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Inventory of Research on the Impacts of Climate Change

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Contents

Abbreviations

Abbreviation		Full name
AOGCM	=	Atmosphere-Ocean Global Coupled Model
CBA	=	Cost benefit analysis
EIA	=	Environmental Impact Assessment
FAO	=	Food and Agriculture Organization
GDP	=	Gross Domestic Product
GEF	=	Global Environment Facility
GIS	=	Geographical Information System
IFC	=	International Finance Corporation
IPCC	=	Intergovernmental Panel on Climate Change
NASA	=	National Aeronautics and Space Administration (USA)
OAS	=	Organization of American States
SIDS	=	Small Island Developing States
UNDP	=	United Nations Development Programme
UNEP	=	United Nations Environment Programme
WHO	=	World Health Organization
WMO	=	World Meteorological Organization

Abstract

Climate change is one of the greatest threats for the global environment today. Global mean temperature has risen by about 0.6°C during the 20th century, greater than during any other century in the last 1000 years. Subsequently, climate change is likely to have detrimental effects on all global natural and anthropogenic systems. Climate change will have consequences for the structure and function of ecosystems and all the major global biomes. Also agricultural production and productivity will alter, and physical effects will take place on the environment affecting those that inhabit it. For example, see level rise and climatic variations will have implications for human health, land use and coastal infrastructure.

This report aims to identify the current and proposed research and assessments being undertaken by international organizations as well as the major national research groups regarding climate change and its effects on ecosystems, on agriculture (including fisheries and forestry) and on the economy and human society. The report also identifies possible gaps in this research.

The IPCC, basing its assessment on peer reviewed and published scientific/technical literature, plays a main role in summarizing climate change research and forming a worldwide consensus on future scenarios. The IPCC published its Third Assessment Report in 2001.

Global research on the effects of climate change amongst the world's ecosystems is being undertaken and/or coordinated by organizations such as the FAO, UNEP, UNDP, the World Conservation Union (IUCN), the International Geosphere-Biosphere Programme (IGBP). They all work on several cross cutting projects in climate change and terrestrial ecosystems and biodiversity. The World Bank is sponsoring numerous projects worldwide to promote research in the subject. Higher latitudes are covered by bodies such as the British Antarctic Survey, the Canadian Institute for Climate Studies and the Nordic Arctic Research Programme among others. In middle latitudes, many leading research groups in Western countries are working on this topic. Research on ecosystem impacts of climate change in lower tropical latitudes include effects of sea surface temperature warming on coral reefs by the Coral Reef Degradation of the Indian Ocean (CORDIO) Programme. Gaps through the relative neglect of research into other tropical ecosystems is, however, noticeable.

The impacts of climate change on agriculture are complex and uncertain. The FAOs Global Terrestrial Observation System Programme and START's Global Change program, takes a long-term predictive approach to its research. A large number of national and regional agencies fund or undertake work throughout the world, such as NASA's Goddard Institute for Space Studies and the WMO's Agricultural Meteorology Programme. National programs include the Canadian Climate Impact and Adaptation

Research Network as well as work in New Zealand though the use of models and data sets to predict climatic effects on agriculture and horticulture, by the National Institute of Water and Atmospheric Research. In the United Kingdom, the Climate Impact Programme (UKCIP) is one of the active players in the field. In the US, the Department of Agriculture has commissioned a number of studies on climate change impacts on US Agriculture.

Work on the effects on forestry appears to be split between large international agencies such as IUCN and the projects under the framework of the World Bank, and again extensive national projects by the Canadians and their CIARN Forest Sector programs among others. Global warming could have many impacts on fisheries and other aquatic and marine resources. The UNEP-World Conservation Monitoring Centre is undertaking a Changing Oceans project and the UNESCO Global Oceans Observation System Programme, involving other bodies such as UNEP WMO and FAO. The US Global Oceans Ecosystems Dynamics project is a multi-disciplinary program to examine the potential impacts of global climate change in marine ecosystems.

Research on the impacts of climate change on the economy and human society is reasonably comprehensive. Several academic institutions such as the Centre for Marine and Climate Research in Germany and the Centre for Social and Economic Research on the Global Environment, and the Climatic research Unit, both working from the University of East Anglia have regional research projects in various regions of the world such as developing African states and low lying small island states. In Germany, the Potsdam Institute for Climate Impact Research (PIK) is also focusing on socio-economic issues while Norway has the Centre for International Climate and Environmental Research (CICERO). Finally, the Tyndall Centre and the International Institute for Environment and Development (IIED), both in the UK are actively involved in the economic and human dimension of climate change impacts.

Based on the survey and on IPCC and UNFCCC Reports, several gaps were identified in climate change research regarding the motioned topics:

- Much of the climate change predictions made are gradual, continuous changes. A science that focuses on discontinuities (tipping points, thresholds, etc.) rather than mean changes and gradual response curves is only developing slowly.
- Much climate change research has focused on a one century time scale. Very little attention has been paid to the evolution of climatic risks over the next 20 years. Climate change scenarios are distinct from present risk (control runs are very poor surrogates for present climate experience) and a 3-10 year time scale of climate prediction remains difficult. Yet, this remains the relevant time scale for policy making, vulnerability assessment and the like.
- Climate change impact research in developing countries is hindered by the virtual absence of good long-term data. Monitoring programs are needed in a variety of areas, such as land-use, ecosystem data, socio-economics, etc.
- Most work in agriculture and fisheries focuses on middle latitude issues. However, in developing countries, the issue of food security should not be neglected.

- Most research has been sectoral, yet there is the need to focus on the interactions between different sectors in society;
- Most research has looked at impacts of one specific stressor, yet there is a need to further our understanding on the cumulative effects of multiple stresses and at different spatial scales;
- Relatively little work has been carried out on vulnerability and integrated risk assessment; Enhanced risks from climate change need to be seen in the light of existing risks, e.g. flooding, hurricanes, environmental, health, political, social, etc. Relevant profiles of vulnerability should be provided and integrated risk management tools should be applied to identify and evaluate how best to cope with climate change related risks. This should also include economic risk assessment.
- Economic impact research has often taken an engineering approach, i.e. the economic loss was calculated as the loss in physical terms times the price based on a marginal analysis. Yet, actual losses need to be based on the total economic changes in terms of quantity and price in the various sectors based on induced changes in demand and supply, and trade, etc.
- Much research has focused on the impacts of climate change on ecosystems and natural resources. Yet, the impacts on humans in their livelihood systems (e.g. human access to natural resources) and other socio-economic linkages as a result of these changes are largely unknown. The social/cultural complexity, especially in developing countries in the context of climate change needs to be studied in depth, as well as issues of induced possible demographic shifts and land-use changes.
- Vulnerability and impact studies, especially in developing countries, need to focus more on impacts on poverty and on the poorest segments in society, given that so much of the aid flows focus on poverty alleviation. The research should address the question how climate change impacts poverty incidence, both rural and urban.
- Disasters linked to climate change can lead to economic and political instability, e.g. related to water scarcity exacerbated by climate change. Hardly any research has been done in this area thus far.
- Though not the focus of the survey here, major gaps exist in our understanding of climate change adaptation. In fact, in this area, much more policy relevant research is needed, for instance in preventing mal-adaptation and encouraging no-regret policies and measures.
- Health impacts of climate change, e.g. malaria outbreaks have only been studied in some areas in the world thus far.

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This report was prepared through a contract between the International Institute for Applied Systems Analysis (IIASA) and Professor Olof Linden at Kalmar University, Sweden. The scientific responsibility for this report is with Dr. Herman Cesar, Arnhem, The Netherlands) with the support of Mr. Ryan Walker (Arnhem, The Netherlands). Background research was carried out by Annabelle Aish and Andrew Finlay. The report was reviewed by Kees Dorland, Richard Klein and Rolph Payet. The findings, interpretations, and conclusions expressed in this report are entirely those of the consultants.

Inventory of Research on the Impacts of Climate Change

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1. Introduction

Climate change and associated adverse impacts form one of the major challenges of this century. Global mean temperature has risen by about 0.6°C during the 20th century, greater than during any other century in the last 1000 years. The 1990's were the warmest decade in the last 100 years and 1998 the warmest year in the instrumental record (1861-2003). The Earth has also witnessed an increase in precipitation (5-10%) in many mid- and high latitudes of the northern hemisphere land areas (IPCC, 2001).

There is much debate over the cause of global climate change. Temperatures have fluctuated naturally throughout history. However, recent increases in greenhouse gas emissions caused by mankind are generally believed to have resulted in the elevated global temperatures. Concentrations of carbon dioxide have increased by 31% and concentrations of methane have increased by about 150% since 1750 (IPCC, 2001). The Intergovernmental Panel of Climate Change (IPCC), established in 1988 by WMO and the United Nations Environmental Programme (UNEP), concluded in 2001 that the Earth will warm by 1.4 to 5.8°C by the year 2100 if no additional climate initiatives are taken. How the oceans respond to these changes is central to predicting both global and regional impacts of any climate change.

Rising sea level poses a serious threat to the existence of low-lying island nations and coastal plains due to an increase their vulnerability to coastal flooding and erosion. In the last 100 years, sea level has risen by between 10 to 25 centimeters. The thermal expansion of the oceans and melting of glaciers and ice caps from expected global warming could increase average sea level by 9 to 88 cm in the next century. Rising temperatures will also cause a shift in terrestrial ecosystems as flora and fauna struggle to adapt to changes in temperature. This may have catastrophic affects on natural ecosystems on which our economies and societies depend. Desertification, drought, flooding, deforestation and coral bleaching are just some of the consequences that climate change may have.

Besides impacts on natural ecosystems, climate change will affect agriculture, forestry and fisheries. Again, the consequences are highly uncertain and complex. Higher temperatures and atmospheric CO_2 levels will *ceteris paribus* meaning an increase in photosynthesis and growth. Yet, the only thing we are certain about is that certain things will not be equal: rainfall patterns are likely to change and so are weed species, soil and insects.

These changes in natural ecosystems and in managed renewable natural resources will affect the economy and human society in many different ways. Climate change is expected to lead to increased frequencies and intensities and changing patterns of extreme weather events such as hurricanes, droughts and precipitation events in

different parts of the world. Increased flooding events, crop losses and malaria outbreaks are just a few of the possible impacts with potentially major economic and human consequences.

To address these different issues, many global and regional institutions have established units to conduct research and assessments of the impact of global climate change. In addition, several national organizations, ministries and research facilities have started to carry out or commission research on climate change and associated impacts. Alongside this, environmental consultancies are contracted to conduct independent assessments for governments as well as private clients who feel their businesses are potentially jeopardized by the impacts of climate change.

This report focuses on research by these different international and national groups. More specifically, the terms of reference for this study are to come up with an inventory of ongoing and planned major projects and programs focusing on the impacts of climate change. The survey will primarily consider research and assessment focusing on: (a) the impacts on the ecosystem and the functions of the ecosystem in higher, middle and lower latitudes; (b) the impacts on agriculture, forestry and fisheries; (c) the effects of climate change on the economy and socio-economy of affected human societies. The survey will focus on projects and programs of regional and international scope but major national initiatives are also part of the investigation. Based on the outcome of the survey, the major gaps in on-going and planned research and assessment activities are identified.

Given these terms of reference, research on climate change adaptation and mitigation will not be discussed in this report. Research groups focusing primarily on these areas are not included. Also, units that work primarily on climate change scenario modeling are excluded unless these modeling efforts include impacts. We focus on ongoing and planned research; past programs are not mentioned. Finally, research groups active under the headings of different sections will be mentioned in the section where they are most active in rather than in all sections.

The structure of the report is in line with these terms of reference. It will start with short introduction into climate change and on the Intergovernmental Panel on Climate Change (IPCC). Next, in Section 4, the impacts of climate change on natural ecosystems and their functions will be discussed, subdivided into subsections on global, higher, middle and lower latitude research. Section 5 lists the groups working on agriculture, forestry and fisheries and Section 6 describes research on socio-economic impacts. Section 7 discusses the major gaps in the research. The report ends with some key recommendations.

2. Climate Change

Climate models predict that the global average temperature may rise by about 1.4 - 5.8°C by the year 2100. Increased temperatures will cause thermal expansion of seawater and ice caps to melt, culminating in a point estimate in sea level rise of 48 centimeters by 2100. At the same time, heavy precipitation and hurricanes are likely to increase in intensity and frequency by 3-5% (IPCC, 2001).

Uncertainty about the human role in causing climate change has been greatly reduced, but there is still considerable uncertainty about 'where' and 'when' 'which' impacts will occur, and 'with which' magnitude and frequency. In warmer climates, higher than average temperatures increase evaporation, and may cause particularly dry conditions leading to desertification and a potential increase in bush fires. Desertification may become commonplace in semi-arid areas as ecosystems struggle to adapt to increased temperatures leading to a rise in the frequency of droughts. In cooler climates, increased precipitation may cause rivers to flood. In areas closer to the sea, flooding may have a major impact on coastal ecosystems. Erosion of beaches, mangroves, coral reefs, salt marshes and sand dunes may all take place as increases in the volume of seawater cause low-lying coastal areas under an elevation of 10m above sea level to be flooded. In coastal areas where deforestation and loss of sand dunes occur, waters may become highly prone to sedimentation, smothering marine ecosystems such as coral reefs and reducing important light levels necessary for such systems to survive.

There may be a global loss of diversity and increase in extinction rates where less robust fauna and flora struggle to adapt to increases in temperatures and are unable to migrate to more habitable climates. For example, increased temperatures in the hottest year on record 1998, caused a bleaching event that impacted 75% of coral reefs and killed 16% worldwide. In addition, over the past 50 years, abnormally long warm spells in the Southern Ocean during the late 1970s contributed to a 50% decline in the population of emperor penguins at Terre Adelie, Antarctica (National Geographic, 2003).

Agricultural areas may be affected by salt-water intrusion as fresh water becomes mixed with water from the sea. This may affect the ability of crops to grow. Alongside this, an increase in the frequency of storms and intensity of rainfall may cause a loss of habitat in areas prone to increased hurricane activity and storm damage with land and mudslides reeking havoc in affected areas.

The impacts of climate change on society and global economies could be devastating. The loss of ecosystems such agricultural land and coral reefs would be disastrous where the dependence of the livelihoods and incomes of local people are the greatest. The economic losses to the 1998 coral bleaching episode in the Indian Ocean alone is estimated at up to US$ 8.2 billion. In addition, damage to infrastructure such as coastal roads, ports, jetties, coastal resorts and towns may have large impacts on local economies due to losses in revenues of industry affected by the damage i.e. tourism. The cost of repair and maintenance to coastal and river defenses are extremely high and often too great to warrant. Rivers and seas flooding low-lying areas may cause migration of towns and the people that live within them, creating overcrowding of dwellings in higher altitudes. Increases in the frequency of hurricanes, storms and regional flooding may lead to increases in health risks as disease may reach epidemic status after national disasters. Fresh water scarcity may become one of the biggest problems in the world as aquifers and wells dry up and fresh water systems become mixed with saltwater. These effects appear to be more detrimental in Small Island Developing States (SIDS) due to the high vulnerability to natural disasters. This also has major economic consequences.

Tol (1997) estimated impacts of climate change for different regions in the world in dollars and as percentage of GDP. For Latin America and the Caribbean, a loss of US$ 109.9 billion was predicted at a hefty 13.8% loss of GDP under moderate climate change predictions, due to extreme weather events, species loss, loss of human life, sea level rise and agricultural losses (see Table). For South and Southeast Asia, these losses were even larger, both in absolute terms and as percentage of GDP. For the world as a whole, a loss of US$ 523.8 billion and 2.7% of GDP was predicted.

Table 2-1. Monetized estimates of the impact of climate change (in 10^9 US$)

Region	*Species loss*	*Loss of hum. life*	*Agriculture loss*	*Sea lev. rise*	*Extreme weather*	*Total*	*Percent GDP*
OECD	52.4	23.7	-1.5	45.8	46.3	166.6	1.2%
Middle East	0.4	5.2	7.6	2.7	0.0	15.9	4.2%
LA&Caribb.	0.6	90.6	13.1	5.6	0.1	109.9	13.8%
S&SE Asia	0.2	101.0	123.9	5.8	3.5	134.3	16.3%
Africa	0.1	22.7	11.4	2.8	0.0	39.1	9.6%
Rest World	6.3	77.7	-26.3	1.5	0.6	5.8	-
Total World	60.0	320.9	28.2	64.2	50.5	523.8	2.7%

Source: Tol (1997)

Whether these estimated impacts materialize depends on the actions of individuals and nations now. Research on the possible impacts of a business-as-usual scenario is important. Ongoing and planned research on the themes discussed in this section is the topic of the rest of the report.

3. Intergovernmental Panel on Climate Change (IPCC)

The IPCC is the world's leading scientific body for assessing the scientific, technical and socio-economic information relevant for understanding climate change. The work of the IPCC is guided by the mandate given to it by its parent organizations the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The IPCC does not carry out research nor does it monitor climate related data or other relevant parameters. It bases its assessment mainly on peer reviewed and published scientific/technical literature.

The IPCC's Task Force on National Greenhouse Gas Inventories is playing an important role in assisting countries to develop internationally consistent ways of accounting for their greenhouse gas emissions. Special Reports and Technical Papers are often prepared in response to requests from the Conference of the Parties to the UNFCCC, or from other environmental conventions, e.g. the Convention on Biological Diversity (CBD), the Convention to Combat Desertification (CCD), or the Vienna Convention on the Protection of the Ozone Layer.

The IPCC published its Third Assessment Report (TAR) in 2001 (IPCC, 2001). The aim is to understand better the potential impacts and associated dangers of global climate change. Building on the Second Assessment Report (SAR), this new reports re-

examine key findings of the earlier assessment and emphasizes new information and implications on the basis of more recent studies.

The TAR systematically reports on the effects of climate change on all of the planets major biomes, for example temperate European forests, the boreal forests of higher latitudes, tundra and polar environments, and tropical savannas, forests near shore coastal environments.

The Climate Change 2001 assessment report confirms that earlier projections of global mean temperature increases were underestimated.

Besides a summary report, the TAR consists of the documents of the three Working Groups:

- Working Group I: Assessment the scientific aspects of the climate system and climate change.
- Working Group II: Assessment of the environmental and socio-economic impacts of climate change negative and positive consequences of climate change, and options for adapting to it.
- Working Group III assesses options for limiting greenhouse gas emissions and otherwise mitigating climate change.

Working group II of the IPCC discusses topics relevant to the remit of this report. The working groups report covers technical, environmental, economic, and social issues associated with the climate system and climate change.

Working Group II's mandate for the TAR is to assess the vulnerability of ecological systems, socio economic sectors, and human health to climate change as well as potential impacts of climate change, positive and negative, on these systems.

This assessment also examines the feasibility of adaptation to enhance the positive effects of climate change and ameliorate negative effects.

4. Research on the Impacts of Climate Change on Ecosystems and their Functions

4.1 Introduction

Climate change can have numerous effects on the world's natural ecosystems and their functions. The shift in regional climatic conditions can alter seasonal growing patterns for species of plants, thus having knock on effects for whole biomes, as whole regions flora and fauna migrate to more favorable conditions. Natural ecosystems will change as a result of increasing temperature and atmospheric concentration of carbon dioxide (CO_2). Subtle temperature changes can alter migration routes for terrestrial, marine and aquatic species effecting predator pray relationships, leading to habitat alteration and ultimately reduced, or altered biodiversity.

For the purpose of this report and ease of reporting the research on the impacts of climate change on ecosystems and their functions, this section has been divided into:

- Organizations that conduct global research and carry out global assessments on ecosystem change.
- Organizations that conduct research and carry out assessments on ecosystem change in higher latitudes (above 50°).
- Organizations that conduct research and carry out assessments on ecosystem change in middle latitudes (between 50° and the tropics).
- Organizations that conduct ecosystem change research and carry out assessments in lower latitudes (between the tropics of Cancer and Capricorn).

The focus here will be specifically on change of ecosystem and its functions. More general impacts of climate change on agriculture, forestry and fisheries as well as on the economy and human society will be discussed later in this report.

The survey focuses on global and regional organizations as well as large national research groups that conduct work on ecosystems potentially affected by climate change. All these organizations carry out research and assessments themselves or commission the research while also having staff working on it. The International Panel on Climate Change (IPCC) was already discussed above and this will not be repeated here. We focus on ongoing and planned research and don't mention finished programs.

4.2 Global Research

FAO's Global Terrestrial Observation System (GTOS).

The GTOS is an FAO/UNEP/UNESCO/WMO/ICSU sponsored program that aims to undertake observations, modeling, and analysis of terrestrial ecosystems to support sustainable development. GTOS facilitates access to information on terrestrial ecosystems, so that researchers and policy makers can detect and manage global and regional environmental change. GTOS has three technical panels: (i) Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD); (ii) Terrestrial Carbon Operations; and (iii) Terrestrial Observation Panel for Climate (TOPC). The GTOS has two regional programs, the South African Programme and the Central and Eastern Europe Programme. The wealth of ecological diversity in the Southern African region renders it a clear and central barometer for global environmental changes. Developing a higher scientific capacity in the region is a prerequisite for a functional global observing system. In early 1999 the terrestrial observing system launched its first regional initiative in Central and Eastern Europe (CEE). The overall goal of the initiative is to identify terrestrial monitoring requirements of countries in the region; to improve access to data and information; and to strengthen the technical capacities for environmental assessment and monitoring.

GTOS also runs a Global Terrestrial Observing Network (GT-NET) and a Terrestrial Ecosystem Monitoring Sites (TEMS). GT-NET is seen as a master network. This generates complete and coherent data sets on global terrestrial ecosystems through international research collaboration. TEMS is an international directory of sites (named

T.Sites) and networks that carry out long-term terrestrial monitoring and research activities. More than 500 T sites are registered. The database provides information on the "who, what and where", useful to both the scientific community and policy-makers.

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

START is a large organization covering cross cutting programs with many other collaborative organizations. START's 'mother organizations' and sponsors include: International Geosphere-Biosphere Programme (IGBP). ICSU, WCRP, WCP, WMO, UN, and the International Human Dimensions Programme on global environmental change (IHDP). As a non-profit NGO, START aims to improve the knowledge base for scientific assessments upon which national and regional policy options for mitigating or adapting to global change can be developed. START has regional networks in: Pan Africa, Temperate East Asia, Southeast Asia, South Asia, Oceania and the Mediterranean, and program aims include, Global Change and Terrestrial Ecosystems/Biodiversity. START's cross-cutting themes include, Global Observation of Forest Covers (GOFC).

International Geosphere-Biosphere Programme (IGBP)

IGBP research projects are funded by a large number of national and regional agencies. Their scientific objective is to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth System, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human actions. They have 9 core projects, including the Global Change and Terrestrial Ecosystems (GCTE) project. GCTE studies the effects of changes in climate, atmospheric composition, and land use on the structure and functioning of terrestrial ecosystems, and how these effects lead to feedbacks to the atmosphere and the physical climate system. GCTE has four main focal areas: (i) the terrestrial carbon cycle with an emphasis on underlying drivers and processes of contemporary and future carbon quantities (fluxes and pools); (ii) vegetation dynamics and the processes controlling them at local and global scales, with an emphasis on landscape processes and patterns that dominate vegetation dynamics; (iii) impacts of global change on food production systems including the major species that provide the bulk of food to humanity (e.g., wheat, rice) with the associated pests and diseases and biogeochemical consequences; and (iv) the links between ecosystem functioning and biodiversity, and associated stability, resilience, and buffering capacity to natural and human perturbations.

UNEP-World Conservation Monitoring Centre (WCMC)

The World Conservation Monitoring Centre (WCMC) was established in 2000 as the world biodiversity information and assessment centre of UNEP. The WCMC Biodiversity and Climate Change Programme link together the many different areas of expertise across the Centre. A number of activities have already been undertaken, with several others ongoing and many more under development. Current projects include "Water Birds on the Edge", which is the first circumpolar assessment of climate change impact on arctic breeding water birds. Another project is "Forests in Flux", a current investigation to undertake a global synthesis of the likely impacts of climate change on

forest distribution and integrity. The findings will hopefully enable better prediction of the impacts on the world's forests and enable the development of recommendations for changes in forest policy and management issues. Much of WCMC work on climate change and its effect on ecosystems are collaborations with other organizations. For example an Inventory of glaciers, glacial lakes and glacial lake outburst floods monitoring and early warning systems in the Hindu Kush - Himalayan Region, Nepal and Bhutan, is a result of research carried out by the non-profit NGO Global Change System for Analysis, Research and Training (START).

World Bank

The World Bank's work follows policy guidance from the United Nations Framework Convention on Climate Change (UNFCCC) in its role as an Implementing Agency of the Global Environment Facility, and is predicated on the scientific work of the Intergovernmental Panel on Climate Change (IPCC). The World Bank's role remains key in helping mainly developing nations through donor funding to combat the effects of climate change on the environment. The World Bank typically commissions other agencies and organizations to carry out such work. Currently the World Bank is involved with 324 projects world wide in either biodiversity conservation or energy conservation regarding global climate change, examples include large-scale biodiversity conservation projects underway in six national parks in Argentina, concentrating on forest ecosystems. Part of its current studies involves global overlays where incremental global benefits of wise local practices are assessed. The World Bank has also commissioned large studies on climate change impacts, e.g. in the Pacific Islands (World Bank, 2000).

World Conservation Union (IUCN) 'Climate Change Initiative'

In light of the potential impacts of climate change, IUCN was requested by its Members to develop a strategy on climate change and to assist countries in climate change adaptation and mitigation. Their work also includes participating in the work of the UN Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC). In response to this request, IUCN created the Climate Change Initiative. IUCN's main concern with climate change is its relationship to the conservation and sustainable use of biodiversity and other natural resources. The Union focuses on four areas of work: (i) Clarifying Vulnerability; (ii) Identifying adaptation options; (iii) Evaluating carbon sequestration activities; and (iv) Supporting implementation of global conventions. For this section, the first area, clarifying vulnerability, is the most relevant. Climate change is considered to be one of the major threats to biodiversity at both the species and ecosystem levels. Through case studies and analysis, IUCN strengthens the understanding of the threat posed by climate change to the world's ecosystems and species as well as the communities dependent upon them. Its prime focus is on biodiversity issues, though some economic work on climate change is being carried out as well.

World Meteorological Organization (WMO) - WCP and GCOS Programmes

The WMO facilitates international co-operation in the establishment meteorological, hydrological and other observations and promotes the rapid exchange of meteorological

information. WMO is responsible for the maintenance and enhancement of programs monitoring key components of the climate system. Including terrestrial ecosystems ie the Geosphere-Biosphere Programme (IGBP). A major program within WMO concerning the effects of climate change on global ecosystems is the World Climate Programme (WCP). Established in 1979, the WCP comprises the following components: the World Climate Data and Monitoring Programme; the World Climate Applications and Services Programme; the World Climate Impact Assessment and Response Strategies Programme; and the World Climate Research Programme.

WCP projects on ecosystems and climate change include the Artic Monitoring and Assessment Programme. The WCP also supports the Global Climate Observing System (GCOS), encompassing all components of the climate system, atmosphere, biosphere, cryosphere and oceans. Both WCP and GCOS are subsidiaries of the UNEP. GCOS was established in 1992 to ensure the promotion of long-term climate monitoring networks. GCOS ensures that observations and information needed to address climate-related issues are obtained and made available to all potential users. It is co-sponsored by the WMO, the Intergovernmental Oceanographic Commission (IOC) of UNESCO, UNEP and the International Council for Science (ICSU). The aims of GCOS include monitoring the impacts of and the response to climate change, especially in terrestrial ecosystems.

Germany - Max Planck Institute for Meteorology (MPI-Met), Hamburg.

MPI-Met based in Hamburg states the major objective of its researchers is to undertake a system analysis of the Earth System dynamics with emphasis on the Earth Climate. More specifically to analyse the natural variability in the Earth system, and assess how the system is affected by changes in land-use, industrial development and urbanization. Among the tools used by MPI-Met scientists are advanced numerical models that simulate the behavior of the atmosphere, ocean, cryosphere and biosphere, and the interactions between these different components of the Earth's system. They have one of the large Global General Circulation Models (GCMs) and impacts are calculated with a REgional Climate MOdel (REMO).

UK - The Hadley Centre

The Hadley Centre for climate prediction and research, part of the Met Office, provides a focus in the United Kingdom for the scientific issues associated with climate change. The main aims of the Hadley Centre are: (i) understand physical and biological processes within the climate system and develop state-of-the-art climate models which represent them; (ii) to use climate models to simulate global and regional climate variability and change over the last 100 years and to predict changes over the next 100 years; (iii) to monitor global and natural climate variability and change; and (iv) to attribute recent changes in climate to specific factors; to understand, with the aim of predicting, the national inter-annual to decadal variability of climate.

The models are two versions of our coupled atmosphere-ocean general circulation model (HadCM2 and HadCM3). The experiments assume that future emissions of greenhouse gases will follow the IS92a scenario, in which the atmospheric concentration of carbon dioxide more than doubles over the course of the 21st century. This is a 'business as usual' scenario, which assumes mid-range economic growth but no

measures to reduce greenhouse-gas emissions. A range of results from various Hadley Centre climate experiments are shown on website of the Climate Impacts LINK project at the Climatic Research Unit, University of East Anglia. The LINK project is the main source for supply of Hadley Centre model data for use in research projects.

4.3 Research on Higher Latitudes

The following organizations are conducting specific research to assess the impacts of climate change on ecosystems and their functions in higher latitudes, above 50°.

The EU Concerted Action "The Arctic and Alpine Terrestrial Ecosystems Research Initiative" (ARTERI).

ARTERI provides a forum for the exchange of information, and the development of collaboration in European arctic and alpine terrestrial research. It also provides a focus for European collaboration with other regional and global research and identifies priorities and proposals for further research. One method to achieve these objectives is the development of scenarios of climate change impacts, through the use of combined results from research experiments, observations, past experience and theory.

The impact scenarios build on a wide range of current knowledge that has been reviewed and summarized in a number of international ARTERI workshop proceedings usually published in the "EU Ecosystem Report Series". These include workshops on "Global change and tundra soil biology", "Scenarios for ecosystem responses to global change", "Europe's cold regions: scenarios of landscape responses to global change", and "Human environmental interactions: issues and concerns in Upper Lapland, Finland". The present volume contributes within this series by including presentations and conclusions from the ARTERI workshop "Europe's cold regions: scenarios for animal responses to global change", held in Abisko, Sweden, in April 1998.

British Antarctic Survey (BAS)

BAS is an institute of the Natural Environment Research Council. Antarctic studies have clarified many key issues in the science of climate change. Antarctic ice cores show that climate has always changed and reveal the clearest link between the levels of greenhouse gases in the atmosphere and surface temperatures. BAS is carrying out on going studies into the effects of climate change on physical and biological systems in Antarctica.

The Canadian Institute for Climate Studies (CICS)

The Canadian Institute for Climate Studies manages the Canadian Climate Research Network (CCRN), which was founded by the Meteorological Service of Canada (MSC) of Environment Canada. One of the research nodes of the CCRN is the investigation of Land Surface Processes, to address the issue of forest floor soil CO_2 efflux (microbial + root respiration) in the ecosystem carbon balance, flux measurements were made with three chamber systems at the Saskatchewan Southern Old Black Spruce site. Coupled with the EC measurements of CO_2 flux at this and other sites, these data provide insight into how forest growth and climate affect respiration and the carbon balance.

Finnish Global Change Research Programme (FIGARE)

FIGARE is a three-year program (1999-2002) supporting research in natural sciences, social sciences, economics and technology with the objective to analyze and understand the changes taking place in the global system. FIGARE consists of 36 research projects, The Academy of Finland funds partly or wholly 14 research units. External funding bodies include the Ministry of Foreign Affairs, the Ministry of Agriculture and Forestry, the Ministry of the Environment, the Ministry of Trade and Industry, and the Ministry of Transport and Communications. FIGARE has funded research into Climate change impacts on the dynamics and functioning of boreal forest, Global change in sub-arctic environments and responses of silver birch (*Betula pendula*) to environmental climate change.

NASA - Land Cover Land Use Change Program (LCLUC) Project

LCLUC is an interdisciplinary scientific theme within NASA's Earth Science Enterprise (ESE). The NASA LCLUC Project conducts change-detection studies of land-cover change in the Alaska region, through a prototype spatially explicit modeling framework capable of using satellite-derived data on land-cover change to estimate how changes in land cover cause changes in ecosystem carbon storage.

Nordic Arctic Research Programme (NARP)

NARP, a research body have recently initiated research into:

- The, effects of climate change on soil animals in the Arctic - population ecological, ecophysiological ecotoxicological.
- Workshop on the effects of climate change on Greenland halibut biology and population dynamics.
- Short and long-term fluctuations in animal populations at Lake Myvatn A model for climatic and human impact on the ecosystem.
- Cross-system analysis of the variation in biological structure and dynamics of North Atlantic lakes related to variations and changes in climate and land use (NORLAKE).

4.4 Research on Middle Latitudes

The following organizations are conducting specific research to assess the impacts of climate change on ecosystems and their functions in Middle latitudes between 50° and the tropics. Note that most of the research on middle latitudes is carried out by groups mentioned in the 'global' section above. In fact, very few groups are mentioned here even though most of the climate change research on ecosystem change is taking place in the middle latitudes.

Asian-Pacific Network on Global Change Research (APN)

APN is an intergovernmental network with a membership of 21 countries, including Australia; Bangladesh; Cambodia; China; Fiji; India; Indonesia; Japan; Korea; Laos;

Malaysia; Mongolia; Nepal; New Zealand; Pakistan; Philippines; Russia; Sri Lanka; Thailand; USA and Vietnam. APN promotes of global change research and links between science and policy making in the Asia-Pacific Region. It promotes, encourages and supports research activities on long-term global changes in climate, ocean and terrestrial systems, and on related physical, chemical, biological and socio-economic processes. It supports research into Changes in Terrestrial Ecosystems and Biodiversity as one of its primary topics.

EU - Advanced Terrestrial Ecosystem Analysis and Modelling (ATEAM)

The EU is funding the Advanced Terrestrial Ecosystem Analysis and Modelling (ATEAM) under its 5th Framework Programme. ATEAM focuses on ecosystem functions and their impacts on fresh water, agricultural products, biodiversity and recreational opportunities. ATEAM is led by the Potsdam Institute for Climate Impact Research (PIK) and involves a great number of European research groups, such as Wageningen University, Université Catholique de Louvain (UCL) and many others.

The Pew Centre on Global Climate Change (PCGCC)

The PCGCC is a non-profit and independent US based organization involved in providing information and solutions in the effort to address global climate change. Established in 1998 by the Pew Charitable Trusts, Thirty-eight major US companies, are working together through the Centre to educate the public on the risks, challenges and solutions to climate change.

The objective of the PCGCC is to educate the public and key policy makers about the causes and potential consequences of climate change, and to encourage the domestic and international community to reduce emissions of greenhouse gases. Research on the effects of climate change on ecosystems has been documented by the PCGCC in several recent reports: Forests & Global Climate Change: Potential Impacts on U.S. Forest Resources, Coastal and Marine Ecosystems and Global Climate Change, Aquatic Ecosystems and Global Climate Change and Ecosystems & Global Climate Change.

US Department of Agriculture - Northern Global Change Program (NGCRP)

The Forest Service of the US Department of Agriculture (USDA) hosts the Northern Global Change Program (NGCRP). The objectives of the NGCRP are to understand: (i) what processes in US forest ecosystems are sensitive to physical and chemical changes in the atmosphere?; (ii) how future physical and chemical climate changes will influence the structure, function, and productivity of forest and related ecosystems, and to what extent forest ecosystems will change in response to atmospheric changes; and (iii) What are the implications for forest management and how must forest management activities be altered to sustain forest productivity, health, and diversity.

The NGCRP currently emphasizes scientific inquiry into the effects of multiple air pollutants and climate changes on forest ecosystems. As the program matures, the impacts of prospective changes on interactions between forest ecosystems and social and economic processes will be evaluated, as will policy options for mitigating or adapting to predict changes. Projects include the Climate change and Disturbance

Program to predict landscape scale disturbances and the effects on ecosystems. NGCRP is currently working on the "FACE" experiment, to investigate the CO_2 and O_3 impacts on northern hardwood ecosystems; of particular interest are the commercially important aspen. The Aspen FACE experiment consists of twelve 30m rings in which the concentrations of carbon dioxide and tropospheric ozone can be controlled. The design provides the ability to assess the effects of these gases alone and in combination on many ecosystem attributes. In the past, NGCRP also had a program for the development of regional scenarios.

4.5 Research on Lower Latitudes

The following organizations are conducting specific research to assess the impacts of climate change on ecosystems and their functions in lower latitudes between the tropics of Cancer and Capricorn.

Asian-Pacific Network on Global Change Research (APN)

APN is an intergovernmental network with a membership of 21 countries, including Australia; Bangladesh; Cambodia; China; Fiji; India; Indonesia; Japan; Korea; Laos; Malaysia; Mongolia; Nepal; New Zealand; Pakistan; Philippines; Russia; Sri Lanka; Thailand; USA and Vietnam. APN promotes of global change research and links between science and policy making in the Asia-Pacific Region. It promotes, encourages and supports research activities on long-term global changes in climate, ocean and terrestrial systems, and on related physical, chemical, biological and socio-economic processes. It supports research into Changes in Terrestrial Ecosystems and Biodiversity as one of its primary topics.

Caribbean Climate Change Centre (CCCC)

The CCCC has just been set up as coordinating body for climate change related work in the Caribbean. Belize City has recently been chosen as their base. The CCCC is executing agency of the Mainstreaming Climate Change in the Caribbean (MACC) Project, a large ongoing GEF project that started end 2002 and that is being implemented with support from the World Bank and the Organization of American States (OAS). Within OAS, its Unit for Sustainable Development and Climate Change is involved in the project. CCCC's purpose is to support twelve Caribbean Community (CARICOM) countries and regional institutions in an effort to cope with the adverse effects of climate change, particularly sea-level rise, in coastal and marine areas.

Caribbean Marine Research Centre (CMRC)

To increase the understanding of global climate change and contribute to informed conservation policies, CMRC supports and conducts research in environmental change and coral reef ecosystems. With laboratories in Florida and the Bahamas, research sites throughout the greater Caribbean region, and affiliated scientists at various U.S. and international universities, CMRC produces scientific data through a comprehensive research and monitoring program.

Coral Reef Degradation in the Indian Ocean (CORDIO)

The Coral Reef Degradation in the Indian Ocean (CORDIO) Programme was established to respond to the degradation of coral reefs throughout the Indian Ocean. The program was initiated by the extensive bleaching and mortality of corals that occurred during 1998. CORDIO is supported by Sida (Swedish International Development Cooperation Agency), the World Bank, FRN (Swedish Council for Planning and Coordination of Research), MISTRA (Foundation for Strategic Environmental Research) and WWF (Worldwide Fund for Nature). In the south Asia, East Africa and Central Indian Ocean Islands regions, several projects are presently investigating bio-physical and socio-economic impacts of coral bleaching. CORDIO is undertaking such projects in Sri Lanka, the Maldives, India, Kenya, Tanzania, and the Seychelles.

Inter-American Institute for Global Change Research (IAI)

The IAI is an intergovernmental organization supported by 18 countries in the Americas responsible for research and the open exchange of scientific information to increase the understanding of global change. To function as a regional entity and to conduct research that no one nation can undertake on its own, the IAI was conceived as a network of collaborating research institutions The IAI encourages comparative analyses of natural and anthropogenic systems from the tropics to temperate and cold latitudes, including terrestrial, coastal and oceanic environments, to include impacts of climate change on biodiversity. Projects include:

- The Assessment of Present, Past and Future Climate Variability in the Americas from Treeline Environments, in Argentina, Bolívia, Chile and Mexico
- The Effects of Biodiversity on Ecosystem Functioning: A comparison across the Americas, in Argentina, Venezuela, USA, Chile, Mexico and Uruguay.
- Comparative Studies of Global Change Effects on the Vegetation of Two Tropical Ecosystems: The High Mountain and the Seasonal Savannah in Venezuela, Argentina, and Brazil.
- Comparative studies and Assessments of the Impacts of Global Change on the Pelagic and Near Shore Ecosystems of the North and South eastern Pacific Boundary Currents.

Intergovernmental Oceanographic Commission (IOC)

IOC works on climate change related topics through its Working Group on Coral Bleaching and Local Ecological Responses (WGCBLER). WGCBLER was initiated in September 2000 with the goal to integrate, synthesize and develop global research on coral bleaching and related ecological impacts of climate change on coral ecosystems, and further new research findings into development of tools and techniques for improved observations, predictions and management interventions at national and global scales. The goal of the project is to fill critical knowledge gaps relating to: (i) tolerance limits and potential mechanisms of corals for adaptation/acclimatization to thermal stress; (ii) long-term responses of coral reefs to large-scale changes in environmental variables; (iii) development of possible molecular, cellular or community

indicator tools that are reliable in their ability to detect environmental stress responses; and (iv) scenario-building regarding the future state of coral reefs and implications for society

The study group is composed of 14 international scientists, bringing together expertise in specific fields of coral physiology and coral reef ecology in a collaborative effort, engaging in discussions, field work and related activities. The effort is being developed in partnership with national research institutions and a GEF/World Bank Targeted Research program on coral ecosystem sustainability and capacity building. The major ambitions of the experimental program will be series of indicators.

NOAA- Tropical Atmosphere and Ocean project (TAO/TRITON)

The NOAA TAO/TRITON array project consists of approximately 70 moorings in the Tropical Pacific Ocean, telemetering oceanographic and meteorological data to shore in real-time via the Argos satellite system. The project is a component of work undertaken by NOAA. The array is a major component of the El Niño/Southern Oscillation (ENSO) Observing System, the Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS). Data is displayed via the TAO Web site and provides useful information about the ENSO phenomenon for both scientists and the general public. Information is provided on different levels with many links to other relevant sites.

The Pacific Islands Climate Change Programme (PICCAP)

PICCAP is a program to help Pacific Island countries to implement the UNFCCC. It began as part of the CC-Train Programme of the United Nations, but was adapted by the South Pacific Regional Environment Programme (SPREP) to be more appropriate to the Pacific countries that would carry it out. PICCAP is funded by the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP). The goals and policies of the project are decided by the Climate Change Convention Secretariat, part of the UN and responsible for each countries (not just those in PICCAP or CC-Train) implementation of the convention. PICCAP's chief goal is to assist countries to build sustainable capacities to do what is required of them in the convention. The country team has members from government agencies, NGO's, Private Industry, and Scientific and Research groups, with a chairman from the National Focal Point.

UK - The Natural Resources Institute (NRI)

The UK based Natural Resources Institute (NRI) is a multi-disciplinary centre for research, consultancy and education for the management of natural and human resources, based at the University of Greenwich. Most of The NRIs research is carried out with partners in developing countries. The NRI has undertaken research into Impacts of climate changes on key natural resources and environments that are critical to Pacific island livelihoods.

Indian Institute of Science (IISc)

The Indian Institute of Science (IISc) works on assessing the impact of climate change on forest ecosystems. This is done with support from ERM, a UK-based consultancy with project and research experience in, among others, the impacts on forests.

5. Research on the Impacts of Climate Change on Agriculture, Forestry and Fisheries

The impacts of climate change on agriculture, forestry and fisheries pose one of the greatest concerns as so many economies and societies worldwide will be affected. Because of this, many assessments and research projects have been developed to address the impacts.

5.1 Agriculture

Agriculture impacts on climate change are highly uncertain and complex. Increasing atmospheric CO_2 levels are expected to influence crop production in many different ways. The response to an initial increase in temperature by itself in isolation should generally be positive for crop yields. In terms of plant growth and development, higher rates of photosynthesis are found in entire canopies placed in a CO_2-enriched atmosphere-due to the CO_2 "fertilization" effect. In general "C3" crops (such as wheat, rice, and soybeans) respond more to CO_2 enrichment than "C4" crops (such as maize, sorghum, sugarcane, and millet) (EPA, 2002a).

At the same time, weeds, soil and water will be affected in yet unpredictable ways. Weeds will be directly affected by changes in climate and in CO_2 levels. Insects and diseases are not likely to be directly affected by CO_2 changes, but may be affected indirectly because of altered host plant metabolism, development and morphology. New, previously unobserved combinations of climate, atmospheric constituents, and soil conditions may result and lead to new infestations of various pests. The overall importance of such developments is unclear at this point, but crop losses due to weeds, insects, and disease are likely to increase. The impacts of climate change on soils are also largely unknown. Only rough, qualitative estimations of the predicted climate change effects on soil are practical now, due to the uncertainties in the forecasts but also to the complex, interactive influences of hydrological regime, vegetation, and land use. Finally, effects on water resources could be very important as climate change is likely to alter the hydrological regimes of entire regions (EPA, 2002a).

The IPCC report by Working Group II: assessment of the environmental and socio-economic impacts of climate change. Outlines the importance to assess the scientific results in interactions between scientists and policy makers. Section 5.3 of the Third Assessment Report (TAR) covers quite comprehensively the pressures placed on the agricultural sector as a result of global climate change.

Assessments of Impacts and Adaptations to Climate Change (AIACC)

AIACC is a global initiative developed in collaboration with IPCC, funded by the Global Environment Facility (GEF) to advance scientific understanding of climate change vulnerabilities and adaptation options in developing countries. AIACC is implemented by UNEP and executed jointly by START and the Third World Academy of Sciences (TWAS). The majority of AIACCs 24 regional projects in 46 countries involve research into climate change and its effect on agriculture in developing nations and ways and means of militating against such problems.

FAO - Global Terrestrial Observation System Programme (GTOS)

The Food and Agriculture Organization (FAO) hosts the Global Terrestrial Observation System Programme (GTOS), involved in observations, modeling, and analysis of terrestrial ecosystems to support sustainable development. GTOS is investigating what impact land-use change and degradation have on sustainable development. A second research question is: can the land produce enough food to support its future population, projected at 12 billion by 2050? This aspect of GTOS's work is being undertaken by a Terrestrial Observation Panel for Climate (TOPC), carrying out activities aimed at improving the understanding of climate change processes in terrestrial systems and potential impacts on mankind.

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

STARTs cross-cutting themes include a Climate Prediction and Agriculture (CLIMAG) program. CLIMAG is a joint program of WCRP, IGBP, IHDP and START aimed at utilizing the capacity to predict climate variability on time scales of weeks to months ahead to improve farm management decision-making and so to increase crop production. CLIMAG includes a West Africa Demonstration Project, a three-year networking effort to explore the applicability of the "CLIMAG approach" to agricultural systems in the semi-arid regions of Mali.

International Geosphere-Biosphere Programme (IGBP)

IGBP research projects are funded by a large number of national and regional agencies around the world. Their scientific objective is to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth System. As one of four international global environmental change research programs, IGBP works towards its objective in close collaboration with the International Human Dimensions Programme on Global Environmental Change (IHDP), the World Climate Research Programme (WCRP), and DIVERSITAS, an international program of biodiversity science. As part of the Global Change and Terrestrial Ecosystems (GCTE) program (one of nine core projects), the program has undertaken research into the impacts of global change on food production systems. Including the major species that provide the bulk of food to humanity (e.g., wheat, rice) with the associated pests and diseases and biogeochemical consequences.

The International Institute for Applied Systems Analysis (IIASA)

IIASA conducts inter-disciplinary scientific studies on environmental, economic, technological and social issues in the context of human dimensions of global change. Within its Environment and Natural Resources Section, IIASA has a 'Modeling Land-Use and Land-Use Cover Changes' (LUC) project. LUCs research plans include help initiate and participate in a new international project on Global Environmental Change and Food Systems (GECaFS), Maintain and extend linkages to institutions and international research programs in the field of, agricultural systems modeling, and regional development. IIASA has produced several publications including Estimation of Agricultural Production Relations in the LUC Model for China, The Impacts of Climate Change, CO_2, and SO_2 on Agricultural Supply and Trade: An Integrated Assessment and Climate Change and Global Agricultural Potential Project: A Case Study of Kenya.

NASA Goddard Institute for Space Studies (GISS)

Research at GISS emphasizes a broad study of global change, using an interdisciplinary research initiative addressing natural and man-made changes in the environment. The research combines analysis of comprehensive global data sets with global models of atmospheric, land surface, and oceanic processes and includes study of past events on Earth such as paleoclimate change, and the study of other planets as an aid to prediction of future evolution of Earth on a planetary scale. GISS use three-dimensional general circulation models (GCMs) to study Earth's climate, both in the development of accurate numerical modeling methods and in analyzing human-climate interaction. GISS carry out international research into social and economic costs of regional changes in variables such as crop yields and water availability.

Organisation for Economic Co-operation and Development (OECD)

OECD is an international organization helping governments tackle the economic, social and governance challenges of a globalized economy. In May 2001, OECD Ministers adopted the OECD Environmental Strategy. It calls for the OECD to assist countries in implementing policy responses to climate change, including adaptation measures to facilitate dialogue and support analysis on the connections between sustainability and climate change, and to assess incentives and policies to achieve long-term stabilization of GHG concentrations. The Group's recent work includes Monitoring and Compliance, Emission Trading and Project-based Mechanisms, Domestic Policies and Measures, as well as Support to Countries with Economies in Transition. The OECD continues to examine the link between development and climate change which, in addition to identifying suitable mitigation and technology options, also examines the costs of the impacts of climate change and appropriate adaptation strategies. National and Sectoral Policies include Agriculture and Forestry.

UNEP-GRID Arendal

As a specific follow-up to the recommendations of the 1987 World Commission on Environment and Development, the Government of Norway and the UNEP established an environmental information centre in Arendal, Norway. Set up as a foundation under Norwegian legislation, the centre was linked to the world-wide UNEP program termed Global Resource Information Database and was therefore called a GRID centre. UNEP

has a ‘Vital Climate Graphics’ system which presents observed changes in global surface temperature, precipitation and sea level rise run out of the GRID centre. These trends form part of the evidence for climate change and identify potential impacts of climate change on health, agriculture, forests, water and other entities.

World Bank

The World Bank's Global Environment Division (ENVGC) has begun applying a new analytical tool called a Global Overlay to integrate Global Environment Externalities into the World Bank's economic and sector work. Climate change global overlays are applied in sectors such as energy, transport, forestry and agriculture.

The majority of the Bank's activities in Greenhouse Gas (GHG) mitigation are co-financed by the Global Environment Facility (GEF), and as experience with these projects grows, and the costs declines, such projects are increasingly being mainstreamed into Bank operations. The challenge is to balance local and global environmental impacts related to agriculture while addressing the priority development needs of the countries. The World Bank also has projects to mitigate GHG's through reducing energy intensity in sectors such as agriculture.

WMO - Agricultural Meteorology Programme (AGMP)

The World Meteorological Organization (WMO) hosts the Agricultural Meteorology Programme (AGMP). The purpose of the AGMP is to support food and agricultural production and activities. The program assists members in provision of meteorological and related services to the agricultural community to help develop sustainable and economically viable agricultural systems, improve production and quality, reduce losses and risks, decrease costs, increase efficiency in the use of water, labor and energy, conserve natural resources and decrease pollution by agricultural chemicals or other agents that contribute to the degradation of the environment. Although sometimes combined, climate information is used mainly for planning purposes, while recent weather data and weather forecasts are used mostly in current agricultural operations.

Canadian CIARN Agriculture

The Canadian Climate Impact and Adaptation Research Network (C-CIARN) is a national network that facilitates the generation of new climate change knowledge by bringing researchers together with decision-makers from industry, governments, and non-government organizations to address key issues. The goal of C-CIARN Agriculture is to build a network of representatives from agri-food, research, and policy communities to promote and facilitate research on climate impacts, vulnerabilities, risks, and adaptation for agriculture. In support of this goal, C-CIARN Agriculture’s list of priorities include: Crop/livestock losses due to extreme events, altered levels of soil moisture, change and severity of pests, increased variability in weather. Costs of current risk management and crop insurance strategies and Increased opportunities for growing new varieties and finding new markets. Recent out puts include Climate Change Impacts and Adaptation: A Canadian Perspective provides a review of the recent Canadian impacts and adaptation research (post-1997) and also highlights results from research funded by the Impacts and Adaptation component of the Climate Change

Action Fund. The report provides information on various sectors such as water resources, agriculture and forestry.

Indo-UK Programme on Impacts of Climate Change in India

The Ministry of the Environment and Forest (MoEF), India and the UK Department for Environment, Food and Rural Affairs (DEFRA) are involved in the Indo-UK program on Impacts of Climate Change in India. Research on climate change scenarios and socio-economic scenarios are being undertaken to provide basic assumptions on key impacts variables such as temperature increase, sea-level rise, precipitation, population and economic growth for the time periods 2020, 2050, and 2080. Also impacts of climate change on sea level variability; water availability and quality; forests; agriculture; health; and energy. industry and transport infrastructure.

New Zealand - National Institute of Water & Atmospheric Research (NIWA)

Established in 1992 as one of nine New Zealand Crown Research Institutes (CRIs), NIWA's aim is to provide a scientific basis for the sustainable management and development of New Zealand's atmospheric, marine and freshwater systems and associated resources. The CLIMPACTS program is jointly led by the University of Waikato and NIWA, in collaboration with AgResearch, Crop and Food Research, HortResearch, Landcare and the University of Auckland. The program aims to provide methods and results that can serve as a basis for improved decision-making and management for environmental protection and sustainable resource use in New Zealand. Through the development and coupling of models and data sets concerning climate, agriculture, horticulture, grasslands and soils, this program is unique in providing the capacity for integrated assessments of the effects of climate variability and change at site-specific, regional and national scales. In the current phase of work the program focuses specifically on: (i) short-term trends in climate variability and extremes; (ii) impacts on water resources; (iii) agricultural pests and diseases, (iv) the human dimensions of environmental change; and (v) software tools that are easily accessible to end-users

Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam

The Institute for Environmental Studies (IVM) is the oldest environmental research institute in the Netherlands. Its purpose is to contribute to sustainable development and the rehabilitation and preservation of the environment through academic research and education. IVM addresses environmental problems and offers solutions. IVM has been contracted to manage the Netherlands Climate Change Studies Assistance Programme (NCCSAP) in co-operation with the Netherlands Coastal Zone Management Centre (CZMC). IVM supervises the studies related to emission inventories, mitigation, and impact and adaptation regarding agriculture and forestry, focusing on Bhutan, Bolivia, Ghana, Mali, Senegal, Yemen, Kazakhstan, Mongolia, and Zimbabwe, as well as coordinating the activities related to these issues between countries. The CZMC on the other hand has supervised the activities in most countries that have a coastal zone study as the main part of the climate studies, namely Costa Rica, Ecuador and Surinam. It also coordinated the coastal zone and water resources studies across countries.

United States Department of Agriculture (USDA)

USDA-sponsored research continues to support long-term studies to improve understanding of the roles that terrestrial systems play in influencing climate change and the potential effects of global change (including water balance, atmospheric deposition, vegetative quality, and UV-B radiation) on food, and forestry production in agricultural, forest, and range ecosystems. Hydrological changes are likely to lead to an increase in the overall acreage under irrigation. If so, this is likely to exacerbate current overdraft and groundwater quality problems in many regions of the West. By way of contrast, other agriculture regions may need to adapt to an increased risk of severe flooding. USDA has commissioned a great number of studies and a considerable amount of work is ongoing.

5.2 Forestry

Studies show that a projected 2°C warming could shift the ideal range for many North American forest species by about 300 km to the north. If the climate changes slowly enough, warmer temperatures may enable the trees to colonize north into areas that are currently too cold, at about the same rate as southern areas became too hot and dry for the species to survive. However, growth to the north depends crucially how seeds spread. Trees whose seeds are spread by birds may be able to spread at that rate. But neither trees whose seeds are carried by the wind, nor such nut-bearing trees such as oaks, are likely to spread by more than a few hundred feet per year. Poor soils may also limit the rate at which tree species can spread north. Thus, the range over which a particular species is found may tend to be squeezed as southern areas become inhospitably hot. The net result is that some forests may tend to have a less diverse mix of tree species (EPA, 2002b).

On the positive side, CO_2 has a beneficial fertilization effect on plants, and also enables plants to use water more efficiently. On the negative side, forest fires are likely to become more frequent and severe if soils become drier. Changes in pest populations could further increase the stress on forests. Managed forests may tend to be less vulnerable than unmanaged forests, because the managers will be able to shift to tree species appropriate for the warmer climate. Perhaps the most important complicating factor is uncertainty whether particular regions will become wetter or drier. If climate becomes wetter, then forests are likely to expand toward rangelands and other areas that are dry today; if climate becomes drier, then forests will retreat away from those areas (EPA, 2002b).

UNEP - World Conservation Monitoring Centre (WCMC)

The UNEP- WCMCs Biodiversity and Climate Change Programme ‘Forests in Flux’ Project is investigating global synthesis of the likely impacts of climate change on forest distribution and integrity, as described in the Research on Impacts of Climate Change on Ecosystems and there Functions, in the Mid latitude regions. Initial stages of this work have gathered all known published data addressing this subject to produce a global summary. Further phases of the same project will combine the forest cover data held at WCMC with Global Climate Models. The findings will enable better prediction of the

impacts on the world's forests and enable the development of recommendations for changes in forest policy and management issues.

World Bank

The World Bank's Climate Change Team is located within the Environment Department and is part of the Bank's Environmentally and Socially Sustainable Network. The Climate Change Team provides resources and expertise for the World Bank's participation in international climate change negotiations under the United Nations Framework Convention on Climate Change (UNFCCC), and provides technical advice to the World Bank's Global Environment Facility Programme on the preparation of GEF climate change mitigation projects in energy efficiency and renewable energy and on development of strategic initiatives with the GEF. The Team also is leading the Bank's efforts related to climate change vulnerability and adaptation issues for its client countries, and coordinates these efforts with the Bank's Disaster Management Facility.

Current ongoing studies are a forestry sector study for Argentina, focusing on the carbon sequestration potential of different forest management and afforestation options. This research, supported by the World Bank is led by a team at Universidad Nacional Autonoma de Mexico (UNAM), under the auspices of the World Bank and the Instituto Nacional de Ecologia.

World Conservation Union (IUCN)

IUCN has a program area 'Forests'. The Kyoto Protocol to the Climate Change Convention could create powerful new incentives for forest activities to enhance carbon sequestration in industrialized countries, and possibly even developing countries. The Initiative and the Forest Conservation Programme are developing a joint program to maintain and restore forest ecosystems in order to respond to climate change. An in-depth analysis of the key issues relevant to climate change and forests is included in an IUCN paper entitled 'Climate Change and Forests'. IUCN has also produced an information paper on how best to balance climate change, biodiversity, and social objectives in the implementation of the forest-related provisions of the UNFCCC and its Kyoto Protocol. The maintenance and, where necessary, restoration of forest ecosystems to promote the conservation and sustainable management of forests, and equitable distribution of a wide range of forest goods and services. Recently, IUCN completed a report on climate change and forestry issues (WRI/IUCN, 2002).

Canadian Atlantic Forestry Centre (AFC)

AFC is one of the five Canadian Forest Services research centers. It plays a vital role in regional and national forestry research programs. Research in this area focuses on: (i) determining and assessing the sensitivity of Canadian forests to climate change; (ii) determining and assessing the contribution of Canadian forests and their management to the carbon cycle; and (iii) understanding, predicting, and assessing changes in ecosystem functioning and changes in disturbance regimes related to fire, insects, and diseases (this involves the ability to identify the rate, magnitude, and location of possible impacts).

Canadian CIARN Forest Sector

C-CIARN Forest sector undertakes a verity of projects. In 2000, a large study was initiated on Climate Change Impacts on the Productivity and Health of Aspen (CIPHA). The CIPHA study involves a network of 150 research plots in 25 climatically sensitive areas across western Canada, where the health of aspen forests is assessed every year. Trembling aspen is a commercially important species of poplar that is dominant over large areas of the Canadian boreal forest. Since the early 1980s, however crown die back and reduced growth of aspen have been noted in some areas of the prairie provinces, especially following drought and multiple-year defoliation by the forest tent caterpillar. The research results from the Boreal Ecosystem-Atmosphere Study (BOREAS) showed that during the summer, aspen forests release nearly twice as much water vapor but only about half as much heat into the atmosphere as adjacent coniferous forests. Thus, aspen forests appear to be acting as "giant humidifiers" on the landscape. It is, therefore, not just a question of how climate change may affect forests: changes in our forests will also affect the rate at which climate change occurs.

5.3 Fisheries

Global warming could have many impacts on fish and other aquatic species. Some bodies of water may become too warm for the fish that currently inhabit those areas; but warmer temperatures may also enable fish in cold ocean waters to grow more rapidly. Global warming may also change the chemical composition of the water that fish inhabit: the amount of oxygen in the water may decline, while pollution and salinity levels may increase. Loss of wetlands could diminish habitat and alter the availability of food for some fish species. Scientists have examined the implications for three types of fisheries: (1) inland freshwater fisheries found in non-tidal rivers, lakes, and streams; (2) coastal fisheries, which extend from tidal freshwater rivers, to estuaries, to coastal ocean fisheries; and (3) deep ocean fisheries (EPA, 2002c).

Regarding inland fisheries, higher water temperatures may have the most important implications. Like plants and birds, most species of fish tolerate — and many require — winter cooling and summer warming by tens of degrees. For coastal fisheries, wetland loss, salinity changes, and higher temperatures are all likely to affect finfish and shellfish in the coastal zone. The most vulnerable species are those that either reproduce in coastal wetlands, spend their entire lifetimes in an estuary, or both. Regarding ocean fisheries, scientists generally expect fish on the high seas to be less affected by global warming than coastal and inland fisheries (EPA, 2002c).

FAO

In 2001 The FAO produced a technical paper titled: Climate change and long-term fluctuations of commercial catches: the possibility of forecasting. The main objective of this study was to develop a predictive model based on the observable correlation between well-known climate indices and fish production, and forecast the dynamics of the main commercial fish stocks for 5–15 years ahead. The report forecast the long-term fluctuations of catches of the 12 major commercial species for up to 30 years ahead. According to model calculations, total catch of Atlantic and Pacific herring, Atlantic cod, South African sardine, and Peruvian and Japanese anchovy for the period 2000–

2015 will increase by approximately two million tons, and will then decrease. During the same period, total catch of Japanese, Peruvian, Californian and European sardine, Pacific salmon, Alaska pollock and Chilean jack mackerel is predicted to decrease by about 4 million tons, and then increase. The probable scenario of climate and biota changes for next 50-60 years is considered.

UNEP-World Conservation Monitoring Centre (WCMC)

WCMC has a Changing Oceans Project which looks at various impacts of Climate Change on the ocean including: (i) the physical and chemical effects of climate change - the build up of greenhouse gases is causing a rise in air and sea temperatures; (ii) physical effects of ozone depletion and enhanced ultraviolet radiation; (iii) effects on biodiversity - the impacts of climate change and ozone depletion on marine life in the oceans are likely to be seen right through the complex food web; and (iv) effects on important ecosystems.

UNESCO Global Ocean Observation System Programme (GOOS)

GOOS is part of an Integrated Global Observing Strategy (IGOS) in which the UN agencies (UNESCO and its IOC; WMO, UNEP, and FAO) are working together and with ICSU and the satellite agencies (via the Committee on Earth Observation Satellites - CEOS). GOOS will provide accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future conditions of the sea for as far ahead as possible; and the basis for forecasts of climate change. The ultimate goal of Coastal GOOS is to encourage and support the development and application of now-casting, forecasting and predictive capabilities as a means of preserving healthy coastal environments, promoting sustainable uses of coastal resources, mitigating coastal hazards, and ensuring safe and efficient marine operations.

World Meteorological Organization (WMO)

WMO's Marine Meteorology and Oceanography Programme coordinates and manages the implementation of an operational ocean observing system in support of the Global Ocean Observing system (GOOS) and the Global Climate Observing system (GCOS). The joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) is the result of the recognition of the increasing demand for integrated marine meteorological and oceanographic data and services, and the efficiencies that may be achieved by combining the expertise and technological capabilities of the WMO and IOC systems.

Canadian CIARN Fisheries

C-CIARN Fisheries is the fisheries sector of the Canadian Climate Impacts and Adaptation Research Network (C-CIARN). The mandate of C-CIARN Fisheries is to establish a network of researchers and stakeholders, facilitate research, and help to provide an independent voice and visibility to climate impacts and adaptation issues. Research is carried out from The Pacific Biological Station on Vancouver Island. C-CIARN Fisheries hosted the Impact and Adaptation Responses of Fish and Fisheries to

Climate Change Workshop January 5th and 6th, 2003. Proceedings of which will come out shortly.

US - Global Ocean Ecosystems Dynamics (GLOBEC)

GLOBEC is a multi-disciplinary research program designed by oceanographers, fishery scientists, and marine ecologists to examine the potential impact of global climate change on ocean ecosystems. U.S. GLOBEC is a component of the U.S. Global Change Research Program and is linked to worldwide research on this topic through the International GLOBEC Program U.S.GLOBEC researchers are developing and applying computer models of the physics and biology of the seas, conducting studies of key processes to be included in these models, undertaking large-scale observational programs using advanced observational systems, and extracting new information from long-standing programs and data sets. The U.S. GLOBEC program currently comprises four principal study sites selected to cover a range of system types, including: (i) An offshore shoal with retentive circulation (Georges Bank); (ii) An up welling region (California Current off Oregon and Northern California); (iii) A down welling system strongly affected by winds and freshwater inputs from land (Coastal Gulf of Alaska), and (iv) An ice-dominated system (the West Antarctic Peninsula region).

6. Research on Impacts of Climate Change on the Economy and Human Society

Climate change can impact the economy and human society in a variety of ways. For example, through impacts on ecosystems, e.g. coral reefs (Section 3) and through impacts on agriculture, forestry and fisheries (Section 4). The loss of ecosystems such as coral reefs, tropical or boreal forests, or prime agricultural land would be disastrous for many communities whose sole livelihood dependence may relies on such natural systems. Climatic change may cause damage physical to infrastructure such as coastal roads, ports, jetties, coastal resorts and towns, having knock on effects on local economies due to losses in revenues of industry affected by the damage i.e. tourism. The cost of repair and maintenance to coastal and river defenses are extremely high and often too great to warrant. Rivers and seas flooding low-lying areas may cause migration of towns and the people that live within them, creating overcrowding of dwellings in higher altitudes. Increases in the frequency of hurricanes, storms and regional flooding may lead to increases in health risks, as disease may reach epidemic status after national disasters. Fresh water scarcity may become one of the biggest social problems associated with climate change in the world, as aquifers and wells dry up and fresh water systems become polluted though saltwater intrusion.

The International Human Dimensions Programme on Global Environmental Change (IHDP)

IHDP is an NGO research body. IHDP was initially launched in 1990 by the International Social Science Council (ISSC) as the Human Dimensions Programme (HDP). In February 1996, the International Council for Science (ICSU) joined ISSC as co-sponsor of the Programme. The programs main research question is how does global

environmental change feed back into daily social, economic and political situations? Research includes: (i) Land-use and land cover change where links between land-use and land-cover change and other critical climate change issues are researched; (ii) Global Environmental Change and Human Security (GECHS), with the core question of how environmental change threatens human security; and (iii) Institutional Dimensions of Global Environmental Change (IDGEC).

WMO - World Climate Programme (WCP)

The World Meteorological Organization (WMO)'s World Climate Programme (WCP) is an authoritative international scientific program whose goals are to improve understanding of the climate system and to apply that understanding for the benefit of societies coping with climate variability and change. One of the four components of the WCP is the World Climate Impact Assessment and Response Strategies Programme (WCIRP). Its aim is to assess the impacts of climate variability and changes that could markedly affect economic or social activities and advise governments thereon, and contribute to the development of a range of socio-economic response strategies that could be used by governments and the community. Additionally, WMO provides through its Public Weather Services Programme meteorological and hydrological support for both relief missions and for sustainable development humanitarian projects. Its main purpose is to assist the national Meteorological and Hydrological Services to provide comprehensive and reliable weather and related services to the public in support of safety of life and property and the general welfare and convenience of the people. Also, the Tropical Cyclone Programme is a part of WMO's World Weather Watch Applications Department tasked to establish national and regionally coordinated systems to ensure that the loss of life and damage caused by tropical cyclones are reduced to a minimum.

World Bank

The Bank focuses on reducing present day climate vulnerability through the implementation of "no regrets" measures and closer coordination with its Disaster Management Facility (DMF). The World Bank is currently in the process of developing internal and client capacity to perform vulnerability assessments, assist regional institutions in forecasting impacts, elevate awareness of long term consequences, and mobilize additional financing for responding to climate vulnerability challenges. The Disaster Management Facility (DMF) aims to reduce human suffering and economic losses caused by natural and technological disasters. We do this by helping the World Bank provide a more strategic and rapid response to disasters, and promoting the integration of disaster prevention and mitigation efforts into the range of development activities.

Besides, the World Bank is carrying out a number of economic studies, both through Global Overlays with economic components as well as socio-economic impact studies such as a recent one for Pacific Islands.

Australia - Commonwealth Scientific and Industrial Research Organisation (CSIRO)

The Australian CSIRO is one of the world's largest and most diverse scientific global research organizations CSIRO contains an Adaptation Working Group (IAWG), a component of the CSIRO Climate and Atmosphere sector. Work undertaken includes regional assessments of the impacts of - and development of strategies to address - climate change, global change and climatic variability. For example, the working group may be involved in an integrated study of global change in one of the catchments identified by the Land and Water Sector. Another example is vertically integrated, industry-wide assessments. For example, it is within the scope of the working group to address the question of how climate change might affect Australia's meat export trade.

Canadian CIARN - Climate Change and Health

The Canadian Climate Impact and Adaptation Research Network (C-CIARN) is a national Canadian network that facilitates the generation of new climate change knowledge by bringing researchers together with decision-makers from industry, governments, and non-government organizations to address key issues. C-CIARN has a Climate Change and Health department, working towards the health and well-being of Canadians, scientists across Canada are working to advance the knowledge on the impacts of climate change on human health, and how the public health sector can begin planning for adaptation, upcoming events In May 2003, the Université du Québec in Montreal (UQAM) is hosting the International Forum on Ecosystem Approaches to Human Health.

Germany - Centre for Marine and Climate Research (ZMK), Hamburg

The Centre for Marine and Climate Research (ZMK) at the Departments of Geosciences and Economics, Hamburg University aims to create multi-disciplinary research and education program, on human-induced environmental change that is either global in nature or pervasive across the world. Current research foci are the economics of climate change and marine resources. Work undertaken at ZMK is often a collaboration with the following institutions, including the following research: (i) The Centre for Integrated Study of the Human Dimensions of Global Change (CIS of HDGC) at Carnegie Mellon University, Pittsburgh, PA. The CIS of HDGC develops and applies integrated assessment techniques to various aspects of global change, emphasizing its social, economic and political dimensions; (ii) The European Climate Forum (ECF) is an industry-sponsored network led by the Potsdam Institute for Climate Impact Research (PIK) and (iii) The Hamburg Environmental Resource Conflict Unit for Law, Economics and Science (HERCULES). It studies conflicts between stakeholders over environmental and natural resources in the context of global change.

Germany - Max Planck Institute for Meteorology - Global Environment and Society (GES) Research Group

The interdisciplinary Working Group Global Environment and Society (GES) investigates the socio-economic aspects of anthropogenic climate change. The aim is to establish a systemic linkage between the different world perspectives of the natural and social sciences and between their respective model worlds. Thereby the working group

try to examine consequences for the society and the economy from demands that are addressed to them in order to save the environment. The major aim is to assess climate protection policies under the condition of future economic growth to further societal welfare as well as the surrounding environment. GES have developed SDEM (Structural Dynamical Economic Model). The general objective is: Development of a coupled environment - socio-economic model for a better understanding of the complex interrelations between the environment and socio-economics.

Germany - Potsdam Institute for Climate Impact Research (PIK)

PIK undertakes global change and earth system analysis, including research into socio-economic causes of global change. At PIK, climate impact studies on the global scale are being conducted in several research areas, such as climate and ocean, biosphere, social and economic systems, for example research into how climate a protection program is highly dependent on economic decisions by politicians, multi-national companies or the financial market. The Global water Resources Modelling and Management (GLOREM) project, GLOREM, aims at global scale modeling and assessment of water availability and demand. The project was instigated as a result of population growth, the overall increase in water consumption and climate change, causing water stress. In its pilot stage, GLOREM is currently evaluating existing approaches and developing a detailed concept and research strategy. The EU-funded project DINAS-COAST (Dynamic and Interactive Assessment of National, Regional and Global Vulnerability of Coastal Zones to Climate Change and Sea-Level Rise) is developing an integrated assessment model that allows for the consistent evaluation of coastal impacts and adaptation at national, regional and global scales, required to satisfy current information needs for international climate policy.

India - Centre for Global Environment Research Tata: Energy Research Institute (TERI)

The impetus for establishing the Centre was provided in 1989, when TERI, a department within the institute took the lead in formulating a developing country perspective on climate change. The aim of the Centre is to undertake research and outline policy initiatives to promote effective and equitable solutions to global environmental challenges, taking into account the concerns of developing countries. Projects have included vulnerability and adaptation to climate change and economic changes in Indian agriculture.

Norway - Centre for International Climate and Environmental Research (CICERO)

CICERO founded by the Norwegian government in 1990, is an independent research centre associated with the University of Oslo. CICERO's mandate is twofold: to conduct research and provide information about issues of climate change. CICERO's three main areas of research are (1) impacts of climate changes and climate policy, (2) design of, implementation of, and compliance with climate policy instruments, and (3) integrated assessment, that is, the relationship between climate, other environmental issues and development. CICERO under takes a variety of global wide projects, current research includes, climate change vulnerability in Norway, investigating socio-

economic perspectives on policies and impacts. Economic change and climate vulnerability in Southern Africa, using case studies in Namibia, Tanzania and Mozambique.

Sweden - Stockholm Environment Institute (SEI)

SEI's Climate and Energy Programme addresses climate change problems in collaboration with a global network of partners, enabling work in locally-defined interests and resources in Africa, Asia, Europe and Latin America. The geographical scope ranges from local village-scale activities, to regional initiatives, to national analyses, to global regimes. SEI's projects include solving socio-economic management issues associated with climate change.

UK - Centre for Social and Economic Research on the Global Environment (CSERGE), University of East Anglia/University College London

CSERGE undertakes policy relevant interdisciplinary research on environmental issues including climate change. Themes include: (i) new indicators of vulnerability and adaptive capacity (Interdisciplinary approach to provide national level robust indicators of vulnerability to climate change); (ii) use of economic, social and institutional variables to provide a comprehensive account of sensitivity and adaptive capacity at the national for various countries.

Projects include the Justice in Adaptation to Climate Change program, which aims to analyse international environmental law on adaptation to identify its strengths, weaknesses and gaps from a justice point of view. The framework will also be applied to case studies on Tuvalu as a small island state; Bangladesh as an Asian Least Developed Country with low-lying coastal area, and Tanzania as a Least Developed Country in Africa. The results will shed light on justice issues in planning, financing and implementation of adaptation projects in developing countries vulnerable to climate change due to lack of wealth, education, skills and infrastructure. The results will be disseminated through direct input to adaptation projects, links with NGOs and negotiators in developing countries.

UK Climate Impacts Programme (UKCIP)

UKCIP helps organizations assess how they might be affected by climate change, so they can prepare for its impact. Set up by the UK Government in April 1997, UKCIP is funded by Defra and based at the University of Oxford. UKCIP aims to co-ordinate and integrate an assessment of the impacts of climate change at a regional and national level that is led by stakeholders. This means that stakeholders or partners commission the research and determine the research agenda, ensuring that it meets their needs. UKCIP provides support and guidance throughout the process for both stakeholders and the researchers, so providing a bridge between the researchers and the decision-makers in government organizations and business.

Areas of research have included: (i) Implications of climate-induced changes in marine biodiversity on society, commercial and non-commercial interests; and (ii) Impacts of climate change on environment, transport and utilities in the UK in the 21st century.

UK - Climatic Research Unit, University of East Anglia

The climate Research Unit has undertook a unique study on how climate change will impact on tourism. Climate change will impact upon tourism, which in turn impacts (through growing GHG emissions and associated environmental changes) on the climate. The effects and impacts of these complex interactions have to date not attracted either research effort nor gained the attention of stakeholders and policy makers. The CRU has undertaken sustainable response strategies for ten regions including Maldives, Europe, Africa, and Australia. The CRU has undertaken several research projects recently including the Impacts of climate change on the built environment in the UK. An international research project to investigate the effects of desertification on land use, and hence on economies and societies, in Mediterranean Europe. The Wise Project. (Weather Impacts on natural, Social and Economic systems) Performed empirical studies of the impacts of climatic variability, in particular hot summers, warm winters and wind storms, on natural, social and economic systems in Europe.

UK - International Institute for Environment and Development (IIED)

International Institute for Environment and Development (IIED) set up a Climate Change Programme (CCP) in February 2001. The overall goal of the program is to enhance understanding of the linkages between sustainable development and climate change. The objective of the programs are among others to improve the understanding of climate change impacts for poor developing countries including both policy makers and poor groups.

UK - Tyndall Centre, University of East Anglia.

The Tyndall Centres head quarters, based at the university of East Anglia develops sustainable responses to climate change. The Centre's research into adaptation to climate change is assessing how people and the environment can adapt to unavoidable changes in climate, whether gradual and continuous or abrupt and extreme. Most discussions about climate change focus on gradual changes in average climate conditions. Researchers in this theme are analyzing the vulnerability of organizations, ecosystems and countries to gradual and extreme changes in climate, and their ability to adapt. They will develop scenarios that take into account extremes, uncertainties and abrupt changes to provide analysis tools that assist decision-makers. They are also investigating critical thresholds beyond which it will be hard to adapt, such as those related to abrupt changes in the thermo-haline ocean circulation or the melting of polar ice sheets. The costs and benefits of adapting to climate change will be considered in the light of uncertainty and timing of adaptive measures. Climate change will have different impacts on various parts of society, so researchers at the centre are also investigating questions of justice and equity.

US - National Centre for Atmospheric Research (NCAR)

The Environmental and Societal Impacts Group (ESIG) is one of the nine divisions at the (NCAR) managed by the University Corporation for Atmospheric Research. Areas of work include an integrated assessment of the impacts of climate variability on the Alaskan north slope coastal region, the project generates a range of scenarios for changing sea ice variability, extreme weather events, storm surges, flooding and coastal

erosion, and other environmental factors. These scenarios can be used to predict the probability of stated that affect marine mammals, transportation and offshore resource development.

US - Global Change Research Program (USGCRP)

USGCRP supported research on human contributions and responses to global change is relevant to each of the other research program elements. The current focus of such research is on improving understanding of the potential effects of global change on human health; human forcing of the climate system, of land use, and other global environmental change; science-based regional and sectoral assessments that accurately reflect the limits of current understanding; decision support under conditions of complexity and uncertainty; and integrated assessment methods.

7. Research Gaps and Concluding Remarks

Based on the survey in the Sections above, and based on discussions with experts and IPCC (2001) and UNFCCC (2002), the following gaps were identified:

- Much of the climate change predictions made are gradual, continuous changes. A science that focuses on discontinuities (tipping points, thresholds, etc.) rather than mean changes and gradual response curves is only developing slowly.
- Climate change research has focused on a one century time scale. Very little attention has been paid to the evolution of climatic risks over the next 20 years. Climate change scenarios are distinct from present risk (control runs are very poor surrogates for present climate experience) and a 3-10 year time scale of climate prediction remains difficult. Yet, this remains the relevant time scale for policy making, vulnerability assessment and the like.
- Climate change impact research in developing countries is hindered by the virtual absence of good long-term data. Monitoring programs are needed in a variety of areas, such as land-use, ecosystem data, socio-economics, etc.
- Most work in agriculture and fisheries focuses on middle latitude issues. However, in developing countries, the issue of food security should not be neglected.
- Most research has been sectoral, yet there is the need to focus on the interactions between different sectors in society;
- Most research has looked at impacts of one specific stressor, yet there is a need to further our understanding on the cumulative effects of multiple stresses and at different spatial scales;
- Relatively little work has been carried out on vulnerability and integrated risk assessment; Enhanced risks from climate change need to be seen in the light of existing risks, e.g. flooding, hurricanes, environmental, health, political, social, etc. Relevant profiles of vulnerability should be provided and integrated risk management

tools should be applied to identify and evaluate how best to cope with climate change related risks. This should also include economic risk assessment.

- Economic impacts has often focused an engineering approach, i.e. the economic loss was calculated as the loss in physical terms times the price based on a marginal analysis. Yet, actual losses need to be based on the total economic changes in terms of quantity and price in the various sectors based on induced changes in demand and supply, and trade, etc.
- Much research has focused on the impacts of climate change on ecosystems and natural resources. Yet, the impacts on humans in their livelihood systems (e.g. human access to natural resources) and other socio-economic linkages as a result of these changes are largely unknown. The social/cultural complexity, especially in developing countries in the context of climate change needs to be studied in depth, as well as issues of induced possible demographic shifts and land-use changes.
- Vulnerability impacts especially in developing countries need to focus more on impacts on poverty and on the poorest segments in society, given that so much of the aid flows focus on poverty alleviation. The research should address the question how climate change impacts poverty incidence, both rural and urban.
- Disasters linked to climate change can lead to economic and political instability, e.g. related to water scarcity exacerbated by climate change. Hardly any research has been done in this area thus far.
- Though not the focus of the survey here, major gaps exist in our understanding of climate change adaptation. In fact, in this area, much more policy relevant research is needed, for instance in preventing mal-adaptation and encouraging no-regret policies and measures.
- Health impacts of climate change, e.g. malaria outbreaks have only been studies in some areas in the world thus far.

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Appendix I. Climate Change Impact Research Groups

E = Ecosystem Research A = Agriculture Research S = Socio-economic Research

International

Asian-Pacific Network on Global Change Research (APN)

http://www.apn.gr.jp/ E A

The APN is an inter-governmental network of 21 member states for the promotion of global change research and links between science and policy making in the Asia-Pacific Region.

Assessments of Impacts and Adaptations To Climate Change (AIACC)

http://www.start.org/Projects/AIACC_Project/aiacc.html A S

AIACC is a global initiative developed in collaboration with the IPCC AIACC is implemented by the UNEP and executed jointly by START and the Third World Academy of Sciences (TWAS). The majority of AIACCs involve research into climate change and its effect on agriculture in developing nations.

Caribbean Marine Research Centre (CMRC)

http://www.cmrc.org/ E

The CMRC was created in 1984 to address the issues associated with environmental degradation, etc. The CMRC currently is involved with research into coral bleaching in the greater Caribbean region.

Coral Reef Degradation in the Indian Ocean (CORDIO) E A S

http://www.cordio.org/

CORDIO is a programme created to research the impacts of the 1998 coral bleaching event. It is supported by Swedish International Development Cooperation Agency (Sida) , the World Bank, and others. CORDIO carried out research into the bio-physical and socio economic effects of climate change and coral bleaching on reef fisheries.

EU - Arctic and Alpine Terrestrial Ecosystems Research Initiative (ARTERI)

http://medias.obs-mip.fr/ricamare/interface/projet/arteri.html E

The EU Concerted ARTERI programme it is a component of the Terrestrial Eco-system Research Initiative (TERI), designed to improve the ability to predict the consequences of the inter-active effects of changes in land-use, climate, composition on terrestrial eco-systems

Food and Agricultural Organization (FAO)

http://www.fao.org/ E A

The Food and Agriculture Organization (FAO) of the United Nations was founded in 1945. The FAO supports the Global Terrestrial Observation System (GTOS) Programme, and is involved in agriculture and fisheries management and conservation.

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

http://www.start.org/ E A

START is a non-governmental, non-profit organization that seeks to establish and foster regional networks of collaborating scientists and institutions in developing countries. START is co-sponsored by the IGBP, the IHDP, the WCRP and the IGBP. Cross cutting themes include Climate Protection and Agriculture (CLIMAG).

Global Ocean Observing System (GOOS)

http://www-ocean.tamu.edu/GOOS/goos.html A

UNESCO houses the Global Ocean Observation System Programme (GOOS). GOOS' aim is to provide accurate descriptions of the state of the oceans, including climate change.

Inter-American Institute for Global Change Research (IAI)

http://www.iai.int/ E

The IAI is an intergovernmental organisation with the aim of increasing the understanding of climate change. Projects include research based on the climatic change effects on natural systems in developing Latin American nations.

Intergovernmental Panel on Climate Change (IPCC)

http://www.ipcc.ch/ E A S

The IPCC was established in 1988 by the WMO and the UNEP. It is open to all members of the UN and WMO. IPCC has been set up to assess scientific, technical and socio- economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation. Its 3rd Assessment Report came out in 2001.

International Human Dimensions Programme on Global Environmental Change (IHDP)

http://www.ihdp.uni-bonn.de/index.html S

IHDP is an international, interdisciplinary and non-governmental research programme, aiming research at the development and integration of research on the human dimensions of global environmental change.

International Institute for Applied Systems Analysis (IIASA)

http://www.iiasa.ac.at/ A

IIASA is an Austrian non-governmental research organization. The institute conducts inter-disciplinary scientific studies on environmental, economic, technological and social issues in the context of human dimensions of global change

Organisation for Economic Co-operation and Development (OECD)

http://www.oecd.org A S

OECD is an international organisation undertaking research based assistance to governments regarding the economic and social governance of a globalised economy. Sectorial policies undertaken by OECD include climate change and Agriculture and Forestry. OECD also has a Development and Climate Change Project.

Organization of American States (OAS)

http://www.oas.org/ E

The OAS is a subsidiary of the USDE, Climate Change and Coastal management is one of the organisations “Areas of Action”. The OAS has research and development projects concerning climate change in the Caribbean.

United Nations Development Programme (UNDP)

http://www.undp.org/ E A S

The UNDP is one of the implementing agencies of the GEF. UNDP and GEF work on a comprehensive approach for developing country-level capacities needed for addressing challenges of global environmental action in areas of biodiversity, climate change, and land degradation.

United Nation Environment Programme (UNEP)

http://www.unep.org/ A S

The UNEP manages a “Vital Climate Graphics” system and The UNEP Collaborating Centre on Energy and Environment (UCCEE) Climate and Development Project. Besides, WCMC falls under UNEP and UNEP is one of the executing agencies of the GEF.

UNEP World Conservation Monitoring Centre (WCMC)

http://www.wcmc.org.uk/ E A

The UNEP World Conservation Monitoring Centre was established in 2000 as the world biodiversity information and assessment centre of UNEP. The Centre oversees the UNEP WCMC Biodiversity and Climate Change Programme.

World Bank

http://www.worldbank.org/ E A S

The World Bank operates and as an implementing agency of the Global Environmental Facility. The World Bank assists developing nations through donor funding for climate change development projects and through research and studies on global overlays, climate change impacts, etc.

World Climate Research Programme (WCRP)

http://www.wmo.ch/web/wcrp/prgs.htm S

The WCRP established in 1980, under the joint sponsorship of International Council for Science (ICSU) and the World Meteorological Organization (WMO), developments global climate models as fundamental tool for understanding and predicting natural climate variations and providing reliable estimates of anthropogenic climate change.

World Conservation Union (IUCN)

http://www.iucn.org/ E A

IUCN brings together States, government agencies and non-governmental organisations in a world partnership of over 980 members, spread across 140 countries. IUCN are involved with the UNFCCC and IPCC, and have created the 'Climate Change Initiative' in response to research concerning climate change and natural resources, conservation and biodiversity.

World Meteorological Organization (WMO)

http://www.wmo.ch/index-en.html E A S

The WMO coordinates global scientific activity to allow prompt and accurate weather information for public, private and commercial use. WMO is responsible for the maintenance of the International Geosphere-Biosphere Programme (IGBP), World Climate Programme (WCP) and the Marine Meteorology and Oceanography Programme.

National

Australia Commonwealth Scientific and Industrial Research Organisation (CSIRO)

http://www.csiro.au/index.asp S

The Australian CSIRO is one of the world's largest and most diverse scientific global research organisations. CSIRO contains an Adaptation Working Group (IAWG), a component of the CSIRO Climate and Atmosphere sector.

Canadian Atlantic Forestry Centre (AFC)

http://www.atl.cfs.nrcan.gc.ca/index-e/index-e.html A

The AFC is one of five Canadian Forest Services (CFS) research centres. It plays a vital role in regional and national forestry research programs. The CFS promotes the sustainable development of Canada's forests and competitiveness of the Canadian forest sector, including research into the effects of climate change on Canada's forest systems.

Canadian Climate Impacts and Adaptation Research Network (C-CIARN)

http://www.c-ciarn.ca/ E A S

C-CIARN is the Canadian national network that facilitates the generation of climate change knowledge. C-CIARN includes departments working in climate change research and its national effects on health, water resources, coastal zone management, forests, agriculture, landscape hazards and fisheries.

Canadian Institute for Climate Studies (CICS)

http://www.cics.uvic.ca/index.cgi E

The CICS is a not-for-profit Canadian corporation initiated by the Meteorological Service of Canada and the Province of British Columbia. CICS undertakes Management of climate related research and public education initiatives, amounst other climate related research.

Finnish Global Change Research Programme (FIGARE)

http://figare.utu.fi/ E

FIGARE is an independent research body supporting 36 research projects in the natural sciences, the social sciences, economics and technology with the objective to analyse and understand the changes taking place in the global system.

Germany - Potsdam Institute for Climate Impact Research (PIK) E A S

http://www.pik-potsdam.de/

PIK is a research institute, undertaking research into climate change on a global scale. Projects include the Global Water Resource Modelling and Management (GLOREM), the Advanced Terrestrial Ecosystem Assessment and Modelling (ATEAM) and Dynamic and Interactive Assessment of National, Regional and Global Vulnerability of Coastal Zones to Climate Change and Sea-Level Rise (DINAS-COAST).

Germany - Max Planck Institute for Meteorology (MPI-Met), Hamburg

http://www.mpimet.mpg.de/en/web/index.html E S

The MPI-Met based in Hamburg undertakes a system analysis of the Earth System dynamics with emphasis on the Earth Climate. Within MPI-Met interdisciplinary Working Group GES, investigates the socio-economic aspects of anthropogenic climate change.

Germany - Centre for Marine and Climate Research (ZMK), Hamburg

http://www.uni-hamburg.de/Wiss/FB/15/Sustainability/ S

The Research Unit of Sustainability and Global Change (Forschungsstelle Nachhaltige Umweltentwicklung) at the ZMK aims to create multi-disciplinary research and education program, on human-induced environmental change that is either global in nature or pervasive across the world.

Indo-UK Programme on Impacts of Climate Change in India

http://www.erm.com/ERM/Loc/erm_india.NSF A S

The Ministry of the Environment and Forest (MoEF), India and the UK Department of the Environment, Transport and the Regions (DETR), have joined forces on a three year joint research programme on the impacts of climate change in India.

Netherlands - Institute for Environmental Studies (IVM), Vrije Universiteit

http://130.37.129.100/ivm/index. html A S

The IVM in Amsterdam manages the Netherlands Climate Change Studies Assistance Programme (NCCSAP) in co-operation with the Netherlands Coastal Zone Management Centre (CZMC). IVM supervises studies related to emission inventories, mitigation, and impact and adaptation regarding agriculture and forestry in a number of developing countries.

New Zealand - National Institute of Water & Atmospheric Research (NIWA)

http://www.niwa.cri.nz E A S

The aim of the National Institute of Water & Atmospheric Research (NIWA) is to provide a scientific basis for sustainable management and development of New Zealand's atmospheric, marine and freshwater systems and associated resources. The CLIMPACTS programme is jointly led by the University of Waikato and NIWA, in collaboration with an number of other local research groups.

Nordic Arctic Research Programme (NARP)

http://thule.oulu.fi/narp/ E

The goal of the programme is to enhance Nordic competence by building scientific cooperation within selected subject areas, including climate change on artic biological and ecological systems.

Norway - Centre for International Climate and Environmental Research (CICERO)

http://www.cicero.uio.no/ S

CICERO an independent research centre associated with the University of Oslo has a twofold mandate conducting research and provide information about issues of climate change.

Sweden - Stockholm Environment Institute (SEI)

http://www.sei.se/ S

SEI is an independent, international research institute specialising in sustainable development and environment issues. SEI undertakes socio economic projects associated with climate change.

UK - British Antarctic Survey (BAS)

http://www.antarctica.ac.uk/ E

BAS is an institute of the Natural Environment Research Council, and has, for the last fifty years, undertaken the majority of Britain's scientific research on and around the Antarctic continent.

UK - Centre for Social and Economic Research on the Global Environment (CSERGE)

http://www.uea.ac.uk/env/cserge/ S

CSERGE, based at the University of East Anglia and University College London's research is based on interdisciplinary research on socio-economic issues related to climate change.

UK - Climatic Research Unit (CRU), University of East Anglia

http://www.cru.uea.ac.uk/ A S

The CRU undertakes studies of natural and anthropogenic climate change. The Unit has developed a number of the data sets widely used in climate research, including the global temperature record used to monitor the state of the climate system, as well as statistical software packages and climate models.

UK Climate Impacts Programme (UKCIP)

http://www.ukcip.org.uk/ S

UKCIP Co-ordinate and integrate research into the impacts of climate change. Research has included climate induced change in marine biodiversity on society and impacts of climate change on environment, transport and utilities in he UK.

UK - The Hadley Centre

E S

http://www.met-office.gov.uk

The Hadley Centre for climate prediction and research, part of the Met Office, provides a focus in the United Kingdom for the scientific issues associated with climate change. The Hadley Centre creates climate prediction models assuming future greenhouse gas emissions. Through LINK, it carries out impact analysis.

UK - International Institute for Environment and Development (IIED)

http://www.iied.org/climate_change/

International Institute for Environment and Development (IIED) set up a Climate Change Programme (CCP) in February 2001. The overall goal of the programme is to enhance understanding of the linkages between sustainable development and climate change.

UK - The Natural Resources Institute (NRI)

http://www.nri.org/ E S

The NRI is an internationally recognized multi-disciplinary centre for research, consultancy and education for the management of natural and human resources. The Institute currently has about 100 scientific, academic and technical staff, working in a wide range of disciplines in the natural and social sciences. Focus on Climate Change Issues.

US-The National Centre for Atmospheric Research (NCAR) S

http://www.ncar.ucar.edu/ncar/

NCAR established in 1960 to undertake research on atmospheric and related science problems, consists of nine divisions including the The Environmental and Societal Impacts Group (ESIG) is managed by the University Corporation for Atmospheric Research.

US - Pew Centre on Global Climate Change (PCGCC) E

http://www.pewclimate.org/

The PCGCC is a non-profit, independent organisation providing credible information, and innovative solutions in the effort to address global climate change. The centre carries out work on climate change and its effects on ecosystems, forest systems, and marine, coastal and aquatic habitat and systems.

US Department for Agriculture (USDA) E A

http://www.usda.gov/

The role of the USDA is multifaceted, conducting agricultural and economic research to assess and develop solutions to agricultural problems, amounst many other topics. The USDAs Forest Service Northern Global Change Program (NGCRP) undertakes research into multiple air pollutants and climate change on forest ecosystems.

US - Global Change Research Program (USGCRP) E A S

http://www.usgcrp.gov/

The USGCRP is a US governmental research programme supporting research on the interactions of natural and human-induced changes in the global environment and their implications for society, including the US National Assessment of Climate Change on Agriculture.

US - Global Ocean Ecosystems Dynamics (U.S. GLOBEC)

http://www.usglobec.org/welcome.html A

GLOBEC is a multi-disciplinary modelling research programme to examine the potential impact of global climate change on ocean ecosystems. Researchers are developing and applying computer models of the physics and biology of the seas.

US - National Aeronautics and Space Administration (NASA)

http://www.nasa.gov/ E A

NASA's Land Cover Land Use Change Program (LCLUC) Project is an interdisciplinary scientific theme within NASA's Earth Science Enterprise (ESE).The NASA Goddard Institute for Space Studies (GISS) carry out international research into social and economic costs of regional changes in variables such as crop yields and water availability.

US - National Oceanic and Atmospheric Administration (NOAA)

http://www.noaa.gov/ E S

NOAA has two programs related to the long term monitoring of climate change. The U.S. Climate Reference Network (USCRN) a network of climate stations to provide future long-term homogeneous observations of temperature and precipitation Tropical Atmosphere and Ocean project (TAO/TRITON) (see research on lower latitudes)