts study is completed 3)Action Plan for limiting the emissions from the Energy Sector and the Transport Sector including reduction technologies and national response strategies is completed 4)Ongoing national greenhouse gas abatement costing study through UNEP/Risø program

	External:	1)Funding national greenhouse gas abatement costing study in Zimbabwe through UNEP/Risø program
Dominica	No studies	
Ecuador	No studies	
Egypt	Internal:	1)Planning to establish a "National Climate Impacts Assessment and Response Strategies Programme" 2)Possible study on sea level rise vulnerability to be undertaken with the Netherlands
Equatorial Guinea	No studies	
Finland	Internal:	1)Emissions inventory and emissions reduction options report completed 2)Assessing the feasibility of committing to greenhouse gas emissions reduction targets proposed during negotiations for the Climate Convention 3)Developing a sustainable forest economy programme 4)Has begun 6-year assessment of climate change (past and anticipated change, impacts assessment, and emissions reduction strategies)
	External:	1)Pledged up to US$200,000 to UNEP to finance cost/benefit studies in developing or transition countries
France	External:	1)Studies in progress (with possible funding from UNEP, under the coordination of Risø National Laboratory) on emissions inventory and costs of abatement strategies for Brazil, with Universidade Federal do Rio de Janeiro 2)Studies in progress on greenhouse gas emissions inventories for Côte d'Ivoire, Mali, and Senegal. 3)Studies in progress (with possible funding from UNEP, under the coordination of Risø National Laboratory) for continental South-East Asia, with the Asian Institute of Technology, Bangkok
Gambia	Internal:	1)Draft emissions inventory prepared 2)Participant country in UNEP/GEF project on greenhouse gas sources and sinks
Germany	Internal:	1)Publishes national CO_2 emissions data regularly 2)Conducting a national research programme on climate change effects 3)Published a report entitled "Protecting the Earth" which includes proposals for national measures to reduce energy-related emissions of trace gases and reduction targets

Ghana	Internal:	1)Undertaking an impacts study in cooperation with the United Kingdom
Grenada	No studies	
Guatemala	No studies	
Honduras	No studies	
Iceland	Internal:	1)Completed report on national greenhouse gas emissions for 1990 2)Evaluating measures and assessing strategies to limit and reduce greenhouse gas emissions and increase fixation
India	Internal:	1)Participating in ADB project to develop regional strategy to address the effects of climate change (includes country studies on potential effects, possible policy options to reduce emissions and to adapt to climate change, and national response strategies) 2)Participant country in proposed UNDP/GEF project on least cost emissions reduction 3)Possible impacts study, to be funded by the United Kingdom, under discussion
Indonesia	Internal:	1)Completed National Strategy on the Anticipation of Climate Change Caused by the Greenhouse Effect 2)Completed cooperative study with UNEP on potential socio-economic effects of climate change in Indonesia, Malaysia, and Thailand 3)A study on impacts and response strategies has been initiated with the support of Japan 4)Participating in ADB project to develop regional strategy to address the effects of climate change (includes country studies on potential effects, possible policy options to reduce net emissions and to adapt to climate change, and national response strategies) 5)Possible study on sea level rise vulnerability to be undertaken with the Netherlands 6)Participant country in proposed UNDP/GEF project on least cost emissions reduction 7)Possible national greenhouse gas abatement costing study through UNEP/Risø program funded by the Netherlands 8)Signed MOU with Norway on environmental cooperation; will include assessment of ecostrategies for carbon fixation such as forest management, development of greenhouse gas emissions inventories and emissions reduction scenarios 9)Has been offered assistance by the United Kingdom for impacts studies

		10)Climate change study with the Environment Agency of Japan planned for FY 1992
Ireland	Internal:	1)Developing greenhouse gas emissions inventory 2)Series of studies on impacts and response strategies completed 3)Ongoing evaluation of emissions control measures
Israel	No studies	
Italy	Internal:	1)Prepared report on energy-related CO_2 emissions reduction options for the Commission of the European Communities
Japan	Internal:	1)Completed emissions inventories 2)Completed impacts assessments 3)Completing assessments of emissions mitigation technologies
	External:	1)Initiated and is funding an assessment of climate change impacts and response strategies in Indonesia 2)Plans to conduct a study on coastal zone management planning in South Pacific countries 3)Participated in, and provided financial assistance for, numerous international climate change programmes
Kenya	Internal:	1)An impacts study underway, funded by the United Kingdom's Overseas Development Administration 2)Potential participant in impacts and mitigation study under Swiss Proclim-Ecosphere Greenhouse Gases Reduction Program through financing from GEF
Korea, DPR	Internal:	1)Participant country in proposed UNDP/GEF project on least cost emissions reduction
Korea, R	Internal:	1)Participant country in proposed UNDP/GEF project on least cost emissions reduction
Madagascar	Internal:	1)Produced preliminary report on national sources of greenhouse gases and the impacts of climate change
Malaysia	Internal:	1)Completed cooperative study with UNEP on potential socio-economic effects of climate change in Indonesia, Malaysia, and Thailand 2)Participating in ADB project to develop regional strategy to address the effects of climate change (includes country studies on potential effects, possible policy options to reduce net emissions and adapt to climate change, and national response strategies) 3)Under the IGBP, collecting information on climate research

Mali	Internal:	1)Study on inventory of greenhouse gas emissions sources undertaken, coordinated, and funded by France
Marshall Islands	Internal:	1)Assessed the vulnerability of the Islands Majuro Atoll to accelerated sea level rise and evaluated possible response options
Mauritius	No studies	
Mexico	Internal:	1)Participant country in UNEP/GEF project on greenhouse gas sources and sinks 2)Emissions inventory study with the U.S. 3)Emissions inventory project through technical assistance from Canada
Mongolia	Internal:	1)Participant country in proposed UNDP/GEF project on least cost emissions reduction
Morocco	Internal:	1)Participant country in UNEP/GEF project on greenhouse gas sources and sinks
Myanmar	Internal:	1)Participant country in proposed UNDP/GEF project on least cost emissions reduction
Namibia	No studies	
Netherlands	Internal:	1)Completed cost/benefit studies on sea level rise responses 2)Expects to complete comprehensive cost/benefit analysis of all sectors 3)Completed a cost analysis of technologies to reduce CO_2 emissions from the energy sector 4)Ongoing national greenhouse gas abatement costing study through UNEP/Risø program
	External:	1)Planning to undertake sea level rise studies in Bangladesh, Egypt, and possibly Indonesia in cooperation with those governments
New Zealand	Internal:	1)Completed sources and sinks inventory 2)Completed impacts studies 3)Completed response strategies studies 4)Completed strategy on first steps to tackle CO_2 emissions
	External:	1)Assists developing countries with studies through contributions to SPREP and UNEP 2)Participated in WMO study to assess climate monitoring capacity in the South West Pacific and to identify critical impacts issues

Nigeria	Internal:	1)Participant country in UNEP/GEF study on greenhouse gas sources and sinks 2)Plans to establish a national task force to develop a climate impacts assessment and response strategies programme, but requires assistance 3)Potential participant in impacts and mitigation study under Swiss Proclim-Ecosphere Greenhouse Gases Reduction Program through financing from GEF
Norway	Internal:	1)Finalized a study on global climate change (subject overview, national inventory of green house gas emissions, potential impacts, policy strategies including the economic effects of limiting CO_2 emissions and increasing fixation); considering follow-up analysis 2)Green Tax Commission has made proposals for economic incentives to reduce greenhouse gas emissions
	External:	1)Signed MOU with Indonesia on environmental cooperation; will include assessment of ecostrategies for carbon fixation such as forest management, development of greenhouse gas emissions inventories and emissions reduction scenarios
Pakistan	Internal:	1)Plans to prepare a study on climate change and its impacts on Pakistan 2)Participating in ADB project to develop regional strategy to address the effects of climate change (includes country studies on potential effects, possible policy options to reduce net emissions and to adapt to climate change, and national response strategies) 3)Participant country in proposed UNDP/GEF project on least cost emissions reduction
Panama	No studies	
Philippines	Internal:	1)Participating in ADB project to develop regional strategy to address the effects of climate change (includes country studies on potential effects; possible policy options to reduce net emissions and to adapt to climate change, and national response strategies) 2)Participant country in proposed UNDP/GEF project on least cost emissions reduction
Poland	Internal:	1)Completed two preliminary emissions inventories 2)Cooperative study in progress with the U.S. on emissions inventory and emissions reduction options 3)Participant country in UNEP/GEF project on greenhouse gas sources and sinks 4)Several preliminary impacts studies completed or underway

		5)National studies on response strategies in fuel producing and consuming sectors being conducted
Romania	Internal:	1)Completed several modest studies on impacts, and plans to continue studies 2)Completed initial inventory of greenhouse gas emissions, and preliminary assessment of policy options for emissions reductions, financed by the United Kingdom
Russian Federation	Internal:	1)Completed preliminary inventory of CO_2 and CH_4 emissions
Saint Lucia	No studies	
Saudi Arabia	Internal:	1)Emissions inventory underway 2)Limited studies under development concerning climate impacts assessment and response strategies
Senegal	Internal:	1)Participant country in UNEP/GEF study on greenhouse gas sources and sinks 2)Study on inventory of greenhouse gas emissions sources being undertaken, coordinated, and funded by France
Seychelles	Internal:	1)Completed impacts assessment
South Africa	Internal:	1)South African Global Change Programme established to coordinate research on global climate change in southern Africa 2)Interdepartmental Coordinating Committee for Global Environmental Change has studied local impacts of global climate change and will draft future policy accordingly
Spain	Internal:	1)Preparation of a National Climate Programme initiated
Sri Lanka	Internal:	1)Participating in ADB project to develop regional strategy to address the effects of climate change (includes country studies on potential effects, possible policy options to reduce net emissions and to adapt to climate change, and national response strategies)
Sweden	Internal:	1)Completed emissions inventory for 1988/89 2)Completed emissions inventory for 1990, as well as an impacts analysis and a preliminary assessment of emissions reduction measures 3)Conducting analysis of emissions reductions and associated costs 4)Completed a survey on future climate change in the Nordic region

Switzerland	Internal:	1)Preparing a national strategy on measures to stabilize and reduce greenhouse gas emissions from key sectors, including emissions inventory and impacts assessments
	External:	1)Financial assistance has been made available to assist developing countries to address global environmental problems 2)Contributed 120,000 Swiss francs in 1991/1992 to support IPCC country study activities 3)Impacts and mitigation studies for developing countries with the assistance of the government-sponsored Proclim Institute, and Ecosphere, a Swiss company, are under consideration
Tanzania	Internal:	1)Preparing to start a collaborative study with Zimbabwe, with financial assistance from Canada, on emissions, development strategies, and policy options in Tanzania and Zimbabwe 2)Participant country in UNEP/GEF project on greenhouse gas sources and sinks
Thailand	Internal:	1)Has begun a national study on emissions, emissions control measures and alternative energy scenarios, and international interaction 2)Completed cooperative study with UNEP on potential socio-economic effects of climate change in Indonesia, Malaysia, and Thailand 3)Assistance from the ADB is expected for a detailed effects study 4)Participant country in proposed UNDP/GEF project on least cost emissions reduction
Togo	No studies	
Tonga	Internal:	1)Study on effects of sea level rise completed with technical and financial assistance from Japan
Tunisia	Internal:	1)Preliminary study on sector impacts and response strategies
Turkey	Internal:	1)Climate change studies underway through "National Climate Coordination Group" (NCCG) 2)National reports by two subgroups of NCCG completed
Turkmenistan	No studies	
Tuvalu	Internal:	1)Preliminary study underway to design and implement comprehensive climate change study through ASPEI, UNEP, and SPREP
Uganda	Internal:	1)Prepared proposal for sector studies on emissions, impacts, and cost/benefits of response options; project requires external funding

		2)Participant country in UNEP/GEF project on greenhouse gas sources and sinks
United Kingdom	Internal:	1)Produced or commissioned a number of national studies on emissions, effects, and emissions reduction options and costs
	External:	1)Undertaking impacts studies in cooperation with Kenya, Ghana, and the Organization of Eastern Caribbean States 2)Has offered assistance to Indonesia and Zimbabwe for impacts studies 3)Discussing funding of an impacts study in India with World Bank 4)Discussing with UNEP possible involvement in UNEP/Risø programme on emissions abatement costs 5)Funded initial inventory of greenhouse gas emissions in Romania
United States	Internal:	1)Produced or supported numerous national studies on emissions, impacts, emissions reduction options, and costs and benefits of response strategies, to provide the foundation for the U.S. Climate Action Plan
	External:	1)Has supported numerous cooperative studies in developing countries and European countries in transition on impacts, emissions inventories, technology assessments, and emissions reduction cost assessments 2)Has offered technical support to Brazil, Mexico, and Poland for development of inventories of greenhouse gas sources and sinks, and additional support to Poland for assessment of technical options and strategies to limit emissions 3)Committed to provide $25 million over a two-year period to support climate change country studies by developing countries and countries in transition
Uruguay	Internal:	1)No national studies 2)Few studies at the sub-regional level on climate change and socio-economic impacts.
Venezuela	Internal:	1)Preliminary inventory of greenhouse gas sources and sinks completed 2)Participant country in UNEP/GEF project on sources and sinks of greenhouse gases 3)Potential participant in impacts and mitigation study under Swiss Proclim-Ecosphere Greenhouse Gases Reduction Program, through financing from GEF
Viet Nam	Internal:	1)Study on vulnerability to climate change and sea level rise completed through UNEP 2)Completed cooperative study with UNEP on potential socio-economic effects of climate change in Viet Nam

		3)Participating in ADB project to develop regional strategy to address the effects of climate change (includes country studies on potential effects, possible policy options to reduce net emissions and to adapt to climate change, and national response strategies) 4)Participant country in proposed UNDP/GEF project on least cost emissions reduction
Yugoslavia	Internal:	1)Preliminary assessment of greenhouse gas emissions and sinks underway
Zaire	No studies	
Zimbabwe	Internal:	1)Preparing to start a collaborative study with Tanzania with financial assistance from Canada, on emissions, development strategies, and policy options in Tanzania and Zimbabwe 2)Developing proposal for sectorial climate change impacts assessments 3)United Kingdom has offered assistance in the preparation of impacts studies, including cost issues 4)Denmark has funded national greenhouse gas abatement costing study through UNEP/Risø program

ANNEX 3
REVIEW AND ASSESSMENT CRITERIA

Methodology

-Promote the use of a method with disaggregation on a level of detail that is necessary for national policy making.
-Recommend the IPCC methods, but national methodologies are acceptable, provided assumptions are set out and scientifically defensible, and reporting categories consistent with the IPCC methodology are used.
-Standard SI units should be used.
-Differentiate between countries with respect to the importance of the different sources and sinks.
-CO_2: Unit for emissions factor: *total C* as CO_2 in mass units per TJ energy input is recommended.
-Inform whether degree of carbon oxidation and/or sequestering is taken into account. If so: Use specific factors clearly distinguishable, allowing for adjustments.
-Clearly define industrial process emissions of CO_2.
-Promote regional/domestic studies (measurements of emissions factors, etc). Such scientific studies should be published and made internationally available and referenced in the report. Emissions factors recommended by the IPCC should be used, if better documentation is not available.
-Establish the role of the sources and sinks in the natural cycles of the gases.
-Should apply a method which makes it easy to update the inventory and make time series.
-Contribute to improvement of the IPCC method based on the experiences from the application of the method.

Documentation requirements

-Inform about which method for estimation of emissions and sinks that are applied. If methods other than the recommended IPCC methods are applied, the emission inventory should be accompanied by a textual description of the methods used, with discussion of the differences between own method and the recommended IPCC methods.
-References sufficient for a reconstruction of the source and sink data should be given.
-Emission factors: Discuss and account for choice of emission factors with references when the factors are different from the recommended.
-Clarify whether CO_2-emissions are based on total amount of carbon in fuel, or whether degree of oxidation is taken into account.
-Report a complete set of activity data and other parameters that are applied which are necessary for reconstructing.
-Explicitly account for assumptions regarding "boundaries" (bunkers in transport).
-Energy data should be given unambiguously in TJ (input) for a calendar year.
-Use the IEA energy balance conventions and definitions for presentation and reporting of the energy data.
-Sub-categories of energy use that are necessary for methane and N_2O calculations should be given.
-Energy data for non-commercial fuels like for instance bio-fuels should be reported.
-Explain differences between the data sets that are used on a national level and those published by the UN or the OECD/IEA if differences are significant. If corrections to official statistics are made or if unpublished data are used, it has to be clearly accounted for.
-It is an advantage if the countries use both a bottom-up method and a top down method (e.g. the IPCC method) for CO_2. If the differences between the results obtained are significant it should be accounted for.
-Account for the roles of the estimated sources and sinks in the natural cycles of the gases.

Reporting format requirement

-Specification of gases to be included (gases with direct effect on climate and gases with indirect effect, halogenated hydrocarbons not regulated by the Montreal Protocol, see chap. 2).
-Reference year, time intervals.

-Emphasize the requirement for common set of source/sink categories (identical definitions among countries). Use the source sector split as identified in the IPCC method (Annex C to OECD report) for reporting of emissions from energy combustion. When further detail might be necessary for industry, ISIC categories should be used as far as possible to report industrial emissions.
-If different definitions are used it should be stated clearly, and effort should be made to indicate the correspondence between the definitions.
-Units for reported emissions: On a full molecular mass basis in metric units per year (for instance CO_2 and not C, N_2O and not N, in Gg/yr)
-If gases are expressed in CO_2 equivalents the calculation method (all parameters and time horizon) must be clearly documented.
-Standard summary for overview and comparison.
-Emission factors should be reported at the same level of detail that is applied in the method.
-Range of uncertainty and explanation of how the range was derived.

A Review of Country Studies on Climate Change

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February 1993

Annex 4

Biological Effects of Climate Change on Natural Ecosystems - Overview of Major International Research Programs

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In this annex[1], some major international research programmes concerned with biological effects on climate change are presented. Programs aimed strictly at environmental monitoring are not included[2]. The first sections (1-4) deals with programs coordinated by ICSU-related units. Then activities within the framework of the United Nations are described (5-6) followed by some Europe-based programs (7-8). Finally, there is a brief introduction to the NATO Science Program (9), merely to point out that their activities include more than political and military dimensions.

The overview is generally quite brief, with the aim to give basic information and to indicate where additional information may be obtained.

1 IGBP - International Geosphere-Biosphere Programme

The IGBP is an interdisciplinary research endeavour, carried out within the framework of the International Council of Scientific Unions (ICSU). Along with the World Climate Research Programme (WCRP) and other international research efforts, it addresses critical unknowns related to global environmental change. The Intergovernmental Panel on Climate Change (IPCC) has identified IGBP and WCRP as the two major research programmes devoted to decreasing our uncertainty in relation to global climate change. The WCRP is concerned with the physical aspects of the climate system and is thus not included here.

The ICSU initiated detailed planning for IGBP in the late 1986 and appointed a Special Committee to guide the planning and implementation of the programme. In order to provide for joint planning and coordination with bodies of the United Nations, an Interagency Coordinating Committee has been formed with the participation of the United Nations Environment Programme (UNEP), The United Nations Educational, Scientific, and Cultural Organization (Unesco) and the World Meteorological Organization (WMO).

A secretariat for the IGBP has been established at the Royal Swedish Academy of Sciences to support the planning and implementation process and to provide a focal point for communication and coordination. The Secretariat publishes the findings of planning group deliberations in a series of IGBP reports, as well as the Global Change Newsletter.

Objective of IGBP:

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 ocurring in this system, and the manner in which they are influenced by human activities.

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1) This annex builds upon chapter 2 of the GCTE/CICERO report entitled "Biological effects of climate change - An introduction to the field and a survey of current research", by Gørill Kristiansen (190 pp). The main report, which may be ordered at CICERO, includes a brief scientific review, research on biological effects in 13 selected countries as well as extensive lists of contactpoints for each project described.

2) For a survey of monitoring programmes, I would suggest the following publication: "A survey of Environmental Monitoring & Information management Programmes of International Organizations". Published by the UNEP-HEM office in April 1991 (second edition).

For practical reasons, the research is based on several Core Projects. The IGBP initially defined a number of research priority questions, within which the Core Projects were developed (see IGBP 1990). The Core Projects are organized into a hierarchy of foci, activities and tasks.
The IGBP-programme is truly interdisciplinary in nature, and most core-projects includes biological research to some extent. The GCTE (Global Change and Terrestrial Ecosystems) core project is however, the most important core project in this regard, and it is given a broad presentation below. Other relevant Core Projects include JGOFS, BAHC, IGAC, GOEZS, LOICZ, and, GAIM These are briefly introduced in the subsequent section.

1.1 GCTE - Global Change and Terrestrial Ecosystems;

The information in this section was drawn from the GCTE Operational Plan (IGBP 1992).

The objectives of the GCTE are:

- *To predict the effects of changes in climate, atmospheric composition, and land use on terrestrial ecosystems, including agricultural and production forest systems;*
- *To determine how these effects lead to feedbacks to the atmosphere and the physical climate system.*

The following introduces the four foci, and their activities and tasks.

1: Ecosystem Physiology
2: Change in Ecosystem Structure
3: Global Change Impact on Agriculture and Forestry
4: Global Change and Ecological Complexity (Proposed).

The first two foci are designed to provide a fundamental understanding of the impacts of global change on ecosystem function, composition and structure, and their feedback effects. The third and the proposed fourth foci, are designed to examine the more specific impacts of global change on systems of great importance to humans - for the production of food and for the earth's biological diversity and complexity. *Focus 3* is however, beyond the scope of the present report and *is excluded from the following description.* However, it should be noted that Focus 3 is closely related to the work on more "natural" ecosystems. The modelling component of this Focus is closely linked to the rest of the GCTE modelling, through LEMA (Long-term Ecosystem Modelling Activity - see "Focus 2 Integrating Activities").

Focus 1: Ecosystem Physiology

The primary aim of is to understand and model the effect of global change on primary ecosystem processes, such as the exchange of energy, water and trace gases with the atmosphere, element cycling and storage, and biomass accumulation or loss.

Activity 1.1: Effects of elevated CO_2

This activity recognizes the critical need for information concerning ecosystem-level interactions between CO_2 and other resources, especially nitrogen and water, and for experiments that explore the suite of ecosystem feedbacks, including changes in soil nutrient availability and herbivory.

Long term objective:

- *To determine and predict the effects of elevated CO_2, interacting with other environmental factors, on ecosystem physiology at the patch scale (10-100m), and to investigate potential feedbacks to the atmosphere.*

Short-term objectives:

- *To assess whether terrestrial ecosystems will serve as a source or a sink of carbon under elevated CO_2 alone and in combination with other environmental changes.*
- *To determine, through case studies, how CO_2 enhancement will affect ecosystem productive capacity through alterations of such processes as plant-pest interactions, nitrogen mineralization and water-use efficiency.*

Task 1.1.1: Whole-Ecosystem FACE Experiments
Task 1.1.2: Integrating Experiments on Ecosystem CO_2 response

Activity 1.2: Changes in Biogeochemistry

The overall emphasis of the biogeochemistry activity is the terrestrial regulation of element pools, transformations, gains, and losses as they are altered by the components of global change.

Long-term objective:

To determine the interactive effects of land use, altered atmospheric composition, and climate change on the biogeochemical cycles of carbon, nitrogen, and other elements.

The more immediate objective are specific to each of the three regions, identified in the following three tasks.

Task 1.2.1: Humid Tropical Forests Undergoing Land-Use Change

Short-term objective:

To determine the effects of land clearing and agricultural intensification on quantities and pathways of carbon and nutrient loss (and their regulation) in several humid tropical regions.

Task 1.2.2: High Latitude Systems

Short-term objective:

To determine the interactive effects of increased temperature and changes in nutrient availability on carbon and nutrient pools and fluxes across the transition from boreal forest to tundra.

Task 1.2.3: Semi-Arid Tropical Ecosystems

Short-term objective:

To determine the interactive effects of altered precipitation pattern and changes in land use (especially grazing and fire frequency) on the biogeochemistry of semi-arid tropical systems along a moisture gradient.

Activity 1.3: Effects of Changes in Vegetation on Water and Energy Fluxes
(To be conducted jointly with the BAHC)

Modelling evaporation from land surfaces in the context of General Circulation Models, (GCMs) requires knowledge of the bulk surface conductance for water vapour transport, which determines

the partitioning of energy into sensible and latent heat. This strongly affects continental hydrological cycles, including evaporation, exchange between surface and ground water and the runoff of surface water. The bulk surface conductance is determined by both the structure and the stomatal properties of the vegetative cover, together with the evaporative properties of the soil surface. The vegetation canopy responds readily to changes in climate and to soil water availability. Evaporation from land surfaces can be modelled in SVAT (soil-vegetation-atmosphere-transfer) models as a submodel of GCMs only if the bulk surface conductance is taken into account. Knowledge of bulk surface conductance is also important for the water balance of ecosystems and its nutrient and carbon fluxes, which in turn feed back to influence vegetation structure and stomatal conductance. The aim of activity 1.3 is to quantify bulk surface conductance which combines stomatal regulation and physical structure of the vegetation to determine terrestrial evaporation.

Task 1.3.1: Bulk Surface Conductance

Long-term objective:

To develop the capability to predict the effects of vegetation changes on water and energy fluxes between land surfaces and the atmosphere, and in particular the changes in bulk surface conductance with season, succession and long-term CO_2 increase.

Short-term objectives:

- *To quantify, as far as possible, bulk surface conductance from the major biomes of the earth, from data in the literature*
- *To assess the requirements in terms of accuracy and spatial representativeness for current and foreseeable models of bulk surface conductance, for the purpose of (i) parameterizing land surfaces in GCMs, and (ii) investigating ecosystem responses to climate or composition changes*
- *To develop a patch-scale model of bulk surface conductance, based on plant physiological mechanisms and the physics of transfer through the soil-plant-atmosphere continuum, accounting for the responses of bulk surface conductance to climate factors (light, vapour pressure deficit), soil water availability and nutrition*
- *To extend the available data on bulk surface conductance by means of appropriate ground-based measurements*
- *To develop the capability for inferring bulk surface conductance from remotely sensed data.*

Activity 1.4: Integrating Activities

Global change will lead to the simultaneous alteration of a number of environmental variables. The whole-system CO_2 enrichment studies, the gradient studies in critical regions, and the water and energy flux studies to be conducted in focus 1 are designed to provide insights into how global change will affect key ecosystem processes involved in the carbon balance, nutrient dynamics and hydrologic cycling. The final requirement in Focus 1 is to bring these changes together so that we can predict the net effect of their simultaneous actions. Task 1.4.1. undertakes this integrating effort, while task 1.4.2. develops one of the important products of integrating models - a better understanding of terrestrial ecosystems in the global carbon cycle.

Task 1.4.1: Integrated Models of Ecosystem Physiology under Global Change

Long-term objective:

To develop (and/or improve) integrated carbon, nutrient and water models at the patch scale to predict how global change will affect the physiology of terrestrial ecosystems in the decades to century time-frame.

Short-term objectives:

- *To develop linked plant-soil models of carbon, nutrient and water interactions at the patch scale to operate at time scales of days to decades*
- *To use the models to predict the consequences of resource changes (CO_2, nutrients, water) for carbon fluxes and storage in conjunction with (i) CO_2 enrichment experiments, and (ii) gradient studies in the critical regions identified by the GCTE - semi-arid tropics, wet tropics and tundra/boreal regions*
- *To incorporate the multiple-resource patch-scale models into the development of Activity 2.1's patch scale models of change in ecosystem structure and composition.*

Task 1.4.2: Carbon Pools and Fluxes in Terrestrial Ecosystems

The major goal of this task is a better understanding of terrestrial ecosystems as sources and sinks for atmospheric CO_2.

Objective:

To understand and model the emissions and sequestration of CO_2 by terrestrial ecosystems for global carbon models

Focus 2: Changes in Ecosystem Structure

Of the driving forces of global change, the most important for determining the distribution and performance of organisms are the range and seasonality of temperature, precipitation, and other environmental factors; the intensity and frequency of severe episodic events, such as fires and hurricanes; and, for much of the earth, the group of demographic, economic and social pressurses related to human activities. These factors, combined, with physiological responses such as sensitivity to high CO_2, longevity and ability to disperse, will determine the future structure of the world's ecosystems.
The goal of focus 2 is to model this complex suite of impacts and responses so that the pattern of change in ecosystem composition can be predicted.

The ability to predict changes in ecosystem structure and composition is being developed for two distinct purposes:

(i) The first, and more important, purpose is to predict the impacts of global change on terrestrial ecosystems in their own right (i.e. independent of their feedback to the atmosphere). If human societies are to adapt and perhaps benefit from global change, then we must be better able to predict what will happen to the terrestrial ecosystems on which we depend. Thus, much of the emphasis of focus 2 will be on the development of a nested set of "impacts" models to predict changes in ecosystem structure at a wide range of scales, from patch to landscape to region. In addition it is essential that models are developed for all the major biomes on earth.

(ii) The second purpose is to build a dynamic global vegetation model that will capture the feedback effects that changes in ecosystem structure and function will have on further atmospheric changes, and which can be linked to the general circulation models (GCMs) that predict future climate. At present the only global models predicting vegetation distributions are static and thus not capable of forming an interactive component in GCMs. GCTE aims to produce a mechanistically-based dynamical model of global vegetation for incorporation in GCMs.

Activity 2.1: Patch Scale Dynamics

A mechanistically-based prediction of the effects of global change on structure and composition of communities can be achieved only by understanding processes. Central to this predictive ability will be the development of one or more models of patch dynamics, which will be both the nucleus of this activity and the basis for integrating over large areas such as landscapes and regions.

Task 2.1.1: Global Key of Plant Functional Types

It will not be feasible to develop models for every ecosystem of the globe nor represent every species within those ecosystems. Thus the concept that the complexity of nature can be reduced in models by treating a smaller number of "functional types" (FTs) is central to the work of Focus 2.

Long-term objective:

To develop a general classification system of plant (and eventually animal) functional types appropriate for predicting the dynamics of change in ecosystem structure due to the impacts of global change.

Short-term objectives:

- *To review the current state of knowledge of the FT approach at a global scale*
- *To elucidate the ecological constraints and trade-offs in morphological and physiological attributes which define morphological types*
- *To initiate case studies where a FT approach can be tested and assessed.*

Task 2.1.2: Experiments on Ecosystem Structure and Function

Objective:

To identify (and, so far as possible, quantify) the important mechanisms that link change in ecosystem function to change in ecosystem structure, and vice versa.

Task 2.1.3: Patch Models of Ecosystem Dynamics

Long-term objective:

To develop patch models of ecosystem dynamics for global application, incorporating mechanistic information on the responses of plant processes to global change and the influence of these responses on ecosystem structure.

Short-term objective:

To develop models of patch dynamics for two study sites, based on the FT approach and the experiments on ecosystem structure and function.

Activity 2.2: Models from Patch to Region

The goal of this activity is to build on experimental and modelling efforts elsewhere in GCTE to develop a suite of models, from patch through landscape to region. These models will be specifically designed to understand and predict the impact of global change on ecosystems.

Task 2.2.1: Ecosystem Dynamics From Patch to Region, based on Change in Climate and Atmospheric Composition

Long-term objective:

To develop a suite of models of climate- and atmosphere driven ecosystem dynamics, based on patch models and incorporating landscape effects, on scales relevant to management decisions.

Short-term objective:

To establish, via LEMA (Long-term Ecosystem Modelling Activity), a core of modelling groups operating at the landscape level, and develop agreed model protocols to meet GCTE requirements.

Task 2.2.2: Ecosystem Dynamics from Patch to Region, Based on change in land Use

Objective:

To develop in collaboration with Focus 3 and HDGEC (Human Dimensions of Global Environmental Change), spatially explicit models of land-cover change; and to determine the effects of these land-cover changes on ecosystem structure, composition, and function.

Activity 2.3: Regional-to-Global Models of Vegetation Change for Element Cycles and Climate Feedback

At present there is no mechanism for incorporating the feedback of a changing land surface in a dynamic, interactive way into global models of the physical climate system or of the biogeochemical or hydrological cycles. Global vegetation is assumed to be static. However, as a result of global change, the earth's distribution of vegetation will change, and this will lead to feedbacks to climate. The ultimate goal of this activity is to develop appropriate dynamic models that can be used to calculate direct feedbacks through changes in surface conductance, albedo and surface roughness and indirect feedbacks through changes in biogeochemical cycles.

Task 2.3.1: Static Models of Global Vegetation Change

Objective:

To improve methodologies for directly scaling up predictions of vegetation distribution from patch to globe.

Task 2.3.2: Dynamic Global Vegetation Model (DGVM)

Objective:

To develop a dynamic model of change in global vegetation that can be linked to GCMs.

Focus 2 Integrating Activities

GCTE will establish a network of modelling centres called LEMA (Long-term Ecosystem Modelling Activity). Its goals are to:

(i) facilitate collaborative research, particularly in the development and improvement of models essential to the GCTE programme

(ii) focus the international modelling effort on a coherent and mutually agreed set of objectives

(iii) synthesize GCTE results into a set of robust models designed to meet GCTE objectives

(iv) provide feedback to experimental efforts as priorities for model parameters, investigation of additional phenomena, and needs for model testing information arise

Although LEMA is formally placed with Focus 2 it will facilitate the entire GCTE modelling effort, across all Foci.

Focus 4: Global Change and Ecological Complexity (Proposed)

Complexity is viewed as the suite of species interactions within an ecosystem. It includes the diversity of species, their connectivity and spatial diversity (patchiness). Connectivity, unlike species diversity, is considered to change with scale because it incorporates such effects as variations in landscape structure and migration. This Focus is therefore designed to understand and determine the importance of species diversity and ecosystem complexity on the dynamic responses of ecosystem function to environmental change. It is also necessary to consider the reverse response, the influence of changes in ecosystem function on diversity and complexity, both to achieve this overall understanding, and because it forms the basis of applied interest groups such as the International Union for the Conservation of Nature and Natural Resources (IUCN).

A specific issue to be considered is the vulnerability of species diversity in reserves to environmental change. Reserves for species conservation are typically isolated landscape units and will be vulnerable to environmental change because of disrupted networks of migration.

Global change and ecological Complexity was originally proposed as a separate IGBP core project (IGBP 1990) and has only recently been incorporated within GCTE as a proposed Focus 4. The operational plan for Focus 4 will be developed in detail in 1993 and published in 1994. A draft operational plan was made available at an IGBP Conference in January 1993 (SAC III, Ensenada, Maxico) from which the following information was drawn. Although the deviding into activities and tasks has been discussed, i.e. some activities may be combined and new tasks may be developed, the brief summary below illustrates the main questions to be addressed in this Focus.

Activity 4.1: Relationships between Ecological Complexity and Ecosystem Function

The aim is to define relationships between species diversity, complexity, and connectivity and selected processes for a range of major ecosystems. The final structure of this and Activity 4.2 will evolve in collaboration with the SCOPE component of the Diversitas programme.

Task 4.1.1 Manipulative experiments on Compexity/Function

Objective:

To determine through manipulative experimentation the effect of changing complexity on function, and vice versa, for a number of ecosystems.

Task 4.1.2: Models of Complexity and Function

Objective:

To construct theoretical models that simulate the complexity (diversity and connectivity) of real ecosystems and relate change in complexity to change in function.

Activity 4.2: Interactive Effects of Global Change on Ecological Complexity and on the Relationship Between Complexity and Ecosystem Function

The aim is to examine how the interactive effects of global change will alter ecological complexity, and how this in turn will lead to changes in function, directly and through changes in the relationship between complexity and function.

Task 4.2.1: Experimental and Observational Studies

Objective:

To determine by experimentation and observation the impacts of various kinds and combinations of global change on ecological complexity and on the relationships between complexity and ecosystem function.

Task 4.2.2: Modelling Impacts of Global Change on Complexity/Function

Objective:

To develop predictive models of the complexity/function relationship under conditions of global change

Task 4.2.3. Complexity/Function under Global Change: Feedbacks to Further Change

Objective:

To determine and quantify whether global change impacts on ecological complexity and on the relationship between complexity and ecosystem function will lead to feedbacks to further global change.

Activity 4.3: Consequences of Global Change for the viability of Isolated Populations

Task 4.3.1: Habitat Fragmentation, Land-Use/Cover Change and Population Viability

Objective:

To develop, refine and verify models to predict the viability of isolated plant and animal populations containing different total number of individuals, with different life histories, on isolated habitat fragments; and to explore the role of inter-patch migration by biota in maintaing biodiversity in rapidly changing landscapes.

Task 4.3.2: Interactive Effects of Habitat Fragmentation and Climate Change

Objective:

To examine and model the implications of climate change for maintenance of biological diversity and connectivity in isolated habitat patches set in a variaty of landscapes.

Activity 4.4; Complexity, Function and Global Change: Regional and Global Synthesis

The other three Activitites of Focus 4 emphasize the fundamental relationships betwen complexity and function, and the impacts of global change both on complexity and on this relationship at the process level. The aim of this activity is to extend this information geographically to build up scenarios of change in ecological complexity, and its implications, at regional and global scales.

Task 4.4.1: Identification of Areas of Functional Sensitivity

Objevtives:

- *To develop and promulgate general methodologies for identifying areas, functional types, and pecies most at risk from global change.*
- *To determine and map the regions of the world were loss of ecological complexity is most likely to lead to significant changes in ecosystem function.*

1.2 Other IGBP Core Projects

This section briefly introduces other relevant IGBP Core Projects: JGOFS, BAHC, IGAC, GOEZS, LOICZ, and, GAIM. For further information, consult IGBP-reports .

JGOFS (Joint Global Ocean Flux Studies, an established Core Project) is primarily concerned with assessing and understanding how carbon flows in the ocean and across its boundaries, both now and in the future. "In principle, this would include understanding the biological effects of climate change in the ocean, because there is potential for a strong biological feedback on oceanic carbon transport. However, within its constraints of people, money and ideas JGOFS will concentrate on assessing the present carbon fluxes and their first-order (physical-chemical) changes. It is quite possible, though, that individual research projects within JGOFS will address biological responses and feedbacks as well, and such extensions are to be welcomed when they occur". (G.T. Evans, JGOFS Executive Scientist, pers. comm.).

Another established core-project, the **BAHC** (Biospheric Aspects of the Hydrological Cycle) expresses the biological relevance through the objective:

> *How do plant communities and ecosystems in combination with the topographic structure of the land surface affect the cycle of water on Earth?*

Sub objectives:

- *To determine the biospheric controls of the hydrologic cycle through field measurements for the purpose of developing models of the energy and water fluxes in the soil-vegetation-atmosphere system at temporal and spatial scales ranging from vegetation patches to GCM grid cells*
- *To develop and implement a long-term commitment to observations designed to test the results of global change modelling of the interactions between the biosphere and the physical Earth system in relation to the hydrological cycle.*

IGAC (International Global Atmospheric Chemistry project - an established core project) was initiated by the IAMAP Commision on Atmospheric Chemistry and Global Pollution (CACGP) and its science plan was developed by an extensive group of atmospheric scientists at a workshop in 1988. It was later accepted and incorporated as an IGBP core project. While there was a strong perception at the workshop that biological interactions with the atmosphere would have to be an essential component of the research activities of the IGBP, it was felt that the biological and ecological community was not sufficiently well represented to formulate the biological component of the overall research program. Effort has therefore been put into establishing close linkages to biological reserach by, for instance, arranging joint workshops (see e.g. IGBP report no. 13).

Objectives:

- *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 forcing on the chemical composition of the atmosphere.*

Regarding marine and coastal ecosystems, it is expected that **GOEZS** (Global Ocean Euphotic Study) and **LOICZ** (Land Ocean Interactions in the Coastal Zone) will provide major contributions to

our understanding of these biological systems in relation to global change. These Core Projects' objectives are, respectively:

- *To develop a predictive understanding of the basic relationships among the physical, chemical and biological properties of the oceanic euphotic zone.*

- *To develop a predictive understanding of the effects of changes in climate, land use and sea level on the global functioning and sustainability of coastal ecosystems, with emphasis on the interactions between changing conditions on land and sea, and on possible feedback effects on the physical enivironments.*

A science plan for LOICZ has recently been developed, and it will be published in the near future as IGBP Report no. 23. GOEZS still has status as "Proposed Core Projects". The main implementation phase is planned to commence in 1998. Active planning, including the development of models and instruments may be initiated already in 1994.
The proposed Core Project **GAIM** (Global Analysis, Interpretation and Modelling) has been developed into a so-called task force, supervised directly by the Scientific Committee of IGBP and undertaking a series of specific tasks. The GAIM Action plan for 1993-1995 will be published shortly as IGBP Report no. 26.

The broadly defined objective is:

> *With the aid of models, synthesize a fundamental quantitative understanding of the global physical, chemical and biological interactions in the Earth system during the last 100,000 years and assess possible effects of future natural and/or man-induced changes.*

2 SCOPE Scientific Programme

The SCOPE (Scientific Committee on Problems of the Environment) scientific programme for 1992-1995 is highly concerned with global change issues. It consists of four separate components:

- Sustainable development
- Biogeochemical cycles
- Health & ecotoxicology
- Global change & ecosystems

In addition there is one component interacting with all the others:

- Sustainable biosphere.

The global change & ecosystem component includes four streams of study:

* climate change and coniferous forests and grasslands
* UV-B effects on biological systems
* ecosystem function of biodiversity
* dynamics of woody plant-grass systems (to be launched in 1994)

It should be noted that SCOPE is not primarily a body for coordination or funding of operational research programmes. Rather it functions as a body for evaluation and assessment of current knowledge. This work includes producing updated reports and books as well as arranging workshops on environmental issues (Véronique Plocq-Fichelet, SCOPE Executive Director, pers. comm.). This

also means a close cooperation with other research programs; for instance are the SCOPE synthesis and analysis used by GCTE in developing its research program.

SCOPE is involved in two specific programmes which is relevant for biological effects of climate changes:

2.1 ISBI - International Sustainable Biosphere Initiative

The programme was initiated by an ecological research agenda for the 1990's, the *Sustainable Biosphere Initiative* proposed by the Ecological Society of America. A further development of this agenda established the *International Sustainable Biosphere Initiative* (ISBI), which is now adopted by SCOPE. The research priorities are defined within three facets of sustainability: Diversity and sustainability; sustainability in a changing biosphere; and in human dimensions of sustainability. Following are the research questions of Sustainability in a changing atmosphere. It should be noted that the research questions are given by way of example only and indicate that new information is needed to answer problems related to global change that include studies at levels from responses of individuals to those of entire regions (see Huntley et al 1991).

1. The state of the biosphere

Goal: *To document the present state of the Earth's biotic systems and the factors controlling the rate and direction of change.*

1) How can we monitor the status of the Earth's biotic resources through time?
2) What are the climatic controls of the growth of organisms at regional scales, and of interactive controlling elements including salinity, pollutants, CO_2, and so forth, and how can these be quantified?

2. Responses and feedbacks of biotic systems to change

Goal: *To develop the information needed to assess the responses and feedbacks of biotic systems to global change.*

1) What are the responses of organisms and whole ecosystems to multiple stress factors, including UV-B, enhanced CO_2, elevated temperature, climate change and pollutants, and how will these responses influence atmospheric projections?
2) How will the controls of distributions, abundance, and productivity of organisms be altered in the context of rapidly changing environment?
3) What are the effects of ecosystem degradation or eutrophication in the past and present, and how can this knowledge guide habitat management and restoration measures?

3. Synthesis and modelling

Goal: *To develop approaches for synthesizing information from various disciplines and taken at different scales in order to understand the functioning of the Earth system.*

1) What new approaches are available to improve the linkage of information from various scales of research (for example, ecosystem change models linked with global circulation models)?
2) What methods can be used to interpret patterns at broad scales (e.g., remote sensing) in terms of processes operating at finer scales?

3) What new approaches can be used for integrating information from the level of the individual organism with that of the ecosystem?

2.2 IUBS[3]- SCOPE - Unesco Programme on Ecosystem Function of Biodiversity - Diversitas.

The general objectives of this programme are to identify scientific issues and promote research projects that require international cooperation in the following areas:

1) The ecosystem function of biodiversity.

The basic questions addressed here are as follows:

- How is sytem stability and resistance affected by species diversity and how will global change affect these relationsips? and,

- What is the role of biodiversity (species and landscapes) in ecosystem processes (e.g. nutrient retention, decomposition, production, etc.) including feedbacks, over short and long term spans and in face of global change (climatic change, land use change, and invasions)?

This component will be undertaken by SCOPE, and will be linked directly to the Focus 4 of GCTE. The Operational Plan for Focus 4 will rely strongly on the SCOPE analysis (Will Steffen, pers. comm.).

2) The origins and maintenance of biodiversity.

The conceptual framework and research hypotheses for this theme have been identified by a workshop (the "Havard Forest Workshop") and will serve as a basis for the development of this theme. The study of biodiversity at the intraspecific genetic and population levels, including research on and processes of speciation and extinction, represents an important step for understanding diversity at higher levels. Also, it is very important to make a clear distinction between local and global extinctions, and their management implications.

3) Inventorying and monitoring biodiversity

In dealing with the question of inventorying and monitoring of biodiversity on Earth, we are faced with formidabel technical and material problems relating to estimating the number of species and their distribution. These problems are compounded by the acute shortage of trained taxonomists all over the world, but especially in the tropical countries where much of the world's biodiversity is found.

The actual sites for study will be chosen from - but not limited to - a selected number of Biosphere Reserves as identified by the Unesco's MAB-programme.

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3) IUBS - International Union of Biological Sciences is an International Scientific Union member of ICSU.

4) Biodiversity of wild relatives of cultivated species.

Within the framework of the programme, four sets of priority hypotheses and recommendations have been developed at a) genetic, b) species to community, and c) ecosystems levels, and d) to deal with the problem of inventorying and monitoring species diversity and their changes around the world.

For more information, see Younes 1991 and 1992. The description given in this section was drawn directly from those two publications.

3 The Role of Antarctica in Global Change (SCAR)

SCAR (Scientific Committee on Antarctic Research - an interdisciplinary ICSU body) has, in consultation with several interested international groups, developed an international plan for a regional research programme on the Role of Antarctica in Global Change. This work has been closely linked to the IGBP through an IGBP-SCAR Steering Committee, and the programme is planned to constitute the Antarctic[4] research contribution of the IGBP. This Committee identified four major, interdisciplinary themes to define and encompass the research priorities of an Antarctic component of the IGBP:

- detection of global change in Antarctica
- study of the critical processes linking Antarctica to the global system
- extraction of paleoenvironmental information
- assessment of ecological effects.

A draft version of the programme implementation plan was finished in March 1992, from which the following information was drawn.[5] Six Antarctic core projects have been identified:

1. The Antarctic sea-ice zone: interactions and feedbacks within the global geosphere-biosphere system.
2. Global paleoenvironmental records from the Antarcic ice sheet and marine and land sediments.
3. The mass balance of the Antarctic ice sheet and sea level.
4. Antarctic stratospheric ozone, tropospheric chemistry and the effect of UV on the biosphere.
5. The role of the Antarctic in biogeochemical cycles and exchanges: atmosphere and the ocean.
6. Detection and monitoring of global change in Antarctica.

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4) The IASC (International Arctic Science Committee) is, although not an ICSU-associated body, the Arctic counterpart of SCAR. The IASC is currently planning a global change programme for the Arctic, corresponding to the SCAR Antarctic programme. A Planning Workshop on a Regional Research Programme in the Arctic on Global Change was held by the IASC in Reykjavik, Iceland 22-25 April 1992.

5) At the time of this writing the Implementation Plan was a draft document, not to be cited, quoted or reproduced. The information above is, however, given with the approval of Dr. Gunter Weller, the lead author of the document. The Implementation Plan will be published in the near future. The reader should turn to this for more detailed information.

Naturally, in Antarctica, the emphasis is more on biota in the ocean than on land. Although it appears that biology is not a field of priority in this programme, sub areas of core project 1 and 6 were identified to be relevant to this survey:

One of eight objectives within **core project 1** is:

To determine the role of Antarctic sea ice in marine biotic systems.

The Antarctic sea-ice zone is a key habitat for marine biota. The biological activity has a strong annual cycle with a very productive spring/summer period which represents a crucial part of the life cycle of marine biota and marine food chains from phytoplankton to fish, birds and mammals. Changes in the timing and periodicity of the cycle as a result of climate and sea-ice changes would have impact on the food chain and marine living resources. In particular, the presence and dynamics of sea-ice influence: 1) the biological habitat and distributions of populations of organisms at all trophic levels; 2) plant and animal populations and food web dynamics; and 3) the flux of carbon from the atmosphere to the deep ocean and its sequestration there by physical and biological processes.

To determine the biological role of sea-ice, we need to understand how major changes in sea-ice thickness, structure and extent may affect physical, chemical, and biological relationships between atmosphere, water column, benthos, and sediments at both short-term and long-term scales. Two topics in the Antarctic sea-ice zone system which need priority attention are:

- the factors controlling population dynamics, life cycles, and survival of the biota; and
- the nature of biogeochemical cycles of carbon, nitrogen, phosphorus, and silicon in the sea ice, water column and benthos.

Within **core project 6** there is one sub area specifically addressing biologically relevant questions, which is headed "Ecosystem sensitivity and indicator species". It puts emphasis on the sensitivity of communities in Antarctic ecosystems which may be manifested as a response in their physiology, life cycle, productivity, or as an influence on ecological processes.

The primary objective of this part of the programme will be to identify key organisms, biological processes, and interactions that are most likely to be influenced by changes in the climatic regime of Antarctic marine and terrestrial ecosystems.

4 GLOBEC - Global Ocean Ecosystem Dynamics (SCOR/IOC/ICES)

GLOBEC is a programme jointly sponsored by SCOR (Scientific Committee on Oceanic Research, - an interdisciplinary ICSU body), IOC (Intergovernmental Oceanographic Commission, - a Unesco Commission) and ICES (International Council for the Exploration of the Sea, -an Intergovernmental Organization).

The programme is motivated by the need to understand how changes in the global environment will affect the abundance, diversity, and production of animal populations comprising ocean ecosystems, and also by the fact that there is no focus on the role of zooplankton in the IGBP. Zooplankton is a critical component in our understanding of biogeochemical cycling in addition to their general importance in the ecosystem; variations in zooplankton dynamics may affect biomass of many fish and shellfish stocks.

GLOBEC will consist of initiatives undertaken directly by the international programme; initiatives undertaken by regional and national programmes as part of GLOBEC; and associations with

long-standing programmes that are oriented towards the GLOBEC goal statement that wish to develop scientific communication links and interaction with GLOBEC, but are not directly related to the GLOBEC organic structure.

The goal of GLOBEC is:

To understand the effects of physical processes on predator-prey interactions and population dynamics of zooplankton, and their relation to ocean ecosystems in the context of the global climate system and anthropogenic change .

The strategy for building the GLOBEC Core Program (GCP) is oriented toward the goal of investigating global-ocean issues in zooplankton dynamics, the relation between zooplankton and primary production, and the relation between fish production and zooplankton in the context of understanding the effects of physical processes on population dynamics of zooplankton.

5 MAB - Man and the Biosphere (Unesco)

MAB is an International Unesco research programme, based upon national research initiatives. The program emphasises multidisciplinary approaches in order to attain an improved understanding of the interrelationships between ecological and social systems. Generally speaking, MAB's objectives are to further research in order to:

- *develop a basis for rational use and preservation of biospheric resources*
- *develop a basis for improving the interaction between man and the environment*
- *predict the consequences of today's actions upon tomorrow's world and thereby improve man's ability to effectively manage biospheric resources.*

There are several networks and sub-projects within the framework of MAB, some of which are relevant for global change. Regarding the more narrow issue of biological effects of climate changes, the following (ITEX) seems to be the most relevant activity. Mentioning of other MAB related activities, i.e. projects in cooperation with the International Union of Biological Sciences (IUBS) also seems appropriate in this context (2.5.2).

5.1 ITEX - International Tundra Experiment

In December 1990, forty-seven reseachers from nine countries (Canada, Denmark, Finland, Great Britain, Iceland, Norway, Sweden, United States, USSR) with polar interest participated in a workshop to develop an International Tundra Experiment (ITEX). The workshop was held after the MAB/NSN (Northern Sciences Network) recommended that MAB committees in all countries with expertise in tundra research should identify experts who could contribute to, and support, the development of ITEX. The NSN of the Unesco MAB Programme was established in 1982 to help stimulate national and international MAB-type interests in northern regions.

ITEX is a long-term arctic research programme. Its objectives are to monitor over the next several decades shifts in arctic climate and vegetation due to on-going global change, and to predict the direction and magnitude of such responses in the entire holarctic realm. The project was designed to obtain ecological evidence about expected or already on-going changes in arctic ecosystems due to global anthropogenic influences.

Large permanent plots are planned to be established in selected Canadian, Alaskan, Scandinavian and Russian tundra ecosystems. Field manipulations will be constructed to simulate expected climatic changes: Shelters to increase tundra temperatures, and snow fences to increase snowcover. Plant population demographics and response variables including phenological traits, morpho-logical traits and performance measures will be monitored in control and experimental sites.

5.2 Unesco/MAB and IUBS cooperative projects.

There are two other MAB programmes of relevance in this context, which have been undertaken in cooperation with IUBS (M. Skouri, Director of the Division of Ecological Sciences, Unesco, pers. comm.):

Soil Fertility and Global Change was initiated in 1984 and is now in a transition phase. A new research agenda is being formulated to address the interaction between soil and the atmosphere. Organizationally it is within the framework of Unesco and the Tropical Soil Biology and Fertility Programme (TSBF) of the IUBS. Its aims are to stimulate research in the tropics, and in particular on the poorly understood topic of biological processes in the maintenance of soil fertility.

Savanna Modelling for Global Change is a proposed continuation of the Unesco/IUBS ten year project entitled "Responses of Savannas to Stress and Disturbance" which started in 1983. The project aims at developing an understanding of the way tropical savannas respond both to natural and to human stresses and disturbances.

The IUBS-SCOPE-Unesco Programme on Ecosystem Function and Biodiversity, see 2.2.2.

6 IPCC - Intergovernmental Panel on Climate Changes (UN)

The IPCC is an intergovernmental panel of scientific and technical experts tasked to assess the current understanding of the scientific aspects of climate change; the environmental consequences and social and economic impacts as well as response options and strategies. Strictly speaking, it does not belong within this context of research programme descriptions. However, the IPCC plays a very central role in the overall climate research effort. As a result of the IPCC work, a number of researcher and research organizations have initiated programmes and projects. For one thing, chapter 1 of this report draws heavily on their results, as well as most of the programmes/projects presented in chapters 2 and 3. Because of this, a brief description of the Panel's work and structural organization is appropriate.

The Panel was appointed in 1988 by the United Nations Environmental Programme (UNEP); and the World Meteorological Organization (WMO);. Almost 1, 000 researchers from sixty countries have taken part in the IPCC's work.

The IPCC has undertaken a global assessment of which the results were presented in three volumes (one for each working groups) which comprise the First IPCC Assessment Report (Houghton et al. 1990). (The volumes are available commercially, se appendix B):

Working Group I: "Climate Change - The IPCC Scientific Assessment"

Working Group II: "Climate Change - The IPCC Impact Assessment"

Working Group III: "Climate Change - The IPCC Response Strategies"

The reports were discussed at the second World Climate Conference in Geneva at the beginning of November 1990. The Conference stressed in its statement the special need for increased research in general and the importance of intensifying activities in the WCRP (World Climate Research Programme) and IGBP (International Geosphere-Biosphere Programme).

In order to produce an update of the First Assessment Report, the IPCC decided at its fifth session (Geneva, March 1991) the six following tasks:

1: Assessment of net greenhouse gas emissions:
   Sub-section 1: Sources and sinks of greenhouse gases;
   Sub-section 2: Global warming potentials;
2: Predictions of the regional distributions of climate change and associated impact studies, including validation studies:
   Sub-section 1: Update of regional climate models;
   Sub-section 2: Analysis of sensitivity to regional climate change:
3: Energy and industry related issues;
4: Agriculture and forestry related issues;
5 Vulnerability to sea-level rise;
6: Emission scenarios.

The publication of the 1992 IPCC Supplement (Houghton et al. 1992) completed the short-term work on these six task. Long term work on the same Tasks continues.

7 ENVIRONMENT (CEC)

The Environment programme (1991-1994) is aimed at contributing to the scientific and technical basis for the implementation of the EC environmental policy. As such it constitutes an extension and expansion of the current STEP (Science and Technology for Environmental Protection) and EPOCH (European Programme on Climatology and Natural Hazards) programmes.
The programme is subdivided into four areas, of which "Participation in global change programmes" is the first. Only this area is presented here. It is specifically expressed that the effort directed to global change problems will be greatly expanded.

The selection procedure for projects under the different topics has not yet been terminated, hence it is impossible to give any details about the exact subjects to be covered. For further information, see appendix B for a list of contact persons of the CEC Environment Programme.

Participation in global change programmes

The goal is to contribute to understanding the processes governing environmental change and to assess the impacts of human activities. The programme will specifically address the following:

- The reduction of ozone concentration in the stratosphere as a consequence of the release of persistent, chlorine containing molecules, such as chlorfluoro-carbons;

- the increasing concentrations of some trace gases and aerosols in the troposphere (volatile organic compounds - VOCs), photo oxidants, nitrogen oxides, sulphur containing molecules), which

overload the mechanisms for cleaning the atmosphere, in particular the oxidation pathways, thus enhancing the long-range transport of pollution;

- the perturbations of biogeochemical cycles through man-made emissions to soil and waterbodies, direct or through atmospheric deposition, enhanced by other factors, like land use.

Consequences for human health and ecosystems are included by addressing problems such as:

- health and ecological effects of UV-irradiation.
- dynamics and vulnerability of ecosystems under stress.

The research topics are naturally closely related to major international programmes, in particular the WCRP and IGBP. Thus the present programme provides a basis for the European contribution to these global programmes. In addition it focuses on topics of more specific European interest, in particular in the field of climate change impacts.

The following gives the programme outline *including a more detailed description of the components relevant to this report:*

A) CLIMATE CHANGE AND CLIMATIC IMPACTS

A.1 Natural climate change

A.2 Anthropogenic climate change

The objectives are to provide:
- *understanding and prediction of anthropogenic climate change with a focus on regional change of climate statistics, including understanding and simulation of natural climate variability*
- *monitoring of ongoing changes of the global environment and climate system, and, with special emphasis on the European continent and surrounding oceans, monitoring of all climate related quantities, including land surface state, i.e. the conditions of soils and vegetation cover.*

A.2.1 Climate change impacts

Objectives:
- *Forecasting and understanding the impacts of the foreseen climate change upon selected sectors of the European environment*
- *Quantitative assessments of impacts on sectors of socio-economic relevance such as human settlement and activities, taking account of both physical and human factors.*
- *Guidelines for risk management and for the development or rehabilitation of areas damaged or at risk.*

Research tasks

1. Prediction of future sea level change
2. Changes in storm surge risk in Europe from climatic change and sea level rise
3. Potential impacts of sea level rise on natural ecosystems and coastal land-use within Europe

Assessment of environmental and land-use impacts on European coastal areas by conduction of case studies on particularly vulnerable locations, suitable for the integrated analyses of the impacts arising from the interaction of sea level, natural systems and human occupancy.

Two types of case studies may be envisaged. The first is the "analogue" case study which focuses on areas where impacts are already being experienced because of relative rise of sea level due to land subsidence. The second type of case study should focus on areas such as deltas and coastal plains, where an increase in the rate of sea level rise would threaten to exceed the natural rates of rejuvenation, leading to degradation of the natural resource base and endangering human habitation.

4. Impacts of sea level rise on surface and ground water supplies.

5. Land resources

a) Bioclimatic shift of crops
b) Impacts of increasing CO_2 and climatic change on European forests and other natural plant ecosystems.

Study of possible changes in productivity, mixture of species, and spatial extent of forests and other natural ecosystems. Expertise from a range of disciplines across Europe should be brought together. The purpose is to provide a strong, rigorous methodological foundation for estimating the potential effects of CO_2 and climatic change, and for evaluating strategies for future management.

c) Sensitivity of European crop yields to increased CO_2 and climatic change

6. Water resources
7. Physical factors, monitoring and prevention [Connected to "Instability and erosion of natural slopes"]
8. Flood hazards development and testing of theoretical and instrumental methods for the study, forecast and control of floods, and for flood hazard assessment
9. Land-use practices favouring or hindering floods

B) GLOBAL CHANGES IN ATMOSPHERIC CHEMISTRY AND BIOGEOCHEMICAL CYCLES AND THEIR CONSEQUENCES FOR LIFE ON EARTH

B.1 Stratospheric ozone

B.2 Tropospheric physics and chemistry.

B.3 Biogeochemical cycles and ecosystem dynamics

Objectives
- *To increase the understanding about sources, pathways and chemical/biological transformations of natural and anthropogenic compounds including the processes controlling the cycling and exchanges of these substances in terrestrial, aquatic, wetland, estuarine and coastal ecosystems in order to*
- *develop a comprehensive scientific basis for pollution control and habitat protection policies for terrestrial, aquatic, wetland, estuarine and coastal ecosystems;*
- *define indicators of environmental change and damage at different ecosystem levels, suitable for the analysis and prediction of the effects of natural and anthropogenic perturbations;*
- *develop or modify existing process-based models to predict the response of ecosystems to such perturbations*

The results should ultimately allow recommendations of normative measures and appropriate management and protection practices enabling soil fertility, water regime, environmental quality and biological diversity to be preserved and restored.

Research will emphasize investigations at the ecosystem or catchment scale, and will address in particular processes and pathways at *transition zones* between different ecosystem types (e.g. terrestrial/aquatic, land/ocean interfaces etc.)

Subareas:

1. Biogeochemical cycles and hydrology
- Changes in the carbon cycle (quantification of uptake by vegetation, allocation into different compartments of ecosystems and release to neighbouring ecosystems or to the atmosphere) with particular attention to modifications of primary production and decomposition of organic matter;
- Changes in the cycles of mineral nutrients, allocation to the different compartments of ecosystems, and losses to surface water and the atmosphere;
- Changes in ecosystem hydrology (mainly due to changes in land use), partitioning of precipitation, evapotranspiration and water use, circulation within ecosystems, and effects of changes in snow cover;
- Identification and quantification of sources and pathways of organic and inorganic matter, and of selected contaminants, and input-output balances at the land-sea interface;
- Mechanisms and rates of processes triggering the fluxes and cycles of natural and anthropogenic compounds in the estuary and the coastal area, and the coupling mechanisms between water column, sediment and biota;

2. Plant physiology
- Tree physiology, in particular the role of hormones, the partitioning and transport of assimilates, remobilisation and translocation of nutrients and senescence processes;
- Effects of pollutants and of combination between pollutants and other environmental stresses (temperature, drought, biotic factors) on physiological processes in plants, in particular forest trees;
- Effects of abiotic changes (increase of temperature and CO_2 levels) on physiological functions (primary and secondary metabolisms), vegetation phenology, rooting patterns and tree ring thickness.

3. Impacts of pollutants on soils and rhizosphere
- Impact of pollutants on biotic processes below ground (decomposition, nitrification/denitrification and other physico-chemical transformations involving mycorrhiza and soil microflora);
- Acidification neutralizing mechanisms, in particular the weathering of parent materials in order to define critical deposition thresholds.

4. Biodiversity
- Impacts of abiotic changes on species composition and biological diversity, vegetation structures and spatial distributions, density and successions.
- Impact on genetic diversity, in particular in forest trees focusing also on the assessment of human influences on genetic diversity and on population/ecosystem stability and adaptability.

7.1 CLIMEX - Climate Change Experiment

CLIMEX is a international, interdisciplinary research project (Germany, the Netherlands, Norway, U.K.). It is partly (about 50%) financed by the EEC (the Environment programme) and partly by the

participating institutions. Preliminary studies will start in the near future, whereas the intensive experimental phase will commence in April 1994. The project will focus on the ecosystem response to climate change, in particular the plant-soil-water linkages and processes. Plant physiology, soil fauna, nutrient cycling, turnover of organic matter, soil and soil solution, hydrological flowpaths, and runoff water quality will be investigated. The results will aid in development of process-oriented models to predict the response of forests and freshwaters in Europe to future changes in atmospheric CO_2 and climate.

CLIMEX will experimentally enrich with CO_2 and raise the temperature of two entire forested headwater catchment ecosystems. It will make use of the two enclosures (1200 m^2 and 650 m^2) located at Risdalsheia in southernmost Norway. Eight years of background data are available from this site, collected as part of the RAIN project (Reversing Acidification In Norway). The project will use greenhouses to study the impact of the greenhouse effect.

Objectives:
The objectives of CLIMEX are by means of large-scale manipulation with CO_2 enrichment and elevated temperature
- *to measure changes in CO_2 uptake, gas exchange and plant phenology*
- *to measure changes in forest growth and nutrient status*
- *to measure changes in ground vegetation and nutrients*
- *to determine change in mineralization of soil organic matter*
- *to determine changes in soil fauna and biologically mediated processes*
- *to measure the effects on runoff water quality and quantity*
- *to develop a process-oriented model of effects linking terrestrial and aquatic response.*

Experimental design:
Climate changes alone: Ambient acid precipitation has been collected by the roof in the KIM catchment since 1984. This has been filtered and cleaned by ion-exchange, natural levels of seasalts re-added and then reapplied beneath the roof and above the forest canopy by a sprinkling system. This treatment will continue in CLIMEX, augmented by increased levels of atmospheric CO_2 and increased ambient temperature (by 5° C) by means of CO_2 dosing and hot air equipment conventionally used in agricultural greenhouses. As untreated reference for the biological studies, a small portion of the KIM catchment will be sectioned off to receive clean precipitation but not elevated CO_2 or temperature.

Interaction between climate changes and acid deposition: At the EGIL catchment ambient acid precipitation collected by the roof is simply recycled beneath the roof without cleaning. For CLIMEX, levels of atmospheric CO_2 will be increased and ambient temperature raised by 5°C. The adjacent ROLF catchment (no roof, ambient acid deposition) serves as a reference for present climatic conditions. At both enclosed catchments, there will be a step change in CO_2 and temperature, starting at the beginning of the growing season.

8 ICAT -Impacts of Elevated CO_2 Levels, Climate Change and Air Pollutants on Tree Physiology (COST)

COST is an acronym for the French equivalent of "European Cooperation in the Field of Scientific and Technical Research". It is, principally a framework for R&D cooperation, allowing for both the coordination and national research projects and/or the participation of third countries in Community programmes, taking the form of precompetitive or basic research or activities of public utility.

COST cooperation involves 23 countries: the twelve EC Member States plus six of the EFTA (European Free Trade Association) countries (Austria, Finland, Iceland, Norway, Sweden, Switzerland), Czechoslovakia, Hungary, Poland, Turkey and Yugoslavia.

All COST projects are funded nationally, and fall within one of fourteen defined scientific or technical areas. "Environment" is one of these areas, and herein is one project relevant for the present survey, namely ICAT.

The information below on ICAT was drawn from a "Technical Annex of the Memorandum of Understanding of COST project 614".

Natural populations will partially have the ability to adapt to a relatively fast changing atmosphere and altered climatic conditions by ecotypic differen-tiation through selection. However, the significance of this adaptation depends on the genetic variation within the population and the length of the plant life cycle. In plants with a long life cycle, such as trees, ecotypic differentiation will be slow and will hardly have any adaptive value. Here the availability of phenotypic plasticity will be the important factor in the adaptation and survival of the species in a reltively fast changing atmosphere.

Objectives:

- *The primary aim of the project is to co-ordinate cooperative European research on the impact of the so-called greenhouse effect and air pollutants and its combination on trees functioning in the different European climate regions. The specific objectives are:*

- Tree functioning and adaptation: *To promote, integrate and intensify cooperative interdisciplinary research on the impact of a combination of elevated CO_2 levels, the consequences of an altered climate (drought, temperature stress) and a polluted atmosphere, also in the various combinations, on the physiological functioning and phenotypic plasticity of trees. To expand the present knowledge of the impact of multiple environmental stress factors on the biophysics, biochemistry and physiology of trees.*

- Forests: *To assess the role of forests as a sink for CO_2. To develop a system analysis for the forests for the various European regions in which the effects of combinations of elevated CO_2 levels and air pollutants on forest functioning can be simulated.*

- Forest fitness and wood production: *To obtain parameters which will be essential in the modelling and prediction of the consequences of the so-called greenhouse effect on forest fitness and commercial wood production in general.*

Participating countries in ICAT are: Austria, Belgium, Finland, France, Germany, Italy, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

9 Science of Global Environmental Change (NATO)

NATO (North Atlantic Treaty Organization) has, in addition to its better known political and military dimensions, a "Third Dimension", which seeks to encourage interaction between people, to consider some of the challenges facing our modern society and to foster the development of the scientific potential of Alliance countries. The NATO Science Programme (Scientific affairs division), established in 1958, plays a major role in this Third Dimension. Research projects are not

funded or coordinated within this framework. Rather it provides support for activities which foster scientific mobility and interchange between scientists.

One programme of the NATO Science Committee is the *Science of Global Environmental Change.* The objective is to promote research dealing with potential global changes within the Earth's environmental system, using the means available to the NATO Science Committee. Its particular aim is to describe and understand the interactive physical, chemical and biological processes that regulate the total earth system. Its primary goal is to advance our capability to predict changes in the global environment, in particular those which result from human impact on the climate. Five thematic areas have been identified for special consideration:

- The climate system and the hydrological cycle
- Biogeochemical processes and dynamics
- Ecosystems and global environmental change
- Global environmental changes of the past
- Human dimensions of global environmental change

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