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INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

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INTEGRATING SUSTAINABLE DEVELOPMENT AND CLIMATE CHANGE IN THE IPCC FOURTH ASSESSMENT REPORT

Mohan Munasinghe
Osvaldo Canziani
Ogunlade Davidson
Bert Metz
Martin Parry
Mike Harrison

Editors

Published for the IPCC by

Munasinghe Institute for Development (MIND)
Colombo, Sri Lanka

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IPCC Secretariat
World Meteorological Organisation
7bis, Avenue de la Paix
C.P.No. 2300
1211 Geneva 2
Switzerland

Published for the IPCC by

Environment

MIND

Society

Economy

Munasinghe Institute for Development (MIND)
10 De Fonseka Place
Colombo 5
Sri Lanka

ISBN 0-86180-370-1

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Proceedings of the IPCC Expert Meeting held in Colombo, Sri Lanka
5-7 March 2003

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Supporting material prepared for consideration by the Intergovernmental Panel on Climate Change. It has not been subjected to the formal IPCC reviewing process. The expert meeting was a part of the agreed IPCC work plan associated with the preparation of the Fourth Assessment Report, but this does not imply working group or panel endorsement or approval of the material contained in this volume

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Intergovernmental Panel on Climate Change (IPCC)
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Internet: http://www.ipcc.ch

Manufactured in Sri Lanka
First printing July 2003

Integrating Sustainable Development and Climate Change in the IPCC Fourth Assessment Report
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IPCC Expert Meeting held in Colombo, Sri Lanka, 5-7 March 2003

Conference Organisation

IPCC Steering Committee

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Leo Meyer, Mohan Munasinghe (Chair), Martin Parry, Paul Van Der Linden

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Contents

Foreword

The subject of climate change and sustainable development goes far beyond issues of mere academic or scientific interest. Climate change would affect the lives of all citizens on planet earth, in both Annex I and non-Annex I countries, with the impacts on the poorest sections of society being the most severe. Sri Lanka has seen very recently the effect of low rainfall, which had negative impacts on agriculture and hydroelectric power generation. Climate change is likely to affect precipitation patterns in South Asia to such a serious extent that the countries of the region will have to set in motion certain adaptation measures that would require significant investments and actions involving a fairly long gestation period. The very fact that the effect of climate change on poor societies would tend to widen the gap between rich and poor and reduce the opportunities for the poor to improve their lives, strikes at the very root of sustainable development.

The Third Assessment Report of the IPCC did take into account the nexus between climate change and sustainable development and attempted to assess the linkages between these two. However, much more remains to be done in providing a comprehensive assessment of this nexus, and how it is likely to affect human civilization in the decades ahead. It is for this reason that the issue of sustainable development is going to be incorporated as a major cross cutting theme in the Fourth Assessment Report of the IPCC.

It is particularly significant that this important scoping meeting took place in Sri Lanka, because by every indicator of development, and by virtue of the endowment of natural resources in this beautiful island, Sri Lanka stands out as an excellent example of sustainable development and an embodiment of enlightened government policy and societal action. On behalf of the IPCC, I would like to compliment the efforts put in by my colleague, IPCC Vice Chair Prof. Mohan Munasinghe in the organization of this meeting. I would also like to convey my thanks to the Honorable Minister Karu Jayasuriya for gracing the occasion with his presence. I am sure the IPCC as a community would benefit greatly from the deliberations of this meeting.

R K Pachauri
Chair, IPCC

Acknowledgements

The editors would like to thank R. Pachauri, G. Love, R. Christ, other members of the IPCC Bureau, and the Technical Support Units of Working Groups II and III, for their advice and assistance. Invaluable help was provided by the IPCC steering committee, Sri Lanka organizing committee, and those involved in compiling and preparing these proceedings (listed earlier). We are most grateful also to the paper authors and discussants for their patience and cooperation, and to all the participants who reviewed papers and provided helpful comments. Thanks are extended to the IPCC, Sri Lanka Meteorological Department, and Munasinghe Institute for Development (MIND), who provided financial support for the expert meeting, and for editing and publishing this volume. Finally, the services rendered by the staff of these institutions are gratefully acknowledged.

PART A

I Editors Introduction

An IPCC Expert Meeting on Climate Change and Sustainable Development was held from 5 to 7 March, 2003, at the kind invitation of the Government of Sri Lanka, and hosted by MIND (The Munasinghe Institute for Development) at the Trans Asia Hotel, Colombo. The Meeting was co-organised by Working Groups II and III (WGII and WGIII) of the Intergovernmental Panel on Climate Change (IPCC), with MIND.

The Expert Meeting held in Colombo on Climate Change and Sustainable Development was the first of two expert meetings approved by the IPCC Plenary in Paris, in February 2003 (see Annex A for details). Sustainable development had been identified as a Cross Cutting Theme (CCT) for the Third Assessment Report (TAR), but was not developed fully therein. The Colombo Expert Meeting was held early, to enable the outcomes to inform the two IPCC Scoping Meetings (scheduled for May and September 2003), and to eventually provide guidance to the Lead Authors.

At the IPCC Plenary XX, Paris, February 2003, seven Cross Cutting Themes (CCTs) were approved as forming a fundamental aspect of the structure of the forthcoming Fourth Assessment Report (AR4). These themes are:

- Risk and Uncertainty
- Regional Integration
- Water
- Key Vulnerabilities including Article 2 issues
- Adaptation and Mitigation
- Sustainable Development
- Technology

The structure of IPCC AR4 will be primarily developed in two major Scoping Meetings, the second of which will have the Cross Cutting Themes as its major focus. Expert Meetings will be held as needed on these CCTs, to inform the Scoping Meetings.

Nineteen experts attended the Colombo Meeting, together with representatives of the IPCC and the two Working Groups (Annex B). Working Group I was represented by one expert. The Expert Meeting agenda is provided in Annex C.

The meeting was opened formally by Honourable Karu Jayasuriya, Minister of Power and Energy for Sri Lanka. In association with the Meeting, press briefings and a Public Forum addressed by IPCC WGII and WGIII Co-Chairs were held after the closure of the meeting, to inform the Sri Lankan public and decision makers on the issues of climate change and implications for Sri Lanka and the global economy as a whole.

Introductory presentations were made by invited speakers, covering many of the key aspects of sustainable development, including linkages both from and to climate change. Summaries of these presentations are provided in this section, while original powerpoint versions of the presentations are included in Part B of the volume.

Subsequently, three discussion groups were formed, each including representatives from both WGII and WGIII. By creating three discussion groups, a rather broader range of issues was addressed than would have been achieved through plenary discussion. This first set of discussion groups was asked to identify the critical issues and linkages relevant to climate change and sustainable development that might be addressed within the CCT. The task was not to assess the need for accommodation of each issue within the AR4 but to provide a background of issues to advise later stages of the process.

The results of each group were presented in plenary by rapporteurs and thoroughly discussed (see Annex D for details). Key issues identified through the process are summarised following this introductory text. Issues have been grouped under various umbrella headings (it is recommended that the individual discussion group reports be examined to provide the detailed backgrounds).

Based on the outcomes from the first three discussion groups, two further sets of discussion groups were formed for the remainder of the Meeting. Each of the latter was organised along IPCC Working Group lines, with the groups asked to develop concepts for the structure of the CCT within AR4. All discussion group results were presented and discussed in plenary. Rapporteurs' reports from the second and third round of discussion groups can be found in Annex E. To a certain extent reports from the first set of discussion groups strayed into the areas of the second and third sets of groups, and where this occurs, the relevant points are recorded in the summary for the subsequent groups. The main conclusions section below, provides a summary of the key issues identified.

II Inaugural Speech

Hon. Karu Jayasuriya, Minister of Power and Energy, Sri Lanka

We are all aware of how the growth of industry, agriculture and related human activities have interfered with complex natural systems such as the global climate. We are indebted to the scientists who initially discovered the link between emissions of greenhouse gases in the atmosphere and the change in temperature and weather patterns. Today the international community is fully aware of the problem and is cautious about the possible consequences of continued emissions of these gases.

The WMO and UNEP have acted timely by establishing the Intergovernmental Panel on Climate Change in 1988, which offers scientific, technical, and socio-economic information about climate change and the possible response options ranging from mitigation to adaptation. We must congratulate the IPCC for the wonderful work it has done so far, by producing 3 assessment reports, covering not only the technical aspects but also the policy and institutional aspects of climate change. I believe that the IPCC has a responsibility by mankind, to go beyond its mandated advisory role and commence an interactive process with the developed and developing countries with a view to finding possible solutions.

Most developing countries, such as Sri Lanka, remain vulnerable to ecological, economic and social impacts of climate change. In Sri Lanka, we have collected meteorological data for over 100 years and have noted an increasing trend in the annual mean temperature, particularly during the period 1960-2000.

Although Sri Lanka's contribution of greenhouse gases is microscopic compared to that of the developed world, we have decided to take certain mitigative measures as a move to support the international community in their endeavour to minimize the impacts of climate change. Our major thrust is in adaptation, and each development sector which has been affected by climate change has developed its own strategies.

Climate change and increased variability will have substantial implications on water resources and related activities including food, livelihood and environment. Evaluation of the exact nature of impacts needs further research. However, analysis of meteorological data, have pointed to decreases in rainfall patterns in the hill country, which serve as the catchments of all major rivers.

The impacts of droughts lead to the depletion of groundwater and decreased river flows during the dry periods. Saltwater intrusion and increases in groundwater salinity are problems related to climate change.

Our biggest concern with regard to climate change is in relation to food production. We have already experienced changes in our main cultivation seasons, mainly the maha and yala. Severe climatic variations make any agricultural planning difficult, particularly in the wet zone where most of the paddy fields are dependent on rain. The changes in the rainfall pattern also affect other vital elements of food security, covering other field crops and livestock. We are also concerned that changes in climate could affect our plantation crops, particularly, tea. The Tea Research Institute has already initiated some important research to cope with changes in climate. We are conscious that the changes in climate may also offer us new opportunities to develop new cropping systems.

In the forestry sector, there is concern that reduction in rainfall and increase in temperature will lead to retardation of forest growth, degradation, and changes in ecological zones. The forestry sector has developed a strategy to protect the existing natural forest cover in view of its biological, hydrological and ecological importance. Commercial reafforestation, and homestead development are expected to mitigate the impacts of climate change.

The largest concentration of population in Sri Lanka is along the coastal belt. Any loss of land due to sea erosion will have an adverse impact on human settlements. This also affects Sri Lanka's tourism potential, as Sri Lanka's beaches are among the major tourist attractions. Migration of coastal fish species due to increases in water temperature have led to adverse effects on the population dependent on fishing for their livelihood. More research needs to be undertaken to understand the capacity of both coastal and inland fishery resources to survive in changing climatic situations.

Changes in rainfall patterns have also led to scarcity of clean water for drinking and other domestic purposes. Stagnant water breeds mosquitoes that could lead to the spread of vector-borne diseases. The patterns of distribution of malaria with changes in climate have been studied by the health authorities, and it is anticipated that malaria transmission zones may shift to areas which are presently free of malaria.

In all the previously mentioned sectors, our strategy was more towards adaptation. An element of mitigation is being considered in the energy sector.

Sri Lanka's energy sources are primarily biomass (57.1%), petroleum (31.5%) and hydro (11.4%). With a higher demand for power, which comes with industrialization and better standards of living, a shift towards thermal energy is expected particularly because major hydropower sources have been fully tapped. All fossil based thermal generation depend on petroleum fuels as crude oil or as refined products. The main fuels used in power generation are furnace oil, residual oil and diesel.

An analysis of the fuels that emit Greenhouse Gases, reveal that the transport sector contributes the highest percentage. Petrol and auto diesel are the main fuels used for road transportation in Sri Lanka. Buses and trucks are the main diesel consumers. Approximately 75% of the vehicle fleet comprises of reconditioned vehicles, hence policies need to be primarily concentrated in the transport sector.

The concept of the sustainable development triangle consisting of economic, social and environmental dimensions was first prepared by Sri Lanka at the 1992 Rio Earth Summit. More recently, Sri Lanka has developed a national communication under the UNFCCC, which covers a wide area of climate change and sustainable development. It is not surprising therefore, that the government looked at the climate change issue in the context of sustainable development even before the international community saw the need to do so.

Many studies have already been done, by both government and independent organizations like the Munasinghe Institute for Development, which used analytical tools such as the Action Impact Matrix, to understand the linkages between climate change and the policies in development sectors. These studies have also pointed to the possible shifts in policy, in order to cope with the changes in climate. My own Ministry is exploring alternative energy sources, such as wind, solar, mini hydro's, not only because of cost effectiveness, but also in view of the reduction in Greenhouse Gas emissions.

We have prepared a Greenhouse Gas inventory and are studying the impacts and vulnerability, adaptation responses, mitigation options, and technological and research needs. We are eagerly waiting the outcome of this consultation in order to make appropriate adjustments in our approach to cope with climate change. I wish your deliberations all success.

III Main Conclusions

Key issues identified by the cross-Working Group discussion groups tasked to identify critical issues and linkages.

Justification

- To address the needs of a wider community and to engage them in the IPCC process
- To provide a structure within the AR4 appropriate to the needs of the wider community, in terms of both sectoral and specific themes
- To assist the wider community in moving towards decisions
- To provide input to a broader range of issues that relate to climate change but have not been addressed by the IPCC to date
- To provide links to international and national development programmes, such as Agenda 21, the Millennium Ecosystem Assessment, the Millennium Development Goals, work under the UNCSD, work under the OECD Environmental Strategy, and national development programmes
- To provide perspectives on various appropriate time scales as required for planning

Linkages

- There is a need to manage linkages in either direction (i.e. climate change to sustainable development as well as sustainable development to climate change). In practice these flows are more complex than indicated here. These complexities need to be incorporated into the report.
- The UNEP Global Environmental Outlook 3 (GEO-3) introduced a new approach based on scenarios of high relevance to sustainable development
- Connections to major development issues such as poverty reduction and equity are required
- Connections to major mitigation activities, including Kyoto mechanisms, are required
- Links to all other AR4 CCTs (as listed earlier), and their handling in a consistent manner, is desirable
- Normative issues will arise inevitably -- these should be handled in a sectoral manner
- Stronger linkages are necessary with activities managing current climate variability, in terms of adaptation, development and costs, as these are currently, in effect, handling climate change and will provide a basis for future adaptation practices
- Use of appropriate language to facilitate communication in all directions is needed

Cross cutting issues of sustainable development and climate change to be covered

- WEHAB provides an important basis and must be incorporated. However, the scope of sustainable development extends well beyond WEHAB *per se*
- Capacities need to change in order to manage transitions and allocate resources, both nationally and internationally
- Technology in all respects, including innovation and transfer
- Financial management in all respects, including development theory
- Governance and institutional mechanisms, including policy/experience aggregation

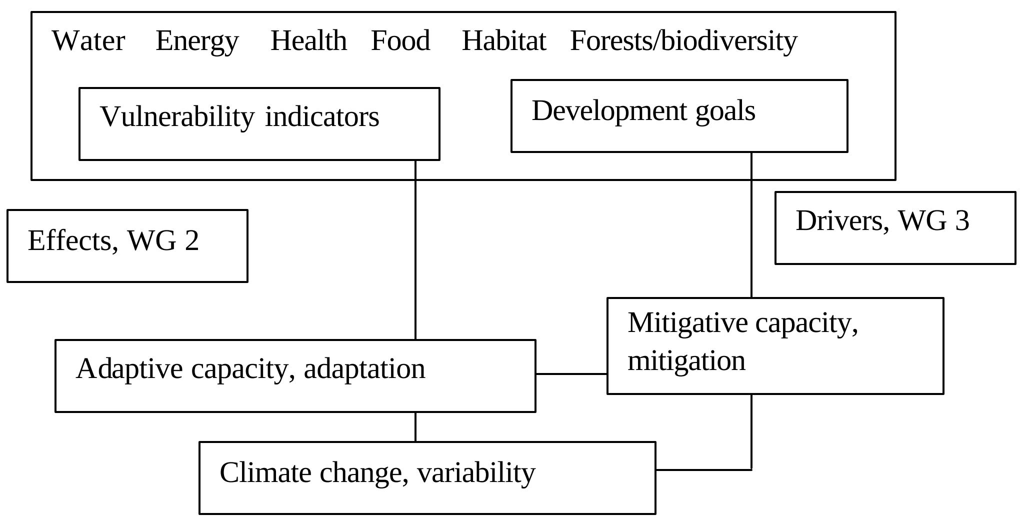
- Trade and globalisation
- Air quality
- National and international security
- Human settlements
- Transport
- Energy (accessibility, supply, affordability, impact on environment, investment returns)
- Ecosystems and biodiversity
- International and national disaster management
- Responses to changing per capita incomes
- Costs and implementation aspects, nationally, regionally and internationally
- Associations with adaptation and mitigation
- Synergies and efficiencies available in all contexts
- Risks and risk management with respect to all considerations

Key issues identified by the within-Working Group discussion groups tasked to develop concepts for the structure of sustainable development within the AR4.

- Linkages need to be established between sustainable development and climate change in both directions, with focus on "*making development more sustainable*" (including climate change concerns).
- The use of the widely-accepted Sustainable Development Triangle (consisting of three pillars -- economic, environmental and social), for structuring the information
- Analysis on four levels: policy processes (including macro aspects); sectoral level analysis; international contexts; integration/co-ordination with other CCTs
- Inclusion of a literature survey of sufficient breadth to cover all issues
- A need for a more comprehensive treatment of time scales than was provided in the TAR; while no specific recommendation was given consensus was towards a short-range period, perhaps out to 15 or 20 years, providing detail appropriate to most current planning activities, a second period perhaps to 50 years, giving less detail but sufficient for planning long-term investments, and a third with less detail again but extending out to such time as stabilisation might be achieved
- Analysing links between climate change strategy and broad national macroeconomic and sectoral policies – Action Impact Matrix (AIM) approach is useful.
- Use of WEHAB++, where WEHAB itself covers all issues appropriate to the sustenance of life while the ++ covers additional issues (i.e. goods and services) relevant to development and economic growth; items, which should be selected based on climate sensitivity and relevance to policy; '++' might include:
  - Habitat and settlements
  - Tourism
  - Air quality
  - Transport
  - Finance, insurance and industry
  - Disasters
  - Technology
  - Equity

- The WEHAB chapters could have a common template, suggested to cover patterns of climate-society interaction, consumption patterns, income generation and poverty, cross-sectoral issues, relationships to impacts/adaptation/mitigation
- Scenarios need to be addressed, as far as possible, in a consistent manner, both within the AR4 and across to other linked activities
- Given that the AR4 structure may be complex in dealing with all CCTs as well as an expanded range of issues, care must be taken to ensure that the structure supports the needs of all users. Options proposed include a) a system based on manageable items drawn together to support more than one CCT and b) a layered presentation
- Following suggestions made elsewhere, there was support for a separate document on regional issues alongside other main documents
- One structure proposed:

Modifications: think of "capacity" more broadly, no separation between adaptive and mitigative



Expertise needed amongst the authorship includes:

- *Domain expertise*
  - → Trade, investment and finance experts
  - → Innovation experts
  - → Sectoral development experts
- *Cross-cutting expertise*
  - → Sustainable development
  - → Institutions
  - → Governance
  - → Development economists
  - → Political economists
  - → Macro policy developers
  - → International relationships
  - → Legal experts
- *Climate Expertise*

- *Methodological expertise*
  - → Decision making
  - → Economics
  - → Risk management
  - → Political science
  - → Technology historians

IVSummaries of Invited Presentations in Session 1

1. CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT LINKAGES – POINTS OF DEPARTURE FROM THE IPCC TAR

Mohan Munasinghe

Chairman, Munasinghe Institute for Development (MIND), Colombo; and Vice Chair, Intergovernmental Panel on Climate Change, Geneva

This paper analyses key issues linking sustainable development and climate change, based on lessons from the TAR and post-TAR developments, using the sustainomics framework. Climate change and sustainable development interact in a circular fashion. Climate change vulnerability, impacts and adaptation will influence prospects for sustainable development, and in turn, alternative development paths will certainly determine emission levels that affect future climate change, and would have implications for mitigation strategies as well.

Many relevant findings which emerged form the IPCC TAR process are identified. They may be grouped into the following categories: (1) conceptual overview of linkages between climate change and sustainable development; (2) consequences of climate change impacts for sustainable development prospects, in various sectors, systems, and regions; (3) consequences of climate change response actions (mitigation, adaptation, and vulnerability reduction) for sustainable development prospects in various sectors, systems, and regions; (4) synergies and tradeoffs between different sustainable development strategies, and options for increasing adaptive capacity and reducing vulnerability to climate change, in various sectors, systems and regions; (5) synergies and tradeoffs between different sustainable development strategies, and options for increasing mitigative capacity and mitigating GHG emissions, in various sectors, systems and regions; and (6) mutual interlinkages between different overall development paths (that cut across various sectors and systems), including strategies for technology development, diffusion and transfer processes, and climate change responses.

Sustainomics is a transdisciplinary and practical framework for making development more sustainable. The approach accepts that the precise definition of sustainable development remains an ideal and elusive goal. A less ambitious, but more focused and feasible strategy would merely seek to 'make development more sustainable'. Such an incremental method is more practical, because many unsustainable activities can be recognised and eliminated. Thus, vulnerability to climate change, impacts, adaptation, and mitigation responses may be analysed and assessed in relation to whether they make development (more or less) sustainable, in terms of specific sustainable development indicators (including greenhouse gas emissions).

Issues need to be analysed first through the prism of the sustainable development triangle -- from the economic, social and environmental viewpoints. Sustainability criteria play an important role. Environmental and social sustainability focus on the overall health of ecological and social systems, with emphasis on increasing resilience to withstand shocks and reduce vulnerability. Economic sustainability aims to maximize the flow of generated income while at least maintaining the stock of assets (or capital), which yield these beneficial outputs. Equity and poverty are also key issues. Integrated analysis is facilitated by a joint optimality-durability approach. Optimal models are used in economic analysis to generally optimize a major objective like welfare, subject to the requirement that the stock of productive assets (or welfare itself) is non-decreasing in the long term. Durable development paths focus primarily on sustaining the quality of life, typically by meeting prudent environmental, social and economic sustainability requirements. They permit growth, but need not be economically optimal. There is more willingness to trade off some economic optimality for the sake of greater safety (i.e., risk aversion), in order to stay within critical sustainability limits.

Development and growth may be restructured more sustainably, using a “tunneling” perspective that internalizes externalities. Sustainable development assessments (SDA) are important, especially at the sub-national and project levels. A mapping model facilitates the implementation of SDA, by incorporating environmental and social assessments (EA and SA) into the conventional economic decision making process, with economic valuation of environmental and social impacts serving as the bridge to cost-benefit analysis. Multi-criteria analysis (MCA) aids in making trade-offs among diverse objectives, especially when economic valuation is difficult.

The Action Impact Matrix (AIM) approach is a sustainomics tool that will identify and analyse economic-environmental-social interactions, and integrate climate change policies with overall sustainable development strategy. The matrix helps to explicitly identify key linkages, focus attention on methods of tracing and analysing important impacts, coherently articulate the links among a range of development actions (both policies and projects), and suggest action priorities and remedies (including climate response measures). Comprehensive, multi-sector models (including computable general equilibrium models) based on an expanded set of national accounts, help to integrate economic, social and environmental issues at the macroeconomic decision making level. Integrated assessment models (IAMs) play a key role in analyzing problems like climate change at the global. A range of sustainable development indicators help to measure progress and make choices at various levels of aggregation.

Integrated national sustainable development and climate change policies must take into account, the powerful sectoral and macroeconomic adjustment policies which have widespread effects throughout the economy. The highest priority needs to be given to finding ‘win-win policies’ which promote all three elements of sustainable development, while with other policies, trade-offs among different objectives need to be analysed. Economywide policies that induce growth, could also lead to environmental and social harm, unless the macro-reforms are complemented by environmental and social safeguards -- e.g., measures to enhance climate change adaptive and mitigative capacities, and protect the most vulnerable communities, sectors, and ecosystems.

These concepts and analytical tools are illustrated through case studies involving climate change problems across a full range of spatial scales. At the global-transnational level, the first case study examines the interplay of optimality and durability in determining appropriate global GHG emission target levels. At the national-economywide level, the second study describes how the AIM may be used to analyse and improve the sustainability of macroeconomic and sectoral policies. On the subnational-sectoral scale, the third example analyses policies for achieving sustainable energy development in Sri Lanka. Finally, multi-criteria analysis is applied in the fourth example, which assesses small hydropower projects at the project-local level, using relevant economic, social and environmental indicators.

2. CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT – VIEW FROM THE DEVELOPING WORLD

Kirit Parikh

Chairman, Integrated Research and Action for Development (IRADe)
New Delhi

Sustainable development (SD) is needed, desirable, and environmentally beneficial. The main environmental concerns of developing countries relating to air quality, water resources, land degradation, biodiversity and habitat protection can be addressed while pursuing development.

This is not true of global commons such as oceans. For example, sustainable fishery requires a global co-operative use restraint. Global co-operation is even more important for dealing with climate change (CC).

Climate change makes it even harder for LDCs (Less Developed Countries) to attain sustainable development as it threatens resources, deepens existing problems, poses new problems, and makes solutions more difficult and expensive.

Unsustainable consumption patterns of the rich is the driving force of CC. 75% of energy resources are consumed by 25% of the population in industrialized countries, who also consume more than 70% of mineral resources (copper, steel, aluminium, etc.), 75% of cars, 75% of newsprints, timber, etc.

The consumption patterns of the rich set a standard for the global village. If India grows at 8-10% for 25 years, its 1.4 billion people may have a per capita income of US$ 20000 in purchasing power parity terms and how they consume will depend on the standard set by the rich today.

The poor are always more vulnerable as the rich can spend more on hedging. An earthquake can kill 10000 in India but only 100 in California. Netherlands can build a wall against sea level rise but Bangladesh may not be able to do it.

In India 3.5°C rise will lower rice and wheat yields by 20% to 50%, lower agricultural GDP by 25%, while increasing poverty and hunger.

LDC's are vulnerable to CC due to increased frequency of storms, floods and other extreme events, change in cropping patterns, loss of livelihoods from fishing and farming, uprooting and migration due to submergence and increased cooling costs.

Adaptation is expensive. If Indian farmers can adapt as Americans, the loss in Agricultural GDP will be 5% not 25%. American farmers adapt better because of public investment in irrigation, research and education.

The Rich are delaying action, but delay is free riding. The difference between the likely emissions of OECD countries, even if Kyoto Protocol is fully implemented, and what would have been under the FCCC understanding will exceed India's emissions of CO_2 over the next 40 years.

Adaptation should not be an excuse for avoiding mitigation. "You adopt, I would not mitigate" is not acceptable. Convergence and contraction in an equitable way should mean developing countries should have the right to converge to the level of per capita emissions of developed countries (DCs) world any time and then to contract together, not that LDCs converge and DCs contract to a sustainable level.

CO_2 emissions are not likely to be reduced by mere political and regulatory instruments but needs incentives to move away from fossil fuels. DCs can adopt energy efficient technologies to reduce CO_2 emissions. CDM/JI (Clean Development Mechanism/Joint Implementation) projects and tradable emission permits (TEPs) can be established in consonance to help the transition to TEPs in the future. LDCs have to consolidate their international negotiating positions to derive fairer benefits from CDM/JI initiatives.

Problems with CDM relate to base line determination that provides perverse incentives to inflate and where technology transfer is not involved in many sequestration programmes. A technology acquisition fund is needed to which every project should contribute and from which the recipient country should be free to buy technology from anywhere.

Carbon trading needs to be made fair so that gains are shared equitably. The UN may set a floor price for trading.

There is need for an equitable approach to mitigate the threat of climate change and that can accommodate different perspectives on risk. Could we design a mechanism that would work? How can we address the concern of developing countries about an unequal bargain in CDM? Paradigm shift from abatement cost to risk minimization for everyone is needed. How can one finance synergistic development in developing countries? What kind of global regime do we need to monitor emissions trade?

An equitable solution is obvious: Tradable emission quotas over a long time horizon in terms of tonne-years of carbon in the atmosphere which are equitably distributed, within specified range that narrows as knowledge firms up, can endogenise many of the problems.

For successful environmental governance, at the global level we need to

- Internalize the externalities for **Efficiency**
- Empowerment for **Equity**
- Education and awareness for **Consensus** and
- Participation for **Enforcement**

3. CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT – VIEW FROM THE DEVELOPED WORLD

Jan Corfee Morlot
OECD

i) OECD on Sustainable Development: Progress and Challenges

a. Review of the economic, social and environmental dimensions of sustainable development in the OECD and non-OECD: sustained economic growth (on the order of 2.5 –3% per year in last decades) accompanied by improved quality of life for most in the OECD. In developing and transition countries (non-OECD) economic growth has been relatively high compared to OECD (3.3% in last decade) but accompanied by fairly rapid population growth so per capita income, remains low. In addition there has been a 70 fold increase in FDI and 30 fold increase in trade since 1970s. However most of this is intra-OECD. ODA relative to GDP is declining. On the social dimension, education and longevity are up in the OECD. Nevertheless poverty still exists, but poverty rates and trends vary by country. In developing countries we see some encouraging trends in education and child mortality but the rates of improvement are not yet sufficient to bring the millennium development goals into reach. On the environmental dimension, significant progress has been made in some areas but problems persist in others e.g. areas that need urgent attention include GHG emissions/climate change, forestry and transport. Overall natural capital is on the decline threatening the vital base for economic and social activity. Overall some slow progress in understanding sustainable development and monitoring progress towards it but can point to significant challenges ahead.

b. Environmental Strategy: Maintaining the integrity of ecosystems through efficient management of natural resources; de-coupling environmental pressures from economic growth; improving information for decision-making: measuring progress through indicators; the social and environmental interface: enhancing the quality of life; global environmental interdependence: improving governance and co-operation.

c. Four point OECD policy framework for SD: Making markets work for sustainable development; strengthening decision making; harnessing science and technology; managing linkages with the global economy. Ministerial mandate also includes developing and using the OECD peer review process to monitor progress.

ii) Implementing Sustainable Development Policy Reforms

Across the OECD
Following a Ministerial mandate set out in 2001, the OECD work on SD is focusing in a few areas:

a) *Making markets work for SD: subsidy reform.* Significant subsidies exist in OECD countries today as well as in non-OECD countries – on the order of 400 billion USD (roughly 2% of GDP) per year in the OECD and 360 billion per year in the non-OECD countries (roughly 6% of GDP). Subsidies hurt poor countries and poor segments of the population in both OECD and non-OECD countries. Reform is a priority and could have significant returns – decrease in energy use and increase in economic efficiency, decrease in emissions (CO2 and other air pollution).

Broader than OECD

b) *Policy coherency: Joint Project on Development and Climate Change* aiming to mainstream climate change policies into development planning; emphasis at this stage is on adaptation and the ability and interest to respond to medium and long term climate signals; includes a review of existing development plans and projects in 7 case study countries;

c) *Benefits of Climate Policy* **–** interested in this as the missing link in the TAR – necessary to help us to think about policies. Also helps with respect to integration of adaptation and mitigation. Aim of the project is to advance a conceptual framework to better structure information on the benefits of policies for policy makers and policy analysts. The project will consider how to improve categories of impacts and metrics for measurement of impacts (or avoided damages), such that they are comprehensive and coherent, covering both physical and economic metrics. Ideally both should relate to 4 forms of capital (preservation of which underpins SD) – in order to relate climate impacts and policy benefits to achievement of SD goals. Going from physical metrics to economic metrics should be transparent and should cover as many notions of valuation as possible.

Sustainable Development and Globalisation

Brief review of the trend toward economic globalisation & its impacts – technological change, improved resource allocation and wealth; increasing ecological globalisation as well with possible down sides (e.g. negative impact of climate change on poorest countries) as well as upsides (e.g. possibilities to use new markets for climate protection); priorities for action: improvements in international investment and subsidy removal; conditions for success.

4. FOOD SECURITY, CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Gustavo Best
Food and Agriculture Organisation of the United Nations (FAO)

The interrelationships between food security, climate change and sustainable development are critical. Chapter 14 in Agenda 21 deals with SARD (Sustainable Agriculture and Rural Development). Agriculture is the meeting point of people and nature and is normally an activity of the poor in developing countries and largely unsustainable. In these countries, the potential impact of climate change depends directly on the situation and level of sustainability of agriculture, forestry and fisheries sectors.

Agriculture is at the base of sustainability of rural areas in both developing and industrialised countries. Three clear linkages with climate change have been identified. Agriculture contributes to climate change emissions; agriculture is impacted by climate change; and, more importantly, agriculture can contribute to climate change mitigation through both CO2 substitution and sequestration. It is now recognised that the poor will be the most affected by climate change. In the case of rural and agricultural communities, high levels of vulnerability, as mentioned before, are aggravated by poverty and low sustainability levels, i.e.:

* many and unprepared farmers
* high population increase rates
* low rural infrastructure
* poor natural resource base (soils, water, energy).

A major component of new efforts in the climate change field must take into account the need for agriculture and rural populations to adapt to climate change impacts. This requires urgent attention if the rural population is to be spared from disaster. Agriculture adaptation could offer new livelihood opportunities, which need to be tapped and developed.

Agriculture, food security, and the climate change equation can only be comprehensively assessed if sustainable development issues are also considered, since behind agriculture and food security are farmers, foresters, fishers and other rural people. The economic, social and environmental context and conditions of this population, and the importance of all society to enhance food security and social stability, make the consideration of the sustainable development dimension essential.

Technical and scientific materials that need to be considered in the IPCC Fourth Assessment Report (AR-4) are as follows.

Natural resource base, adaptation considerations are:

* biological species (new and adapted)

* agronomics
* agro-technologies
* agro-practices
* genetics and biotechnology
* resilience to:
    - soil toxicity
    - draughts
    - pests
    - diseases.

Socio-economic factors:

* needs of change and opportunities for livelihoods
* knowledge/training at various levels
* new markets/trading (bioenergy as an example)
* traditions/cultures
* information technology
* employment and agriculture
* redirecting investment

In defining the new material on Climate Change and Sustainable Development the following could be considered:

* preparing a record on the present knowledge of the SD/CC equation
* polishing methodologies and projections of impact
* establishing indicators for SD with CC impact in mind
* identifying main areas for action for the Agriculture/Forestry/Fisheries sectors

Areas for renewed action:

* review of rural development policies
* training of farmers and extension services
* promotion of agro meteorological support to farmers
* review of the different roles of agriculture as means for future adaptation strategies

It is important to note the importance the FAO gives to the establishment of the basis of the sustainable development/climate change equation and to the building upon it to identify strategies and actions oriented to the benefit of the poor, and in particular to the rural poor. He reiterated FAO's commitment in cooperation with IPCC in these efforts.

5a. WATER SECURITY, CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

W. Neil Adger
Tyndall Centre for Climate Change Research
University of East Anglia, UK

[Provided to, but not presented at, the Workshop. A presentation on water was made by Paul van der Linden, WGII TSU, and is summarised below.]

<u>*At the top of the agenda*</u>

Many thanks for the opportunity for input into this meeting – I apologise this is by written contribution rather than in person.

The agenda of the meeting ('climate change and sustainable development including poverty and equity issues') is timely and topical. If the Fourth Assessment Report does not tackle these issues head on and provide guidance for the scientific community and the policy-makers of the key governments in terms of sustainability then I would suggest that the possibilities of post-Kyoto settlement are diminished.

The interdependence of mitigation and adaptation are clear in that political sense. Just this week, Prime Minister Tony Blair, in launching the UK's new Energy White Paper and in a speech entitled, 'Concerted international effort necessary to fight climate change' linked these issues at hand: 'There will be no lasting peace while there is appalling injustice and poverty. There will be no genuine security if the planet is ravaged by climate change'.[1]

<u>**Purpose and a proposal**</u>

This note proposes that a checklist for sustainability can be drafted such that the dimensions of sustainability are included when there is review of adaptation, impacts, vulnerability in Working Group 2 and of actions for mitigation in Working Group 3.

First, it is necessary to recognise that sustainable development is primarily a normative issue – in other words assessing the sustainability of development can only be done through reference to values. There are, of course, narrow interpretations of the ability to sustain a phenomenon (such as an ecosystem) without altering its fundamental structure in the very long run. But there is fundamentally no universal acceptance of what constitutes broad sustainable development since the values inherent in its goals are contested. In other words there are different views regarding what is the system to be sustained, and these views variably emphasise economic, social, or natural sub-systems while in reality all element need to be addressed simultaneously. Thus, suggesting that

[1] Prime Minister Tony Blair 'Concerted international effort necessary to fight climate change', Downing Street, London, 24th February 2003. www.number-10.gov.uk

development should be sustainable (and in this case suggesting some criteria in a check list) involves making explicit what values are being promoted.

As a good starting point, the goals of sustainable development may be to 'create and maintain prosperous social, economic, and ecological systems'.[2] But any appraisal of actions with regard to such a goal within an IPCC report must, I would argue, be qualified by reference to resource efficiency, equity and justice, effectiveness and risk reduction, and the legitimacy of the action.

One further issue that needs to be highlighted is that the goals of development lead to alternative management strategies, not all of which are sustainable when the wider system sustainability is considered. Much traditional environmental management, including managing systems to cope with climate variability, in effect promote stability rather than resilience. Evidence from riverine flooding through to intensive agricultural systems, shows that locking systems into particular technologies can promote stability and reduce risk in the short term, but eventually may sow the seeds for chronic stress and non-linear systematic change.[3] It may be these phenomena that are most difficult to deal with. Adaptation to climate change then is likely to be punctuated by system collapse and flips unless resilience is recognised as a central goal of sustainable development.[4] So sustainable development should be recognisable in the climate change context by how it promotes and facilitates resilience, and by how it promotes legitimate and broad-based development that allows individuals and societies to cope with risk and adapt to changing circumstances over time.

Towards some normative criteria for assessing sustainability

The cross-cutting guidance paper on DES for the Third Assessment Report, Mohan Munasinghe provided a useful tool in the Action Impact Matrix for analysis and remediation of the economy wide linkages that result from actions that may be undertaken to reduce emissions or adapt to impacts climate change. As an author in the TAR on the regional chapter on Asia and a contributor to the Adaptation chapter, I did not observe the guidance paper being used, even though I found it useful myself.

If the next round of IPCC is to instigate a similar cross-cutting paper, it would need to be made much more straightforward to use. There is a danger, of course, that any scheme becoming so simple may not be meaningful. Nevertheless, I suggest that four elements are necessary for sustainability and that these are a minimum starting point for a check list approach.

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[2] Folke, C., Carpenter, S., Elmqvist, T., et al. (2002) *Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations.* Report 2002:1, Swedish Environmental Advisory Council, Stockholm. Prepared for WSSD.

[3] Scheffer, M., Carpenter, S., Foley, J. A., et al. (2001) Catastrophic shifts in ecosystems. *Nature* 413, 591-596.

[4] Folke et al. *op cit*.; Tompkins, E. and Adger, W. N. (2003) Building resilience to climate change through adaptive management of natural resources. Tyndall Working Paper 27, Tyndall Centre, University of East Anglia, Available at www.tyndall.ac.uk/

Sustainability requires simultaneous consideration of diverse and sometimes competing elements. Sustainability in both mitigation and adaptation responses can be assessed through recognition of the efficiency, effectiveness, equity and legitimacy dimensions to response actions.[5]

- Efficiency is usually focussed on welfare-maximising use of scarce resources but the limits to efficiency are in incorporating other values. The cost-effectiveness elements of mitigation are well understood. In terms of adaptation, the costs of adaptation involve estimating the costs of impacts avoided, the expected value of future impacts over time, the transaction costs of new information and the costs (and probabilities) of misplaced foresight.

- Effectiveness relates to the capacity of a decision or alternative to achieve its expressed objectives. In terms of mitigation this is the effect on the carbon cycle. In adaptation effectiveness essentially has two elements: effectiveness in reducing impacts (exposure) and effectiveness terms of reducing risk, avoiding danger and promoting security. There are emerging insights into the nature of risk management in adaptation stemming from the realisation of the role of expectations in formulating response options.[6]

- Equity usually focuses on the distributional consequences of environmental decisions - from the uneven spatial impacts of environmental change to the distribution and consequences of political and social change. There are numerous ways to frame equity, in terms of desert, equality or other criteria. For both mitigation and adaptation, the simplest means to highlight equity dimensions, as in vulnerability assessment, is to highlight who gains and who loses from any impact, adaptation or mitigation policy decision.[7] There also needs to be a distinction in adaptation between gains and losses from impacts and gains and losses from adaptation actions.

- Legitimacy relates to the extent to which decisions are acceptable to participants on the basis of who makes and implements the decisions. Legitimacy can be gained as well as compromised through the process of making environmental decisions. There are no universal rules for procedures that guarantee the legitimacy of policy responses because cultural expectations and interpretations define what is or is not legitimate.[8] But again the social acceptability of the procedures for implementation of mitigation or adaptation actions (e.g. carbon taxes, land use zoning, or provision of flood shelters) should be described.

[5] See Adger, W. N., Brown, K., Fairbrass, J. et al. (2003) Governance for sustainability: towards a 'thick' analysis of environmental decision-making. *Environment and Planning A* in press.

[6] Reviewed in Dessai, S., Adger, W. N., Hulme, M. et al. (2003) Defining and experiencing dangerous climate change. Tyndall Working Paper 28, Tyndall Centre, University of East Anglia, Available at www.tyndall.ac.uk

[7] In the context of mitigation efforts in forestry for example see Brown, K. and Elisalde-Corbera, E. (2003) Equity in the new carbon economy. *Climate Policy* in review.

[8] On methods see for example Brown, K. et al. (2002) *Making Waves: Integrating Coastal Conservation and Development.* Earthscan: London.

Guidance could be provided to assess the sustainability of actions in these different dimensions. The dimensions of sustainable development are not universal and are country and context specific. Thus, in terms of decision-making criteria, this is a minimum set of dimensions by which adaptation and mitigation actions could be appraised.

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Links between adaptive and mitigative capacity

The interdependence between mitigation and adaptation is clear in the context of sustainable development. But it should also be recognised that the constituencies (particularly in government) of adaptation and mitigation are only marginally overlapping – energy planning and the carbon intensity of economic growth are usually dealt with by sectors of industry, and government and by consumers that are interested in security of energy, etc. Adaptation will be primarily be dealt with by spatial planners, different (non-energy) sectors of the economy, and in different consumption and production decisions by households from those about energy use.

The divergence between the parties responsible for adaptation and mitigation poses a problem at one scale – that of policy integration. But at another level, the pre-conditions for enhancing adaptive capacity are similar to those that can lead to enhanced mitigation. Adaptive capacity and mitigative capacity describe the ability to make use of the spectrum of options that are available in responding to climate change. The capacities are determined are at present only hypothesised. They are driven by technology and societal factors in the form of individual or group behaviour, economic markets and institutions. Both sets of factors can expand or constrain the set of response options that exist, and both have implications for sustainable development. A joint response capacity could be elaborated in terms of resource needs; the distribution of risk; and the institutions required for the social learning processes that enable ability to adjust to climate change.

How should activities be organised for AR4?

I offer these observations above in the spirit of promoting debate concerning how sustainable development and the key issues of poverty and equity can be brought to the centre of Working Groups 2 and 3.

I can see the advantages of a single cross-cutting paper on sustainable development (though it is a significant agenda to be promoted). If this route is taken then I would suggest that a check list approach similar to the 'uncertainty' check list (despite its flaws) from the TAR would be useful.

I have two related recommendations on mitigation and adaptation:

1. A cross-cutting paper should be undertaken on the co-determinants of mitigative and adaptive capacity as a clear link to show to policy-makers why both are institutionally constrained and how they could be taken forward.

2. In Working Group 2 the issues raised by this meeting are so important that there needs to be, at a minimum, an assessment of, perhaps Chapters or sections in the Report, on:

   - Differential adaptive capacity by country and sector using indicators
   - Equity and justice of both impacts and adaptation
   - Responding to irreversible, singular, rapid climate change
   - Perspectives on dangerous climate change as observed, modelled, and experienced.

5b. WATER, CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Paul van der Linden
Hadley Centre, Met Office, UK

- Water interacts with many other sectors (all of which themselves are impacted by climate change). The main sectors are: Financial, Health, Settlement, Coastal/marine, Freshwater ecosystems, Food and fibre, Energy/industry/transport

- The 'picture' of water today is one of crisis:
  - 20% of the world have no safe drinking water, 50% have inadequate sanitation
  - Water use is currently unsustainable (overuse, ecosystem damage)
  - Climate change will exacerbate this.
  - Water and SD must be examined in the wider context of adaptation / mitigation

- Stress threshold for water resources - one common measure is 1000 m^3 / capita / year. This measure indicates that 24% of the worlds population is living in water stressed areas

- 70% of water usage is for irrigation, 20% for industry and 10% is for domestic use.

- There are projected changes for water, even without climate change:
  - demand for water will increase due to population increase. This increase in demand means more people will be living in water stressed areas, leading to lower quality of supply and posing a challenge for the goal of sustainable development.
  - the scenario with the highest population growth (A2) shows the biggest increase in water stress (132% rise)
  - a regional pattern of changing water stress emerges

- Climate change impacts on water in the following ways:
  - supply will change (rainfall, streamflow, climate variability)
  - demand will change
  - water quality will be affected
  - CC impacts depend on water resource management systems

- Climate models show moderately good agreement in projected changes to regional and seasonal patterns of precipitation (WGI TAR fig 10.6)

- Changes in run-off have to be deduced from the changes in precipitation (run off is affected by precipitation intensity, duration, ground cover, soil moisture and management systems) (TSR SYR SPM fig 4) Changes in run off are judged to be 'significant' when they change by more than 1 standard deviation.

- Climate models project changes to water resource stress (derived from runoff models), with both increases and decreases. However, the changes do not cancel out due to other factors.

- Changes in climate variability and extremes also have to be considered, as well as other hydrological factors (hydrological extremes, groundwater, water quality, lakes, cryosphere)

- Agricultural demand for water is the most sensitive to climate change, but there are also many non-climate-related influences on demand. Irrigation demands are projected to generally increase over the next 25 years

- Impacts of CC and SD for water resources:
  - CC impacts depend on Water Resource Management Systems (WRMS)
  - WRMSs will develop in response to SD
  - CC impacts on water pose additional threats to SD in other areas (economic, social, and environmental)

- Adaptation to CC
  - WRMS have (or should have) built-in resilience
  - supply / demand options are available
  - Uncertainty of CC is a challenge for planning

- Water in a SD context
  - is already unsustainably used
  - consider MDGs
  - Adaptation / mitigation, water resource management should be fully integrated with other sectors

- IPCC 4AR
  - water and SD are both themes
  - IPCC focus is first CC and then SD
  - what information is needed by the SD community?

6. HUMAN HEALTH, CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Martin Parry
Hadley Centre, Met Office, UK

- Climate models project temperature increases of about 2ºC over the next 50 years
- Climate models project changes in precipitation with regional increases and decreases over the next 50 years
- Droughts, floods, water quality, climate extremes, crop production, aquaculture, sea level, temperature and moisture all have an effect on health
- Millions of people are at risk from water shortage, hunger, exposure to malaria and flooding, under all scenarios
- Droughts and changes in runoff will affect human health (directly: water stress, indirectly: crop yields)
- Changing monsoon patterns over SE Asia, as projected by the Hadley Centre GCM, indicate a changing pattern of dryer and wetter areas within the region.
- Projected increases in water stress will lead to increased health problems, due to: unsafe drinking water; poor sanitation; less food due to lower crop yields/loss of crops
- Increased risk of hunger - crop yields are projected to increase in some regions and decrease in others (this include the CO_2 fertilisation effect), where crop yields drop, associated risk of hunger /malnutrition.
- Crops respond in different ways to temperature increases - e.g. rice production drops significantly above 32ºC, some temperature resilient cultivars have been bred to overcome this.
- Increases in the projected number of people at risk from hunger is impacted more by the reference scenario than by the climate scenario
- Increased risk of coastal flooding. People at risk from sea-level rise increases greatly in the 2080's even with evolving protection.
- Stabilisation levels of 550ppm or 750ppm atmospheric CO_2 concentration arise from very different emissions profiles
- Millions at Risk in the 2080s: Risk of water shortage, malaria, hunger and coastal flooding have non-linear profiles when plotted against temperature rises associated with the different possible amounts of atmospheric $C0_2$ concentrations
- The effect of different global economic pathways effect health: cf. A2 and B2
  - A2: high population, moderate economic growth, 180 million at risk from hunger in 2080
  - B2: low population, high economic growth, 40 million at risk from hunger in 2080

- Global millions at risk [due to (for example) water shortage, hunger, coastal flooding, and malaria] may increase greatly over time. More frequent droughts, famines, floods due to change in AVERAGE climate.
- Climate variability will also have an impact (more frequent weather disasters)
- Both adaptation and stabilisation are necessary. Effective response to climate change may need to be part of a package that aim at 'sustainable development' (NB: global damages evidently much less in B2 development pathway).
- Investing in adaptation will increase resilience. Disaster management is effective when dealing with long term climate change. Focus on vulnerable regions (e.g. small island states)
- IPCC is now starting to think about the key questions for its next assessment; and welcomes advice from you.

7. BIODIVERSITY, ECOSYSTEM PROTECTION, CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Mike Harrison
Hadley Centre, Met Office, UK

- Biodiversity is an issue that readily can fall below the radar when contrasted against development issues that have greater day-to-day prominence. Nevertheless various reasons for maintaining concern can be given:
  - Ecosystem support for human activities
  - Environmental maintenance
  - Quality of life – aesthetic, recreational
  - Future opportunities – materials, chemicals. Biota
  - Support of ecosystem dynamics
- According to Chapter 5 of the WGII TAR, Goods and Services provided by the Ecosystem include:

Value	**Examples of Goods and Services**
Direct Use	Food, fibre, fuel, fodder, water supply, recreation, non-wood forest products
Indirect Use	Biodiversity, biochemical cycles, tourism, flood and storm control, clean water supply, pollution control
Option	Future discoveries (i.e. pharmacological and biotechnological), future recreation
Bequest	Intergenerational and sustainable development
Existence	Mostly conservation, aesthetic, spiritual

- Reviewed aspects of Biodiversity as included in Chapter 5 of the WGII TAR. Apart from agriculture, were discussions on:
  - Wildlife
  - Rangelands
  - Forests and Woods
  - Lakes and Rivers
  - Inland wetlands
  - Arctic and Alpine regions

Each discussion included a brief review of the relevance to human activities, and an overview of adaptation options in the face of climate change.

- ♦ Wildlife goods and services included pollination, nutrient cycling, pest control, ecosystem stability and recreation. Adaptation to lost services might be possible in some, but not all, cases, but would be costly. Lowest income groups may suffer the most.

- Rangelands protect against desertification and salinisation, loss of plant productivity and of species. Many countries experience infrastructure and investment problems for mitigation against adaptation.
- Loss of forests and woods is often through unsustainable logging, resulting in loss of biomass and non-wood products. Adaptation is uncertain in terms of costs and due to the complexities of forest productivity.
- Impacts on lakes and rivers, including affects on culture, recreation and fisheries, may vary locally. As a result adaptation is difficult. Attempts to manage water flows have been made along with aquaculture development.
- Inland wetlands play important roles in maintaining biodiversity and as carbon sinks/methane source. Adaptation to change is often impossible, being intimately dependent on catchment-level hydrology.
- Human impacts in Arctic and Alpine regions are already substantially larger than those from Climate Change. Economic diversification was suggested as an adaptation prospect.

The complexity of the ecosystem was illustrated through slides kindly loaned by Professor Christian Körner, of the University of Basel. Results presented were obtained in Swiss environments in which great care had been taken not to disturb natural processes. Amongst the results were:

- When two tree species, one deciduous the other coniferous, are compared for growth rate according soil type, nitrogen fertilisation and CO_2 fertilisation, a complex of results emerges. The deciduous species, in particular, did not necessarily respond positively to CO_2, but its response was conditioned by both soil type and nitrogen fertilisation. The coniferous species always responded positively to CO_2 fertilisation in these tests. Hence CO_2 fertilisation does not necessary lead to overall enhanced growth, but can lead to differential growth between species that may have unexpected consequences.
- Needle nitrogen concentrations in coniferous species reduce as atmospheric CO_2 concentrations increase. Some caterpillars require this nitrogen in their feed. As a result that they consume more but finish with reduced adult weights.
- Factors that determine biomass growth responses include: species; nitrogen availability; sunlight availability; competition with other plants/species; CO_2 levels. Prediction of outcomes to a changed environment is difficult, if not impossible.

In summary the ecosystem, and its inherent biodiversity, play a substantial role on Sustainable Development. However the processes of change are complex and chaotic making impacts on Sustainable Development difficult to assess.

8. ENERGY, CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Anand Patwardhan
Indian Institute of Technology, Bombay, India

- Energy use is the main proximate driver for climate change, and is also a key developmental indicator.
- Sustainable use of energy may be evaluated along multiple dimensions (economic, social, environmental) using multiple criteria (efficiency, equity – distributional and intergenerational, availability and affordability).
- The energy sector is critical with regard to climate change and sustainable development:
  - Much of the energy infrastructure in developing countries will be built out in the next two decades, and a significant portion of the post World War-II energy-related capital stock in the developed world will turn over during the same period.
  - Technology and system choices during this period will constrain and direct greenhouse gas emissions through much of this century.
  - Climate change affects energy supply and demand directly, and indirectly, through the range of goods and services that depend on energy availability and use.

What should we do in AR4? (SD – CC)

- SRES was a good start, but perhaps we need to focus on building scenarios that emphasize transitions, and the potential for non-marginal, regime change.
- More critical assessment and evaluation of alternative development pathways, and on the elucidation of processes & mechanisms, particularly those associated with technological change.
- Joint consideration of adaptation and mitigation will require significant interaction and integration across WG 2 & 3 (and perhaps WG 1).

What should we do in AR4? (CC – SD)

- What are the end-points or final outcomes that we assess?
- It is important to document the changes in final outcome variables (health, yields, water availability).
- Perhaps equally important to document, describe and characterize the mechanisms and pathways – gives us an entry point into adaptation design.
- For example, in the case of vector-borne disease, we may have different end-points: vector prevalence, disease prevalence, observed mortality / morbidity.
- Each end-point requires the consideration of more complex and often non-climate related processes. However, if we want to inform adaptation policy we may have to do this.

9a. GOVERNANCE, CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Leena Srivastava
TERI, India

As economic growth, social development and environmental protection are the three cornerstones of the triangle of sustainable development, so too can mitigation, adaptation and trade be defined as the cornerstones of the climate change issue. Seeking to develop a similar scheme to defining the elements of governance, structural efficiency, financial mobilisation, and legal frameworks, were identified as the cornerstones of good governance.

Structural efficiency in the above context encompasses the efficiency of organizations and the efficacy of related attributes such as accountability, transparency and participation. Financial mobilisation has broadly been used to cover issues of financial commitments and technology transfer whereas legal frameworks refer to the degree of empowerment, enforcement and compliance.

Having defined the elements of governance, sustainable development and climate change thus, the presentation went on to highlight the apparent differences in emphasis on the governance related priorities as applicable to different contexts. The challenges of governance in developing countries are significantly higher and more immediate in relation to sustainable development (WEHAB issues) although the adaptation cornerstone of the climate change issue is also important. In contrast the governance challenge of developed countries lies largely around the issue of climate change with issues of sustainable development having been addressed in a much more satisfactory manner. Accordingly, the governance challenge at the international level cuts across the issues of sustainable development and climate change, focussed primarily on the cornerstone of financial mobilisation.

The common challenges of governance however relate to the need to recognise the interlinkages between climate change and sustainable development issues and, therefore, the need to develop coordinated policies and strategies for addressing both synergistically. The governance challenge also revolves around recognising the vulnerability enhancing effect of mismanaging either the climate change or the sustainable development issue both as a direct consequence as well as indirectly through its impact on the other.

The presentation went on to identify access to income, credit, targeted subsidies, technologies and markets as some of the possible common solutions to enhance sustainable development and encourage climate related action. Among other issues, it identified technology development and adaptation designed for developing country markets as a challenge for the developed countries and highlighted the protection of the principles of the Framework Convention on Climate Change and adoption of the attributes of good governance (transparent, independent, equitable) as major challenges for international governance.

9b. GOVERNANCE, CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Tom Heller
Stanford University, USA

- The basic approach of the UNFCCC has marginalized key issues central to the political priorities of developing countries and has thereby failed to generate either salience or engagement with climate action. The IPCC should bring issues of development to the core of the climate change agenda, understanding that climate benefits may, in many cases, be ancillary to economic polices including energy, transport, land use and food security of central priority to developing states.

- It is essential to explore both how economic growth impacts climate and how the opportunities it may open to grow along more climate favoring (sustainable) pathways may be enhanced.

- The UNFCCC must recognize multiple forms of commitment to climate action by developing countries, some of which have already been in evidence, rather than focusing on accession to the regime as imagined for developed countries. In this regard, goals may be better related to key climate inputs (e.g. energy; transportation) than to climate outputs (e.g. targets).

- Given the problematic characteristics of the Kyoto mechanisms, especially CDM, as drivers of large scale climate favoring action in developing countries, we must examine new forms of international support for these various types of commitment that are based less on projects than on policies and investments that shift baselines toward more climate favoring development paths.

- AR4 should incorporate social science expertise on the political economy of development so as to increase the applicability of climate related policy to those issues perceived and institutionalized as salient in developing countries. In this regard, it must focus on changes underway that affect the theory of development, the practice of development assistance, the strategies and behavior of multinational firms able to mobilize capital and technology for more climate friendly investment, and, especially, the complex political dynamics of state reform that constitutes the operational context in which development elites will analyze their engagement with climate concerns and incentives.

- It may become necessary to differentiate and address the issues concerning mitigation that concern a limited number of developing nations in the near-term and the wider issues of adaptation that concern a much larger number of developing states and are unavoidable due to greenhouse gas loadings already in place or in process. This differentiation within the climate regime should not be taken as a sign of failure in as much as it already characterizes many functioning international regimes.

10. PANEL ON CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

a. View From The World Bank

Ajay Mathur
Team Leader for Climate Change, World Bank

Climate-change risks threaten development

In most developing countries, the effects of climate change threaten to adversely affect livelihoods, especially those of poor people, as well as opportunities for development. These **climate change stresses add to the existing stresses** (such as falling commodity prices, AIDS/HIV, etc.) that challenge development, and in some cases, can be the crucial barriers to development. Though the impacts of climate change are site specific, in general, they affect livelihoods and development because they:

- increase the risk of disruptions in food and energy supply chains
- lower the margin of tolerance for livelihoods based on natural resources
- enhance vulnerability to natural disasters, and
- increase the probability for the sustained incidence of vector-borne diseases.

The key negative impacts, as a result of changes in climate implies, variability and extremes, exacerbated stress due to current climate, and, **in an increasing number of cases would overwhelm the current coping capacity** of poor people and poor societies.

Approach & Instruments

In order to address the additional stresses due to climate change, it is essential that, as a first step, **all development incorporates current climate stress** in the social, economic and environmental analysis associated with development planning and implementation. At the same time, because of the additional climate-change related stresses that manifest themselves over time, it is important to simultaneously **strengthen institutions (which manage natural resources, health, agriculture and infrastructure) to be able to change processes and methodologies as the stresses increase over time**.

The site-specific nature of climate-change impacts, as well as of the exposure and of the current adaptive capacity of people argues for **differential responses** – amongst countries and regions, but also amongst different socio-economic classes of people at the same location. This suggests a **risk-management approach** to climate-change adaptation, consisting of:

- risk assessment to identify differential vulnerabilities with and without a range of adaptation options,
- risk reduction through integration of climate concerns in economic and sectoral development, better infrastructure design, and policy and institutional changes planning (including correcting for biases that encourage "maladaptation" to current climate), and,

risk transfer of irreducible risk through social protection schemes, insurance, catastrophic bonds, etc.

Promoting renewables and energy efficiency can address development needs in addition to lowering the carbon-emissions trajectory
While the adverse impacts of climate change threaten developing countries now, the increasing carbon emissions from these countries, as they develop, pose a longer-term threat to the stabilization of greenhouse gas concentrations in the atmosphere. However, since this latter threat is longer term, and since the first priority in these countries is to accelerate the sustainable development process, the key objective is to find **opportunities where climate-change mitigation can be piggy-backed on sustainable development initiatives**. Some such opportunities include:

- enhanced rural energy access and improved financial health of utilities
- new opportunities for rural income generation, and
- enhanced quality of health services

Approach & Instruments

In order to promote renewable-energy and energy-efficiency applications within sustainable-development objectives, the priority is to enable applications which support development goals such as rural income generation, education, health, economic diversification, and social justice. Interventions to support the adoption and growth of these applications include:

- policies and regulatory processes to support these applications
- "first-of-a-kind" transactions and demand-chain development
- guarantees and risk instruments to promote commercial financing of these applications, and
- integration of carbon finance in energy-sector development financing; and a measured move towards tradeable emission quotas

The immediate development benefits of these applications increase the likelihood for their continued use and adoption; thus providing the market anchor for their further penetration into other areas of application as they become feasible. Consequently, **as developing economies and their infrastructure grow, renewable-energy and energy-efficiency applications become more viable options.**

Again, as in the case of climate-change adaptation, it is important to underscore the differential nature of interventions – based on opportunities, as well as on existing experience and capacities.

10. PANEL ON CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

b. Integrating Sustainable Development into AR4 : Implications for Working Group I

Neville Nicholls
BMRC, Australia

1. An issue slowing consideration of adaptation measures is the widespread belief that climate change is something that "will happen in 2030 or 2070" so it will not affect the present generation of decision makers. There is, however, clear evidence, at least in some regions, that climate change is already happening and likely affecting development (e.g., Manton *et al.*, 2001; Nicholls, 2003). A focus on "climate change is happening NOW, and is already an important influence on the economy and environment" rather than an emphasis on target dates set decades away, should enhance recognition of the importance of climate change, in discussion of sustainable development and other issues.

2. WGI could provide results that are more useful to WGII (especially) and WGIII. For a start, a greater focus on the regional-scale (sub-continental) is needed for impact and adaptation studies. Although TAR provided more information on these scales, more detail is required if we are to design adaptation strategies. In particular, strategies to detect and attribute climate change on a regional scale are needed. Detection and attribution studies have thus far concentrated on the global and 3-dimensional temperature fields – this is useful for mitigation discussions, but of limited value for impact and adaptation studies.

3. Predictions, not just scenarios, are important to make room for development of adaptation strategies. Scenarios are, of course, useful in mitigation discussions, but unless real predictions with associated, quantitative uncertainties attached are available, it will be difficult to assess possible adaptation strategies. There is a great deal of work in the climate variability literature regarding decision making using climate forecasts – much of this work could be useful in attacking the adaptation problem, as long as climate change forecasts, not scenarios, are available.

4. Not all the climate variables can be predicted with the same expectation of accuracy. In particular, regional rainfall is less predictable than temperatures trends. In many sectors, e.g. agriculture, rainfall is considered the most important variable. However, even if rainfall does not change or is unpredictable, we can expect that continued warming will impact even these sectors where rainfall is important. For instance, warming over Australia over the past 50 years has tended to exacerbate droughts, even though rainfall has not declined. These warming impacts could be ameliorated by addressing adaptation options. We should not focus on the "most important variable" at the expense of neglecting what could be learned from a focus on the "more predictable variables".

5. Many lessons can be learned from experience with operational seasonal climate prediction. There is well-developed literature discussing problems and opportunities in applying seasonal climate predictions in decision making. Some lessons of this work are that it is essential to attach uncertainties to the predictions, that people have trouble interpreting such as uncertainties and risk, but that there are ways to improve this usage. Another lesson is that sometimes the most "important" decisions may not be the best decisions to which to apply climate forecasts – we need iteration between climate forecast providers and potential users of climate forecasts to determine which decisions should be impacted by the forecasts.

6. Seasonal climate prediction studies have also shown that there are trade-offs between profit, economic risk, and environmental risk, in using climate forecasts. The most appropriate decision depends upon the decision-maker's attitude to risk, as well as the expected uncertainty in the forecast. The approaches developed in seasonal climate prediction studies can be developed to allow the comparison of strategies to adapt to climate change.

10. PANEL ON CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

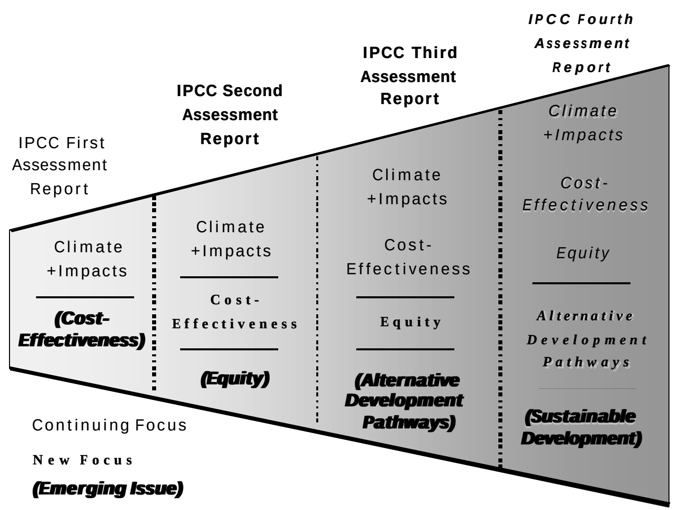
c. Climate Change and Sustainable Development: Some Issues

Adil Najam
Pakistan

i *Sustainable Development is not just about developing countries*. Both sustainable development and climate change are intrinsically dependent on the patterns of consumption as much as they are on poverty; both these challenges need to be responded to in developing and industrialised countries alike.

ii. *Although rather slow, there has been a real evolution of ideas concerning the CC-SD linkage within the IPCC process*. Each IPCC report has inched closer to incorporating sustainable development parameters relevant to development. Key amongst these parameters is equity. TAR brought the IPCC closer to dealing with these linkages and AR4 has the mandate to take it further still.

iii. *The conceptual basis on which to link climate change with sustainable development already exists.* There is general agreement that sustainable development is best envisioned as having three essential elements:environmental, social and economic. The environmental dimension is best reflected in climate change debates through their focus on climate variability and impacts. The economic dimension is encapsulated most potently in discussions related to cost-effectiveness. The social dimension is best captured through a focus on equity. Relating this ideology to the evolution of the IPCC assessment process, it is evident that while the environmental and economic dimensions have been the focus of IPCC assessments to date, the social dimension has remained under-represented. Sustainable development cannot be fully integrated into IPCC assessment until all three dimensions are equally and centrally brought into focus. A more comprehensive and consistent treatment of equity metrics in AR4 would allow for all three dimensions to be incorporated.



iv. *Steps that can be taken by 4AR to better link SD and CC.*

- First, in relation to the *structure* of future assessment reports, *the treatment of sustainable development in any IPCC assessment will remain incomplete and largely ineffective unless undertaken consistently throughout the assessment*. This would require all author teams to include a few experts to deal directly with the linkage between climate change and sustainable development in the context of that chapter.

- Second, in terms of the composition of assessment *teams*, there is a need to *continue broadening the base of expertise and scholarship reflected in the panels of authors and reviewers* of the IPCC reports. Given the practical limitations of the number of individuals who can be involved in such a consultative enterprise, it is vital that no country – industrialized or developing – dominate the process disproportionately.
- Finally, in relation to the larger assessment *process*, the integration of sustainable development into the Fourth IPCC assessment process should be jump-started by *commissioning a special report on the sustainable development and climate change*.

10. PANEL ON CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

d. Climate Change and Sustainable Development in Developing Countries

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- The relative importance of mitigation and adaptation to climate change in the developing countries is not evenly distributed.

- For the smaller and most vulnerable developing countries (namely the least developed countries or LDCs and the small island developing states or SIDS) the most important issue is the need for them to adapt to climate change - as even a drastic reduction in their greenhouse gas emissions will not affect global emission levels significantly.

- On the other hand for the small number of large developing countries (such as China, India, Brazil, South Africa, etc) whose greenhouse gas emissions in the future are likely to be significant, the issue of mitigation is as important as adaptation.

- Thus in examining the linkages between climate change and sustainable development in the case of the developing countries the relative importance of adaptation and mitigation efforts need to be taken into account.

PART B

CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT LINKAGES: POINTS OF DEPARTURE FROM THE IPCC TAR

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1. INTRODUCTION

The wide ranging potential impacts of climate change on sustainable development and vice versa, suggest that the linkages between these two topics need to be critically analysed. Such an analysis was attempted in the IPCC third assessment report (TAR), and while some progress was made, the work was incomplete. This paper summarizes key lessons from the TAR and relevant post-TAR findings, as a starting point for preparations for the fourth assessment report (AR4). Results are presented within a transdisciplinary integrative framework (sustainomics), which is applied to the nexus of sustainable development and climate change.

The global development community is looking for new solutions to traditional development issues such as economic stagnation, persistent poverty, hunger, malnutrition, and illness, as well as newer challenges like environmental degradation and globalisation. One key approach that has received growing attention is the concept of sustainable development or 'development which lasts' (WCED 1987). Following the 1992 Earth Summit in Rio de Janeiro and the adoption of the United Nations' Agenda 21, the goal of sustainable development has become well accepted world-wide (UN 1993).

Meanwhile, the threat of global climate change poses an unprecedented challenge to humanity. While climate change is important in the long run, it is crucial to recognise that (especially for the developing countries) there are a number of other development issues that affect human welfare more immediately – such as hunger and malnutrition, poverty, health, and pressing local environmental issues. Climate change and sustainable development interact in a circular fashion. Climate change will have an impact on prospects for sustainable development, and in turn, alternative development paths will certainly affect future climate change. Seen from the development viewpoint, climate change vulnerability, impacts and adaptation are the main elements of concern. From the climate perspective, development pathways also determine emission levels, and they have implications for mitigation strategies as well.

In this context, many relevant findings emerged form the IPCC TAR process, as documented in the three working group reports, special reports, and other documents like the guidance paper on development, equity and sustainability and proceedings of two expert meetings on climate change and sustainable development. These results may be grouped into the following categories (see Annex 1 for details):

1. Conceptual overview of linkages between climate change and sustainable development.
2. Consequences of climate change impacts for sustainable development prospects, in various sectors, systems, and regions.
3. Consequences of climate change response actions (mitigation, adaptation, and vulnerability reduction) for sustainable development prospects in various sectors, systems, and regions.
4. Synergies and tradeoffs between different sustainable development strategies, and options for increasing adaptive capacity and reducing vulnerability to climate change, in various sectors, systems and regions.
5. Synergies and tradeoffs between different sustainable development strategies, and options for increasing mitigative capacity and mitigating GHG emissions, in various sectors, systems and regions.
6. Mutual interlinkages between different overall development paths (that cut across various sectors and systems), including strategies for technology development, diffusion and transfer processes, and climate change responses.

This paper addresses the same basic issues within a more systematic framework. It is organised as follows. Section 2 introduces sustainomics as a transdisciplinary framework for making development more sustainable. Section 3 links sustainable development and climate change. In section 4, tools and methods of integrating and analysing the social, economic, and environmental dimensions of this nexus are briefly presented. These ideas are illustrated in section 5, by applying them to specific examples involving climate-related problems across the full range of spatial scales -- at the global, national-economy-wide, sub-national-sectoral, and local-project levels. Section 6 contains some concluding thoughts and implications.

2. OVERVIEW OF KEY CONCEPTS

2.1 Sustainomics and sustainable development concepts

The multiplicity and complexity of issues involved in sustainable development cannot be covered by a single discipline. Munasinghe (1992, 1994) proposed the term sustainomics to describe "a transdisciplinary, integrative, comprehensive, balanced, heuristic and practical meta-framework for making development more sustainable" (see Box 1 for details). Sustainomics accepts that the precise definition of sustainable development remains an ideal, elusive (and perhaps unreachable) goal. A less ambitious, but more focused and feasible strategy would merely seek to ***'make development more sustainable'***. Such an incremental (or gradient-based) method is more practical, because many unsustainable activities can be recognised and eliminated. This approach seeks continuing improvements in the present quality of life at a lower intensity of resource use, and aims to leave behind for future generations an undiminished stock of productive assets -- manufactured, natural and social capital -- that will enhance opportunities for improving their quality of life (Munasinghe 1992). The current state of knowledge is inadequate to provide a comprehensive definition of sustainomics, but we are learning about some of its key constituent elements, and how they might fit together. Starting from such an initial approach, sustainomics is emerging as a heuristic, dynamically evolving framework that could address rapidly changing sustainable development and climate change issues, in a practical manner.

Key elements of sustainomics relevant to climate change are outlined in this paper as follows. Issues are analysed first through the prism of the sustainable development triangle -- from the economic, social and environmental viewpoints. Integrated analysis is facilitated by a joint optimality-durability approach. Development and growth may be restructured more sustainably, using a “tunneling” perspective that internalizes externalities. Sustainable development assessments (SDA) are important, especially at the sub-national and project levels. A mapping model facilitates the implementation of SDA, by incorporating environmental and social assessments (EA and SA) into the conventional economic decision making process, with economic valuation of environmental and social impacts serving as the bridge to cost-benefit analysis. Multi-criteria analysis (MCA) plays a key role in making trade-offs among diverse objectives, especially when economic valuation is difficult. The Action Impact Matrix (AIM) approach and comprehensive, multi-sector models (e.g., computable general equilibrium or CGE models) based on an expanded set of national accounts helps integrate economic, social and environmental issues at the macroeconomic decision making level. Integrated assessment models (IAMs) play a key role in analyzing global level problems, such as climate change. A range of sustainable development indicators help to measure progress and make choices at various levels of aggregation.

Box 1. Introduction to Sustainomics

Munasinghe (1992, 1994) proposed the term sustainomics to describe “a transdisciplinary, integrative, comprehensive, balanced, heuristic and practical meta-framework for making development more sustainable”, to remedy the lack of a specific approach or practical framework that attempts to define, analyse, and implement sustainable development. Hitherto, multidisciplinary approaches involving teams of specialists from different disciplines have been applied to complex sustainable development issues. A step further has also been taken through interdisciplinary work, which seeks to break down the barriers among various disciplines. However, what is now required is a truly transdisciplinary meta-framework, which would weave the knowledge from existing disciplines into new concepts and methods that could address the many facets of sustainable development – from concept to actual practice. As shown in Figure 1(b), sustainomics would provide a comprehensive and eclectic knowledge base to support sustainable development efforts.

The sustainomics approach seeks to synthesize a ‘science of sustainable development’ which integrates knowledge from both the sustainability and development domains. Such a synthesis will need to draw on a wide range of core disciplines from the physical, social and technological sciences. Methods that bridge the economy-society-environment interfaces are especially important. For example, environmental and resource economics attempts to incorporate environmental considerations into traditional neoclassical economic analysis (Freeman 1993; Teitenberg 1992). The growing field of ecological economics goes further in combining ecological and economic methods to address environmental problems, and emphasizes the importance of key concepts like the scale of economic activities (for a good introduction, see Costanza et al. 1997). Sustainomics is also related to recent initiatives on a 'sustainability transition' and 'sustainability science' (Clark 2000, Parris and Kates 2001, Tellus Inst. 2001). Newer areas of ecological science such as conservation ecology, ecosystem management and political ecology have birthed alternative approaches to the problems of sustainability, including crucial concepts like system resilience, and integrated analysis of ecosystems and human actors (Holling 1992). Recent papers in sociology have explored ideas about the integrative glue that binds societies together, while drawing attention to the concept of social capital and the importance of social inclusion (Putnam 1993). The literature on energetics and energy economics has focused on the relevance of physical laws like the first and second laws of thermodynamics (covering mass/energy balance and entropy, respectively). This research has yielded valuable insights into how energy flows link physical, ecological and socioeconomic systems together, and analysed the limits placed on ecological and socioeconomic processes by laws governing the transformation of 'more available' (low entropy) to 'less available' (high entropy) energy (Georgescu-Roegen 1971; Munasinghe 1990; Hall 1995). Recent work on sociological economics, environmental sociology, cultural economics, economics of sociology, and sociology of the environment, are also relevant. The literature on environmental ethics has explored many issues including the weights to be attached to values and human motivations, decision making processes, consequences of decisions, intra- and inter-generational equity, the 'rights' of animals and the rest of nature, and human responsibility for the stewardship of the environment (Andersen 1993; Environmental Ethics; Sen 1987; Westra 1994).

While seeking to build on such earlier work, sustainomics projects a more neutral image. The neologism is necessary to focus attention explicitly on sustainable development, and avoid the implication of any disciplinary bias or hegemony. For example, both biology and soicology can provide important insights into human behaviour, which challenge the 'rational actor' assumptions of neoclassical economics. Thus, recent studies seek to explain phenomena such as hyperbolic discounting (versus the more conventional exponential discounting), reciprocity, and altruistic responses (as opposed to selfish, individualistic behaviour) (Gintis 2000, Robson 2001). In the same vein, Siebhuner (2000) has sought to define '*homo sustinens*' as a moral, cooperative individual with social, emotional and nature-related skills, as opposed to the conventional '*homo economicus*' motivated primarily by economic self interest and competitive instincts.

The substantive trans-disiplinary framework underlying sustainomics leads to the balanced and consistent treatment of the economic, social and environmental dimensions of sustainable development (as well as other relevant disciplines and paradigms). Balance is also needed in the relative emphasis placed on traditional development versus sustainability. For example, much of the mainstream literature on sustainable development which originates in the North tends to focus on pollution, the unsustainability of growth, and population increase. These ideas have far less resonance in the South, whose priorities include continuing development, consumption and growth, poverty alleviation, and equity.

Many disciplines contribute to the sustainomics framework, while sustainable development itself involves every aspect of human activity, including complex interactions among socioeconomic, ecological and physical systems. The scope of analysis needs to extend from the global to the local scale, cover time spans extending to centuries (for example, in the case of climate change), and deal with problems of uncertainty, irreversibility, and non-linearity. The sustainomics framework seeks to establish an overarching design for analysis and policy guidance, while the constituent components (or disciplines) provide the ‘reductionist’ building blocks and foundation. The heuristic element underlines the need for continuous rethinking based on new research, empirical findings and current best practice, because reality is more complex than our models, our understanding is incomplete, and we have no consensus on the subject. Since the precise definition of sustainable development remains an elusive (and perhaps unreachable) goal, a less ambitious strategy that merely seeks to ‘make development more sustainable’ offers greater promise. Such an incremental (or gradient-based) method is more practical, because many unsustainable activities may be easier to recognize and eliminate. In particular, it will help us avoid sudden catastrophic (‘cliff edge’) outcomes.

While many attempts have been made to define sustainable development, one widely accepted and useful concept that has evolved encompasses three major points of view: economic, social and environmental [Figure 1(a)]. Each viewpoint corresponds to a domain (and a system) that has its own distinct driving forces and objectives. The economy is geared mainly towards improving human welfare, primarily through increases in the consumption of goods and services. The environmental domain focuses on protection of the integrity and resilience of ecological systems. The social domain emphasises the enrichment of human relationships, achievement of individual and group aspirations, and strengthening of values and institutions.

Figure 1(b) indicates how an emerging ‘sustainomics’ framework (i.e., science of sustainable development), and associated trans-disciplinary knowledge base, would support comprehensive and balanced assessment of the trade-offs and synergies that might exist between the economic, social and environmental dimensions of sustainable development (as well as other relevant disciplines and paradigms) (Munasinghe 1994, 2001; OECD 2001). Balance is also needed in the relative emphasis placed on traditional development (which is more appealing to the South) versus sustainability (which is emphasised by the North) (Munasinghe1992).

Current approaches to sustainable development draw on the development experience of the 20th century. For example, the dominant development paradigm during the 1950s was growth, focusing mainly on increasing economic output and consumption. In the 1960s, development thinking shifted towards equitable growth, where social (distributional) objectives, especially poverty alleviation, were recognized to be as important as economic efficiency. Since the 1970s, environment has emerged as the third key element of (sustainable) development.

Figure 1. Sustainable development triangle supported by sustainomics trans-disciplinary framework

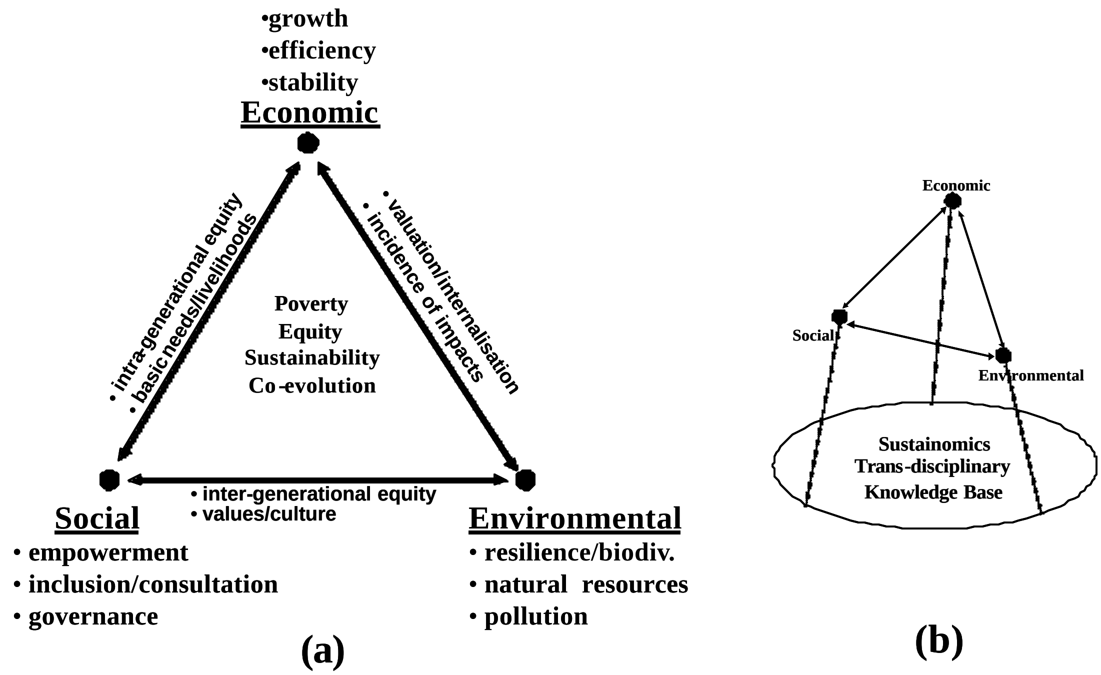


Figure 1 (a). Elements of sustainable development
1 (b). Sustainable development triangle supported by the sustainomics framework.
Source: adapted from Munasinghe [1992, 1994]

One (among many) broad descriptions, defines sustainable development as "a process for improving the range of opportunities that will enable individual human beings and communities to achieve their aspirations and full potential over a sustained period of time, while maintaining the resilience of economic, social and environmental systems" (Munasinghe 1994). Thus, sustainable development requires (i) opportunities for improving economic, social and ecological systems; and (ii) increases in adaptive capacity (Gunderson and Holling 2001). Expanding the set of opportunities for system improvement will give rise to development, while increasing adaptive capacity will improve resilience and sustainability. The evolving behaviour of individuals and communities facilitates learning, the testing of new processes, adaptation, and improvement.

2.2 Economic Domain

Welfare (or utility) – measured as willingness to pay for goods and services consumed – is the widely used benchmark of economic progress. Thus, many economic policies typically seek to enhance income, and induce more efficient production and consumption of (mainly marketed) goods and services. The stability of prices and employment are among other important objectives. Nevertheless, the equation of welfare with monetary income and material consumption has also been challenged for centuries, while more recently, Maslow (1970) and others have identified hierarchies of needs that provide psychic satisfaction, beyond mere goods and services.

Pareto optimality is considered the goal of economic efficiency. It favours actions that will improve the welfare of at least one individual without worsening the situation of anyone else. The idealized, perfectly competitive economy is an important (Pareto optimal) benchmark. In this state, (efficient) market prices play a key role in both allocating productive resources to maximize output, and ensuring optimal consumption choices which maximize consumer utility. If significant economic distortions are present appropriate shadow prices need to be used. The well known cost-benefit criterion accepts all projects whose net benefits are positive, i.e., aggregate benefits exceed costs (see Section 4). It is based on the weaker 'quasi' Pareto condition, which assumes that such net benefits could be redistributed from the potential gainers to the losers, so that no one is worse off than before. More generally, interpersonal comparisons of (monetized) welfare are fraught with difficulty – both within and across nations, and over time (e.g., the value of human life).

Economic sustainability

The pioneering work of Lindahl and Hicks (1946) laid the foundation for the modern concept underlying economic sustainability. It seeks to maximize the flow of income that could be generated while at least maintaining the stock of assets (or capital) which yield these beneficial outputs (Solow 1986; Maler 1990). Economic efficiency continues to play a key role. It is difficult to identify the kinds of capital to be maintained (for example, manufactured, natural, and human resource stocks, as well as social capital have been identified) and their substitutability (see next section). Further problems arise in valuing these assets and the services they provide, particularly in the case of ecological and social resources (Munasinghe 1992). Uncertainty, irreversibility and catastrophic collapse are issues that pose additional difficulties, in determining sustainable development paths (Pearce and Turner 1990). Marginal analysis based on small perturbations (e.g., comparing incremental costs and benefits of economic activities) is commonly used in microeconomic approaches. Such methods are rather inappropriate for analysing large changes, discontinuous phenomena, and sudden transitions among multiple equilibria, because they assume smoothly changing variables. More recent work (especially at the cutting edge of the economics-ecology interface) has begun to explore the behaviour of large, non-linear, dynamic and chaotic systems, as well as newer concepts like system vulnerability and resilience.

2.3 Environmental Domain

The environmental dimension of development is a more recent concern, arising from the realization that human welfare ultimately depends on ecological services. It seeks to manage scarce natural resources in a prudent manner, reduce pollution, and protect biodiversity, because ignoring safe ecological limits will increase the risk of undermining long-run prospects for development. Dasgupta and Maler (1997) point out that until the 1990s, the mainstream development literature hardly mentioned the topic of environment (see for example, Stern 1989; Chenery and Srinivasan 1988, 1989; and Dreze and Sen

1990). Examples of the growing literature on the theme of environment and sustainable development include books by Faucheux et al. (1996) describing models of sustainable development, and Munasinghe et al. (2001) explicitly addressing the links between growth and environment.

Environmental sustainability

Sustainability in the environmental sense highlights the overall viability and health of ecological systems – defined in terms of a comprehensive, multiscale, dynamic, hierarchical measure of resilience, vigour and organization (Costanza 2000). Holling (1973) provided the classic definition of resilience, based on the ability of an ecosystem to persist despite external shocks. Resilience is determined by the amount of change or disruption that will cause an ecosystem to switch from one system state to another (for further details, see Pimm 1991; Ludwig et al. 1997; and Petersen et al 1998). Vigour, which is associated with the primary productivity of an ecosystem, is analogous to output and growth as an indicator of dynamism in an economic system. Organization depends on both structure and complexity of an ecological or biological system. Higher states of organization imply lower levels of entropy. Thus, the second law of thermodynamics requires that the sustainability of more complex organisms depend on the use of low entropy energy derived from their environment, which is returned as (less useful) high entropy energy. The ultimate source of this energy is solar radiation.

Natural resource degradation, pollution and loss of biodiversity are detrimental because they increase vulnerability, undermine system health, and reduce resilience (Perrings and Opschoor 1994; Munasinghe and Shearer 1995). Carrying capacities and safe thresholds are important concepts to avoid catastrophic ecosystem collapse (Holling 1986). Sustainability may be thought of in terms of the normal functioning and longevity of a nested hierarchy of ecological and socioeconomic systems, ordered according to scale – e.g., a human community would consist of many individuals, each of whom is composed of a large number of cells. 'Panarchy' is a term used to denote such a hierarchy of systems and their adaptive cycles across scales (Gunderson and Holling 2001). Any system is able to operate in its stable (sustainable) mode, because it is invigorated and energized by the faster cycles taking place in the sub-systems below it, while being simultaneously protected by the slower and more conservative changes in the super-system above it. In brief, both conservation and continuity from above, and innovation and change from below, are integral to the panarchy-based approach, helping to resolve the apparent paradox between the simultaneous need for both stability and change.

Maintaining the ecological *status quo* is not necessarily synonymous with sustainable development. From an economic perspective, a coupled ecological-socioeconomic system should evolve so as to maintain a level of biodiversity that will guarantee the resilience of the ecosystems on which human consumption and production depend. Compensation for the opportunities foregone by future generations is required by sustainable development, because today's economic activity narrows the options available to unborn generations.

2.4 Social Domain

The concept of social development involves improvements in both individual well-being and the overall welfare of society (more broadly defined). This process requires increases in social capital – typically, the accumulation of capacity for individuals and groups of people to work together to achieve shared objectives. Social capital has an institutional component, which refers mainly to the formal laws as well as traditional or informal understandings that govern behaviour. It also has an organizational component, which is embodied in the entities (both individuals and social groups) that operate within these institutional arrangements. The stock of social capital is determined by the quantity and quality of social interactions that underlie human existence, including the level of mutual trust and extent of shared social norms. Unlike economic and environmental capital which are depreciated or depleted by use, social capital tends to grow with greater use and erodes through disuse,. Furthermore, some forms of social capital may be harmful (e.g., cooperation within criminal gangs may benefit them, but impose far greater costs on the larger community).

Equity and poverty alleviation are also important elements (see section below). Thus, protective strategies that reduce vulnerability, improve equity and ensure basic needs, are key aspects of social development. Future social development will require socio-political institutions that can adapt to meet the challenges of modernization -- which often destroy traditional coping mechanisms that have evolved in the past (especially to protect disadvantaged groups).

Social sustainability

Many of the ideas discussed earlier regarding environmental sustainability, are also relevant to social sustainability -- since habitats may be interpreted broadly to include also man-made environments like cities and villages (UNEP, IUCN, and WWF 1991). It is important to reduce vulnerability and maintain the health (i.e., resilience, vigour and organization) of social and cultural systems, and their ability to withstand shocks (Chambers (1989; Bohle et al. 1994; Ribot et al. 1996). Key aspects include, enhancing human capital (through education) and strengthening social values and institutions (like trust and behavioural norms). Conversely, weakening social values, institutions and equity will reduce the resilience of social systems and undermine governance. Many such harmful changes occur slowly, and their long term effects are often overlooked in socio-economic analysis. Preserving cultural diversity and cultural capital across the globe, strengthening social cohesion and networks of relationships, and reducing destructive conflicts, are integral elements of this approach. Subsidiarity is an important aspect of empowerment and broader participation – i.e., decentralization of decision making to the lowest (or most local) level at which it is still effective. To summarize, for both ecological and socioeconomic systems, the emphasis is on improving system health and its dynamic ability to adapt to change across a range of spatial and temporal scales, rather than the conservation of some 'ideal' static state.

2.5 Equity and Poverty

Two important issues in this framework are equity and poverty. They have social, economic and environmental dimensions – see Figure 1(a). Recent worldwide statistics are compelling. 1.2 billion people barely survive on under US$1 per day (almost a quarter of the global population). The top 20 percentile of the world's population consumes about 83 percent of total output, while the bottom 20 percentile consumes only 1.4 percent. Inequality is worsening – the per capita income ratio between the richest and the poorest 20 percentile groups, has risen from 30 to 1 in 1960, to over 80 to 1 by 1995. In poor countries, up to half the children under five years of age are malnourished, whereas the corresponding figure in rich countries is less than 5 percent.

Equity has primarily social, and some economic and environmental dimensions. It is an ethical and usually people-oriented concept, which focuses on the basic fairness of both the processes and outcomes of decision making. Societies normally seek to achieve equity by balancing and combining several criteria that help to assess the equity of any action. Such generic approaches include parity, proportionality, priority, utilitarianism, and Rawlsian distributive justice. For example Rawls (1971) stated that "Justice is the first virtue of social institutions, as truth is of systems of thought".

Economic policies seeking to increase overall human welfare, rely on elements like poverty alleviation, improved income distribution and intra-generational (or spatial) equity (Sen 1981, 1984). There are shortcomings in utilitarianism, which underlies much of the economic approach to equity (*Brown 1998*). Broadly speaking, equity principles provide better tools for choosing (from a social perspective) among alternative patterns of consumption, whereas economic efficiency provides guidance on producing and consuming goods and services more efficiently.

Sustainability also depends on social equity, because highly skewed or unfair distributions of income and social benefits are less likely to be acceptable or lasting in the long run. Equity is likely to be strengthened by empowering disadvantaged groups, as well as by enhancing pluralism and grass-roots participation in decision making (Rayner and Malone 1998). Key considerations in the long term include, inter-generational equity and safeguarding the rights of future generations. Meanwhile, the economic discount rate plays a key role with respect to both equity and efficiency aspects (Arrow et al. 1995).

Environmental equity has received more attention recently, because of the disproportionately greater environmental damages suffered by disadvantaged groups. At the same time, poverty alleviation efforts (which traditionally focused on raising monetary incomes), are being broadened to assist the poor -- who also face degraded environmental and social conditions.

Both equity and poverty need to be assessed using a comprehensive set of indicators (rather than income distribution alone), because they have not only economic, but also social and environmental dimensions. From an economic policy perspective, emphasis needs to be placed on expanding employment and gainful opportunities for poor people through growth, improving access to markets, and increasing both assets and education. Social policies would focus on empowerment and inclusion, by making institutions more responsive to the poor, and removing barriers that exclude disadvantaged groups. Environmentally related measures to help poor people might seek to reduce their vulnerability to disasters and extreme weather events, crop failures, loss of employment, sickness, economic shocks, etc. In this context, an important objective of poverty alleviation is to provide poor people with assets (e.g., enhanced physical, human and financial resources) that will reduce their vulnerability. Such assets increase the capacity for both coping (i.e., making short-run changes) and adapting (i.e., making permanent adjustments) to external shocks (Moser 1998). The sustainable livelihoods approach also falls within this framework. It focuses on access to portfolios of assets (social, natural and manufactured), the capacity to withstand shocks, gainful employment, and social processes, within a community or individual oriented context.

The concept of fairness in the treatment of non-human forms of life or even inanimate nature, provides an even broader non-anthropocentric approach to equity. One view asserts that humans have the responsibility of prudent 'stewardship' (or 'trusteeship') over nature, which goes beyond mere rights of usage (see for example, (Brown 1998)).

2.6 Consistent integration of economic, social and environmental considerations

Let us compare the concepts of ecological, social and economic sustainability, before discussing integration. One useful approach stresses the maintenance of the set of opportunities, as opposed to the preservation of the value of the asset base (Githinji and Perrings 1992). Merely preserving a constant valued asset base is less meaningful, if preferences and technology vary through successive generations. The preservation of biodiversity enhances the size of the opportunity set and allows the system to retain resilience against external shocks, in the same manner that preservation of the capital stock protects economic assets for future consumption. However, there are differences. For example, using an ecological approach, loss of resilience (sustainability) implies a reduction in the self-organization of the system, but not necessarily a loss in productivity. By contrast, under the Hicks-Lindahl income measure, a society that consumes its fixed capital without replacement is not sustainable. For social systems, resilience depends to a certain extent on the capacity of human societies to adapt and continue functioning in the face of stresses and shocks. Thus, the similarities between the organization of human societies and ecological systems, and between biodiversity and cultural diversity, indicate parallelism between socio-cultural and ecological sustainability. The concept of co-evolution of social, economic and ecological systems within a larger, more complex adaptive system, provides useful longer term insights regarding the harmonious integration of the various elements of sustainable development – see Figure 1(a) (Munasinghe 1994; Costanza 1997).

A holistic and balanced sustainable development framework needs to integrate and reconcile the economic, social and environmental aspects. Because some of the most important decisions fall within the economic domain, economic analysis has a special role in contemporary national policy making. Until recently, many crucial environmental and social issues had been ignored in mainstream economics. Fortunately, there is a small but growing body of literature which seeks to address such shortcomings – see for example, recent issues of the journals *Ecological Economics* and *Conservation Ecology* (published on the internet).

The concepts of *optimality* and *durability* constitute two broad approaches for integrating the economic, social and environmental dimensions of sustainable development (see Box 2 for details). The main thrust is somewhat different in each case, although there are overlaps between the two approaches. The preferred approach is often determined by uncertainty. For example, subsistence farmers facing chaotic and unpredictable circumstances might opt for a more durable response that simply enhances their survival prospects, whereas relatively steady and well-ordered conditions may encourage macroeconomic planners to rely on optimizing models that attempts to control and even fine-tune outcomes.

Box 2. Integrative Approaches

Optimality

The optimality-based approach has been widely used in economic analysis to generally maximize welfare (or utility), subject to the requirement that the stock of productive assets (or welfare itself) is non-decreasing in the long term This assumption is common to most sustainable economic growth models – for useful reviews, see Pezzey (1992) and Islam (2001). The essence of the approach is illustrated by the simple example of maximization of the flow of aggregate welfare (W), cumulatively discounted over infinite time (t), as represented by the expression: $\mathrm{Max}\int_0^\infty W(C, Z).e^{-rt}\, dt$. Here, W is a function of C (the consumption rate), and Z (a set of other variables that influence welfare), while r is the discount rate. Further side constraints may be imposed to satisfy sustainability needs – e.g., non-decreasing stocks of productive assets (including natural resources).

Some ecological models also optimize variables like energy use, nutrient flow, or biomass production – giving more weight to system vigour as a measure of sustainability. In economic models, utility is often measured mainly in terms of the net benefits of economic activities, i.e., the benefits derived from development activities minus the costs incurred to carry out those actions (for more details about valuation, see Annex 2 below, and *Munasinghe 1992* or *Freeman 1993*). More sophisticated economic optimization approaches seek to include environmental and social variables (e.g., by attempting to value environmental externalities, system resilience, etc). However, given the difficulties of quantifying and valuing many such 'non-economic' assets, the costs and benefits associated with market-based activities tend to dominate in most economic optimization models.

Basically, the optimal growth path maximizes economic output, while the sustainability requirement is met (within this framework) by ensuring non-decreasing stocks of assets (or capital). Some analysts support a 'strong sustainability' constraint, which requires the separate preservation of each category of critical asset (for example, manufactured, natural, socio-cultural and human capital), assuming that they are complements rather than substitutes. One version of this rule might correspond roughly to maximizing economic output, subject to side constraints on environmental and social variables that are deemed critical for sustainability (e.g., biodiversity loss or meeting the basic needs of the poor). Other researchers have argued in favour of 'weak sustainability,' which seeks to maintain the aggregate monetary value of the total stock of assets, assuming that the various asset types may be valued and that there is some degree of substitutability among them (see for example, Nordhaus and Tobin 1972).

Side constraints are often necessary, because the underlying basis of economic valuation, optimization and efficient use of resources may not be easily applied to ecological objectives like protecting biodiversity and improving resilience, or to social goals such as promoting equity, public participation and empowerment. Thus, such environmental and social variables cannot be easily combined into a single valued objective function with other measures of economic costs and benefits (see Sections on cost-benefit and multi-criteria analysis, below). Moreover, the price system (which has time lags) might fail to anticipate reliably irreversible environmental and social harm, and non-linear system responses that could lead to catastrophic collapse. In such cases, non-economic indicators of environmental and social status would be helpful – e.g., area under forest cover, and incidence of conflict (see for example, Munasinghe and Shearer 1995; Hanna and Munasinghe 1995; UNDP 1998; World Bank 1998). The constraints on critical environmental and social indicators are proxies representing safe thresholds, which help to maintain the viability of those systems. In this context, techniques like multicriteria analysis may be required, to facilitate trade-offs among a variety of non-commensurable variables and objectives (see for example, *Meier and Munasinghe 1994*). Risk and uncertainty will also necessitate the use of decision analysis tools [for a concise review of climate change decisionmaking frameworks, see Toth 1999). Recent work has underlined the social dimension of decision science, by pointing out that risk perceptions are subjective and depend on the risk measures used, as well as other factors such as ethno-cultural background, socio-economic status, and gender (Bennet 2000).

Durability

The second broad integrative approach would focus primarily on sustaining the quality of life – e.g., by satisfying environmental, social and economic sustainability requirements. Such a framework favours 'durable' development paths that permit growth, but are not necessarily economically optimal. There is more willingness to trade off some economic optimality for the sake of greater safety, in order to stay within critical environmental and social limits -- especially among increasingly risk-averse and vulnerable societies or individuals who face chaotic and unpredictable conditions (see the discussion on the precautionary principle in Section 3.1). The economic constraint might be framed in terms of maintaining consumption levels (defined broadly to include environmental services, leisure and other 'non-economic' benefits) – i.e., *per capita* consumption that never falls below some minimum level, or is non-declining. The environmental and social sustainability requirements may be expressed in terms of indicators of 'state' that seek to measure the durability or health (resilience, vigour and organization) of complex ecological and socio-economic systems. As an illustrative example, consider a simple durability index (D) for an ecosystem measured in terms of its expected lifespan (in a healthy state), as a fraction of the normal lifespan. We might specify: $D = D(R,V,O,S)$; to indicate the dependence of durability on resilience (R), vigour (V), organization (O), and the state of the external environment (S) – especially in relation to potentially damaging shocks. There is the likelihood of further interaction here due to linkages between the sustainability of social and ecological systems – e.g., social disruption and conflict could exacerbate damage to ecosystems, and *vice versa*. For example, long-standing social norms in many traditional societies have helped to protect the environment (Colding and Folke 1997).

Durability encourages a holistic systemic viewpoint, which is important in sustainomics analysis. The self-organizing and internal structure of ecological and socioeconomic systems makes 'the whole more durable (and valuable) than the sum of the parts'. A narrow definition of efficiency based on marginal analysis of individual components may be misleading (Schutz 1999). For example, it is more difficult to value the integrated functional diversity in a forest ecosystem than the individual species of trees and animals. Therefore, the former is more likely to fall victim to market failure (as an externality). Furthermore, even where correct environmental shadow prices prevail, some analysts point out that cost minimization could lead to homogenization and consequent reductions in system diversity (Daly and Cobb 1989; Perrings et al. 1995). Systems analysis also helps to identify the benefits of cooperative structures and behaviour, which a more partial analysis may neglect. The possibility of many durable paths favours simulation-based methods, including consideration of alternative world views and futures (rather than one optimal result). This approach is consonant with recent research on integrating human actors into ecological models (*Ecological Economics 2000*). Key elements include, multiple-agent modeling to account for heterogeneous behaviour, recognition of bounded rationality leading to different perceptions and biases, and more emphasis on social interactions which give rise to responses like imitation, reciprocity and comparison.

In the durability approach, constraints based on sustainability could be represented also by the approach discussed earlier, which focuses on maintaining stocks of assets. Here, the various forms of capital are viewed as a bulwark that decreases vulnerability to external shocks and reduces irreversible harm, rather than mere accumulations of assets that produce economic outputs. System resilience, vigour, organization and ability to adapt will depend dynamically on the capital endowment as well as the magnitude and rate of change of a shock.

2.7 Reconciling optimal and durable approaches

There is considerable scope to examine how both the optimality and durability approaches might be applied side-by-side, in a consistent manner, to the various sub-models within integrated assessment models or IAMs. In the case of climate change, researchers are currently exploring the application of large and complex IAMs, which contain coupled sub-models that represent a variety of ecological, geophysical and socioeconomic systems – see next section, and (IPCC 1997). The determination of an appropriate target trajectory for future global GHG emissions (and corresponding target GHG concentration) also provides a simple but clear illustration of the interplay of the durability and optimality approaches (for details see Example 1 below, and (IPCC 1996a; Munasinghe 1998a)).

National economic management provides another good example of how the two approaches complement one another. Typically, economywide policies involving both fiscal and monetary measures (e.g., taxes, subsidies, interest rates and foreign exchange rates) might be optimized on the basis of quantitative macroeconomic models. Nevertheless, decision makers inevitably modify these economically 'optimal' policies before implementing them, by taking into account other sociopolitical considerations based more on durability. These considerations include protection of the poor, regional factors, etc., which facilitate governance and stability.

There are several ways to realize the practical potential for convergence of the two approaches. First, wastes ought to be generated at rates less than or equal to the assimilative capacity of the environment – for example, emissions of greenhouse gases and ozone depleting substances into the global atmosphere. Second, renewable resources, especially if they are scarce, should be utilized at rates less than or equal to the natural rate of regeneration. Third, non-renewable resource use should be managed in relation to the substitutability between these resources and technological progress. Both wastes and natural resource input use might be minimized by moving from the linear throughput to the closed loop mode. Thus, factory complexes are being designed in clusters – based on the industrial ecology concept – to maximize the circular flow of materials and recycling of wastes among plants. Finally pluralistic and consultative decision making, inter- and intra-generational equity (especially poverty alleviation), , and enhanced social values and institutions, are important additional aspects that should be considered (at least in the form of safe limits or constraints).

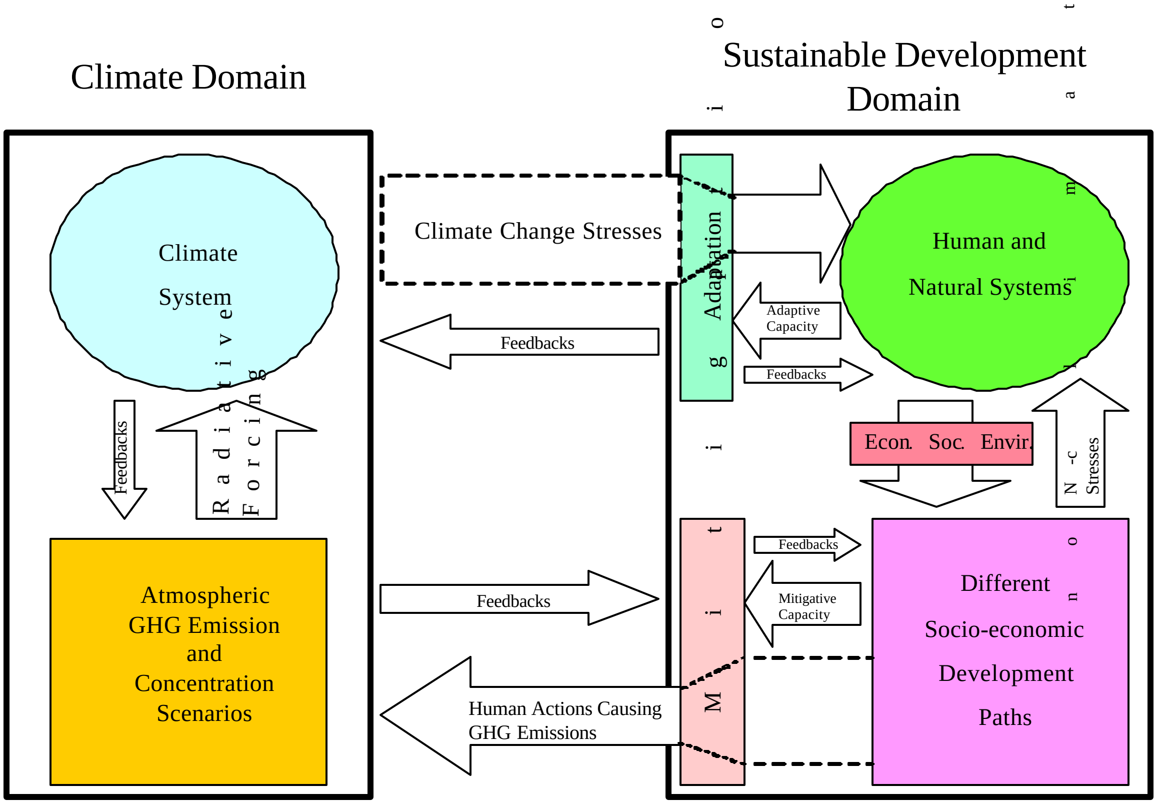
3. NEXUS OF CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

3.1 Circular relationship between climate change and sustainable development

The full cycle of cause and effect between climate change and sustainable development is summarised in Figure 2, which outlines an integrated assessment modelling (IAM) framework (IPCC 2001a).

Each socio-economic development path (driven by the forces of population, economy, technology, and governance) gives rise to different levels of greenhouse gas emissions. These emissions accumulate in the atmosphere, increasing the greenhouse gas concentrations and disturbing the natural balance between incident solar radiation and energy re-radiated from the earth. Such changes give rise to the enhanced greenhouse effect that increases radiative forcing of the climate system. The resultant changes in climate will persist well into the future, and impose stresses on the human and natural systems. Such impacts will ultimately have effects on socio-economic development paths, thus completing the cycle. The development paths also have direct effects on the natural systems, in the form of non-climate stresses such as changes in land use leading to deforestation and land degradation.

Figure 2. Integrated Assessment Modelling (IAM) Framework for Analysing Climate Change and Sustainable Development linkages



Source: Adapted from IPCC 2001a

To summarise, the climate and sustainable development domains interact in a dynamic cycle, characterised by significant time delays. Both impacts and emissions, for example, are linked in complex ways to underlying socio-economic and technological development paths. Adaptation reduces the impact of climate stresses on human and natural systems, while mitigation lowers potential greenhouse gas emissions. Development paths strongly affect the capacity to both adapt to and mitigate climate change in any region. In this way adaptation and mitigation strategies are dynamically connected with changes in the climate system and the prospects for ecosystem adaptation, food production, and long-term economic development.

Thus climate change impacts are part of the larger question of how complex social, economic, and environmental sub-systems interact and shape prospects for sustainable development. There are multiple links. Economic development affects ecosystem balance and, in turn, is affected by the state of the ecosystem. Poverty can be both a result and a cause of environmental degradation. Material- and energy-intensive life styles and continued high levels of consumption supported by non-renewable resources, as well as rapid population growth are not likely to be consistent with sustainable development paths. Similarly, extreme socio-economic inequality within communities and between nations may undermine the social cohesion that would promote sustainability and make policy responses more effective. At the same time, socio-economic and technology policy decisions made for non-climate-related reasons have significant implications for climate policy and climate change impacts, as well as for other environmental issues. In addition, critical impact thresholds, and vulnerability to climate change impacts, are directly connected to environmental, social and economic conditions, and institutional capacity.

3.2 Economic, social and environmental risks arising from climate change

First, global warming poses a significant potential threat to the future economic well-being of large numbers of human beings. In its simplest form, the economic efficiency viewpoint will seek to maximize the net benefits (or outputs of goods and services) from the use of the global resource represented by the atmosphere. Broadly speaking, this implies that the stock of atmospheric assets, which provide a sink function for GHGs needs to be maintained at an optimum level. As indicated in Example 1 below, this target level is defined at the point where the marginal GHG abatement costs are equal to the marginal avoided damages. The underlying principles are based on optimality and the economically efficient use of a scarce resource, i.e., the global atmosphere.

Second, climate change could also undermine social welfare and equity in an unprecedented manner. In particular, more attention needs to be paid to the vulnerability of social values and institutions, which are already stressed due to rapid technological changes (Adger 1999). Especially within developing countries, erosion of social capital is undermining the basic glue that binds communities together – e.g., the rules and arrangements that align individual behaviour with collective goals (Banuri et al. 1994). Existing international mechanisms and systems to deal with transnational and global problems are fragile, and unlikely to be able to cope with worsening climate change impacts.

Furthermore, both intra- and inter-generational equity are likely to be worsened (IPCC 1996a). Existing evidence clearly demonstrates that poorer nations and disadvantaged groups within nations are especially vulnerable to disasters (Clarke and Munasinghe 1995; Banuri 1998). Climate change is likely to result in inequities due to the uneven distribution of the costs of damage, as well as of necessary adaptation and mitigation efforts – such differential effects could occur both among and within countries. Although relevant information is unavailable, on global scale phenomena like climate change, some historical evidence based on large scale disasters like El Nino provide useful insights.

Two catastrophic famines or holocausts during the late nineteenth century, killed tens of millions in the developing world. Recent research indicates that they were the outcome of negative synergies between adverse global environmental factors (i.e., the El-Nino droughts of 1876-78 and 1898-1901), and the inadequate response of socio-economic systems (i.e., vulnerability of tropical farming forcibly integrated into world commodity markets). In the eigteenth century, the quality of life in countries like Brazil, China, and

India were at least on par with European standards. However, colonial dictates and rapid expansion of world trade, re-oriented production in developing countries to service distant European markets. By the time the El-Nino droughts struck in the nineteenth century, the domination of commodity and financial markets by Britain, forced developing country small holders to export at ever deteriorating terms of trade. This process undermined local food security, impoverished large populations, and culminated in holocausts on an unprecedented scale – identified as one major cause of the present state of underdevelopment in the third world. From a sustainomics perspective, the corollary is clear, based on the precautionary principle (see next section). The future vulnerability of developing country food production systems to a combination of climate change impacts and accelerated globalisation of commodity and financial markets, poses significant risks to the survival of billions, especially in the poorest nations.

Inequitable distributions are not only ethically unappealing, but also may be unsustainable in the long run (Burton 1997). For example, a future scenario that restricts *per capita* carbon emissions in the South to 0.5 tons per year while permitting a corresponding level in the North of over three tons per year will not facilitate the cooperation of developing countries, and therefore is unlikely to be durable. More generally, inequity could undermine social cohesion and exacerbate conflicts over scarce resources.

Third, the environmental viewpoint draws attention to the fact that increasing anthropogenic emissions and accumulations of GHGs might significantly perturb a critical global subsystem – the atmosphere (UNFCCC 1993). Environmental sustainability will depend on several factors, including:

- climate change intensity (e.g., magnitude and frequency of shocks);
- system vulnerability (e.g., extent of impact damage); and
- system resilience (i.e., ability to recover from impacts).

Changes in the global climate (e.g., mean temperature, precipitation, etc.) could also threaten the stability of a range of critical, interlinked physical, ecological and social systems and subsystems (IPCC 1996b).

3.3 Vulnerability, resilience, adaptation and adaptive capacity

As discussed earlier, durability criteria or constraints focus on maintaining the quality and quantity dimensions of asset stocks. In the area of climate change, the various forms of capital are viewed as a bulwark that decreases vulnerability to external shocks and reduces irreversible harm, rather than mere accumulations of assets that produce economic outputs. System resilience, vigour, organisation and ability to adapt will depend dynamically on the capital endowment, as well as on the magnitude and rate of change of a shock.

It is useful at this stage to define certain terms more precisely, in the context of climate change (IPCC 2001a). ***Vulnerability*** is the extent to which human and natural systems are susceptible to, or unable to cope with the adverse effects of climate change. It is a function of the character, magnitude and rate of climate variation, as well as the sensitivity and adaptive capacity of the system concerned. ***Resilience*** is the degree of change a system can undergo, without changing state. ***Adaptation*** refers to the adjustments in human and natural systems, in response to climate change stresses and their effects, which moderate damage and exploit opportunities for benefit (*e.g.*, building higher sea walls, or developing drought- and salt-resistant crops). Different types of adaptation include anticipatory versus reactive adaptation, private versus public adaptation, and autonomous versus planned adaptation. ***Adaptive capacity*** is the ability of a system to adjust to climate change.

Strengthening adaptive capacity is a key policy option, especially in the case of the most vulnerable and disadvantaged groups. Adaptive capacity itself will depend on the availability and distribution of economic, natural, social, and human resources; institutional structure and access to decision making processes; information, public awareness and perceptions; menu of technology and policy options; ability to spread risk; etc. (Smit et al. 2001; Yohe and Tol 2001). In turn, performance across these variables is likely to be linked to patterns of economic and social development in a given country or specific location.

3.4 Mitigation and mitigative capacity

The IPCC recently elaborated six different reference scenarios that show a wide variety of alternative development pathways over the next century, each yielding a very different pattern of GHG emissions (IPCC 2000). Lower emission scenarios require less carbon-intensive energy resource development than in the past. In the past decade, progress on GHG emission reduction technologies has been faster than anticipated. Improved methods of land use (especially forests) offer significant potential for carbon sequestration. Although not necessarily permanent, such methods might allow time for more effective mitigation techniques to be developed. Ultimately, mitigation options will be determined by differences in the distribution of natural, technological, and financial resources, as well as mitigation costs across nations and generations (IPCC 2001a).

Although the path to a low emission future will vary by country, the IPCC results indicate that appropriate socio-economic changes combined with known mitigation technology and policy options could help to achieve a range of atmospheric CO2 stabilisation levels around 550 ppmv or less, in the next 100 years. Social learning and innovation, and changes in institutional structure could play an especially important role. Policy options that yield no-regrets outcomes will help to reduce GHG emissions at no or negative social cost. However, the incremental costs of stabilising atmospheric CO2 concentrations over the next century rise sharply as the target concentration level falls from 750 ppmv to 450 ppmv.

Integrating climate policies with non-climate national sustainable development strategy will increase the effectiveness of mitigation efforts. However, there are many technical, social, behavioural, cultural, political, economic, and institutional barriers to implementing mitigation options within countries. Coordinating actions across countries and sectors could reduce mitigations costs, and limit concerns about competitiveness, conflicts over international trade regulations, and carbon leakage. To summarize, early actions including mitigation measures, technology development, and better scientific knowledge about climate change, will increase the possibilities for stabilising atmospheric GHG concentrations.

The effectiveness of future mitigation could be improved by strengthening ***mitigative capacity*** (i.e., the social, political and economic structures and conditions required for mitigation). The mitigative capacity among nations is inevitably varied and suggests that more research and analytic capacity is needed in developing countries. Increases in mitigative capacity could allow climate change considerations to be more effectively integrated with action to address other (non-climate) sustainable development challenges in a manner that effectively limits GHG emissions over time, while maximising the developmental co-benefits of mitigative actions. Such a 'win-win' approach is examined below.

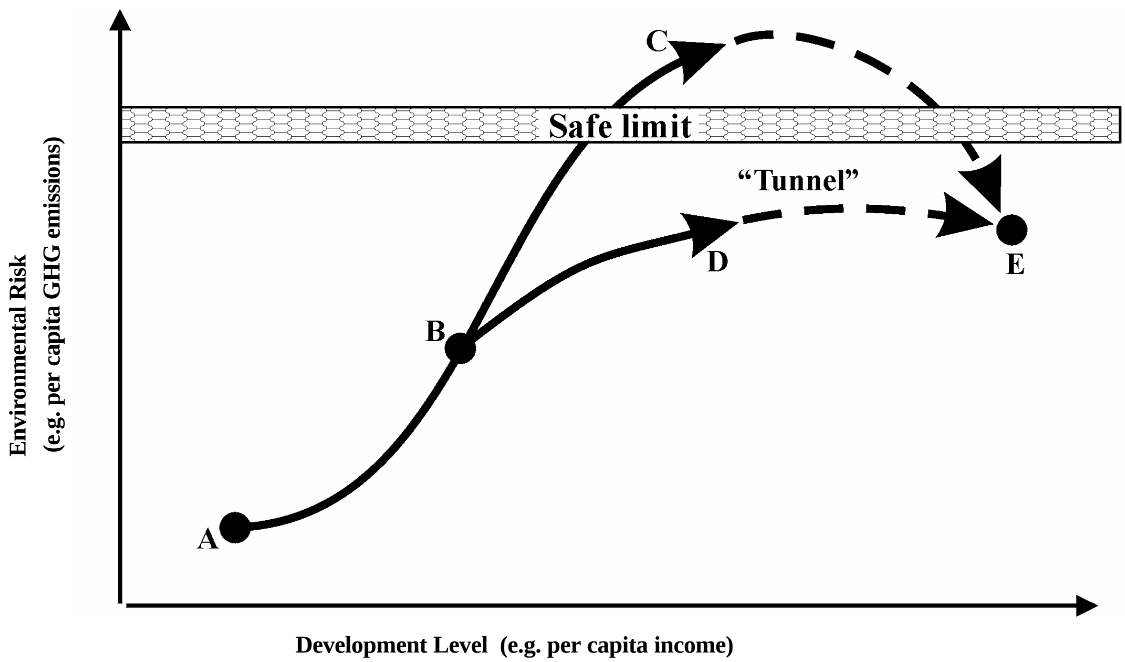
3.5 Tunneling to restructure growth more sustainably

Economic growth continues to be a widely pursued objective of most governments, and therefore, the sustainability of long term growth is a key issue (Munasinghe et al. 2001) – in particular, reducing the intensity of GHG emissions of human activities is an important step in mitigating climate change (Munasinghe 2000). Given that the majority of the world population lives under conditions of absolute poverty, a climate change strategy that unduly constrained growth prospects in those areas would be more unattractive. A sustainomics based approach would seek to identify measures that modify the structure of development and growth rather than restricting it, so that GHG emissions are mitigated and adaptation options enhanced.

The above approach is illustrated in Figure 3, which shows how a country's GHG emissions might vary with its level of development. One would expect carbon emissions to rise more rapidly during the early stages of development (along AB), and begin to level off only when *per capita* incomes are higher (along BC). A typical developing country would be at a point such as B on the curve, and an industrialized nation might be at C. The key point is that if the developing countries were to follow the growth path of the industrialized world, then atmospheric concentrations of GHGs would soon rise to dangerous levels. The risk of exceeding the safe limit (shaded area) could be avoided by adopting sustainable development strategies that would permit developing countries to progress along a path such as BD (and eventually DE), while also reducing GHG emissions in industrialized countries along CE.

As outlined earlier, growth inducing economywide policies could combine with imperfections in the economy to cause environmental harm. Rather than halting economic growth, complementary policies may be used to remove such imperfections and thereby protect the environment. It would be fruitful to encourage a more proactive approach whereby the developing countries could learn from the past experiences of the industrialized world – by adopting sustainable development strategies and climate change measures which would enable them to follow development paths such as BDE, as shown in the Figure (Munasinghe 1998b). Thus, the emphasis is on identifying policies that will help delink carbon emissions and growth, with the curve in Figure 3 serving mainly as a useful metaphor or organizing framework for policy analysis.

Figure 3 Environmental risk versus development level



Source: adapted from Munasinghe (1995)

This representation also illustrates the complementarity of the optimal and durable approaches discussed earlier. It has been shown that the higher path ABC in the Figure could be caused by economic imperfections which make private decisions deviate from socially optimal ones (Munasinghe 1998c). Thus the adoption of corrective policies would reduce such divergences from optimality and reduce GHG emissions per unit of output, thereby facilitating movement along the lower path ABD. Concurrently, the durability viewpoint suggests that flattening the peak of environmental damage (at C) would be especially desirable to avoid exceeding the safe limit or threshold representing dangerous accumulations of GHGs (shaded area in Figure 3).

Several authors have econometrically estimated the relationship between GHG emissions and *per capita* income using cross-country data and found curves with varying shapes and turning points (Holtz-Eakin and Selden 1995; Sengupta 1996; Unruh and Moomaw 1998; Cole et al. 1997). One reported outcome is an inverted U-shape (called the environmental Kuznet's curve or EKC) – like the curve ABCE in the Figure. In this case, the path BDE (both more socially optimal and durable) could be viewed as a sustainable development 'tunnel' through the EKC (Munasinghe 1995, 1998c).

In this context, mitigation policy provides an interesting example of how an integrative framework could help to incorporate climate change response measures within a national sustainable development strategy. The rate of total GHG emissions (G) may be decomposed by means of the following identity:

$$G = [Q/P] \times [Y/Q] \times [G/Y] \times P;$$

where [Q/P] is quality of life per capita; [Y/Q] is the material consumption required per unit of quality of life; [G/Y] is the GHG emission per unit of consumption; and P is the population. A high quality of life can be consistent with low total GHG emissions, provided that each of the other three terms on the right hand side of the identity could be minimized (see also the earlier discussion on ‘tunnelling’ and ‘leapfrogging’). Reducing [Y/Q] implies ‘social decoupling’ (or ‘dematerialization’) whereby satisfaction becomes less dependent on material consumption – through changes in tastes, behaviour and social values. Similarly [G/Y] may be reduced by ‘technological decoupling’ (or ‘decarbonization’) that reduces the intensity of GHG emissions in consumption and production. Finally, population growth needs to be reduced, especially where emissions per capita are already high. The linkages between social and technological decoupling need to be explored (see for example, IPCC 1999). For example, changes in public perceptions and tastes could affect the directions of technological progress, and influence the effectiveness of mitigation and adaptation policies.

3.6 Relevant principles for policy formulation

When considering climate change response options, several principles and ideas which are widely used in environmental economics analysis would be useful – these include the polluter pays principle, economic valuation, internalization of externalities, and property rights. The polluter pays principle argues that those who are responsible for damaging emissions should pay the corresponding costs. The economic rationale is that this provides an incentive for polluters to reduce their emissions to optimal (i.e., economically efficient) levels. Here, the idea of economic valuation becomes crucial. Quantification and economic valuation of potential damage from polluting emissions is an important prerequisite. In the case of a common property resource like the atmosphere, GHG emitters can freely pollute without penalties. Such ‘externalities’ need to be internalized by imposing costs on polluters that reflect the damage caused. An externality occurs when the welfare of one party is affected by the activity of another party who does not take these repercussions into account in his/her decision making (e.g., no compensating payments are made). The theoretical basis for this is well known since Pigou (1932) originally defined and treated externalities in rigorous fashion. In this context, the notion of property rights is also relevant to establish that the atmosphere is a valuable and scarce resource that cannot be used freely and indiscriminately.

An important social principle is that climate change should not be allowed to worsen existing inequities – although climate change policy cannot be expected to address all prevailing equity issues. Some special aspects include:

- the establishment of an equitable and participative global framework for making and implementing collective decisions about climate change;
- reducing the potential for social disruption and conflicts arising from climate change impacts; and
- protection of threatened cultures and preservation of cultural diversity.

While economic theory is best suited to designing efficient economic policies, ethical and social considerations are helpful in addressing equity issues (Pinguelli-Rosa and Munasinghe 2002). From the social equity viewpoint, the polluter pays principle (mentioned above) is based not only on economic efficiency, but also on fairness. An extension of this idea is the principle of recompensing victims – ideally by using the revenues collected from polluters. There is also the moral/equity issue concerning the extent of the polluters' obligation to compensate for past emissions (i.e., a form of environmental debt). As mentioned earlier, weighting the benefits and costs of climate change impacts according to the income levels of those who are affected, has also been suggested as one way of redressing inequitable outcomes. Kverndokk (1995) argued that conventional justice principles would favour the equitable allocation of future GHG emission rights on the basis of population. Equal *per capita* GHG emission rights (i.e., equal access to the global atmosphere) is consistent also with the UN human rights declaration underlining the equality of all human beings.

Traditionally, economic analysis has addressed efficiency and distributional issues separately – i.e., the maximization of net benefits is distinct from who might receive such gains. Recent work has sought to interlink efficiency and equity more naturally. For example, environmental services could be considered public goods, and incorporated into appropriate markets as privately produced public goods (Chichilnisky and Heal 2000).

Several other concepts from contemporary environmental and social analysis are relevant for developing climate change response options, including the concepts of durability, optimality, safe limits, carrying capacity, irreversibility, non-linear responses, and the precautionary principle. Broadly speaking, durability and optimality are complementary and potentially convergent approaches (see earlier discussion). Under the durability criterion, an important goal would be to determine the safe limits for climate change within which the resilience of global ecological and social systems would not be seriously threatened. In turn, the accumulations of GHGs in the atmosphere would have to be constrained to a point, which prevented climate change from exceeding these safe margins. It is considered important to avoid irreversible damage to bio-geophysical systems and prevent major disruption of socioeconomic systems. Some systems may respond to climate change in a non-linear fashion, with the potential for catastrophic collapse. Thus, the precautionary principle argues that lack of scientific certainty about climate change effects should not become a basis for inaction, especially where relatively low cost steps to mitigate climate change could be undertaken as a form of insurance (UNFCCC 1993).

4. TOOLS FOR ANALYSIS AND ASSESSMENT

Some important tools and policy principles that may be used for analysis and assessment are summarised below. More details are provided in Annex 2.

4.1 Action impact matrix (AIM)

The Action Impact Matrix (AIM) is a tool to facilitate the sustainability of development by analysing economic, environmental and social interactions of various development policies. Global environmental problems, such as climate change, should be a key aspect of the assessment. For example, macroeconomic policies adopted routinely by national policy makers often have significant environmental and social impacts (Munasinghe 2002). In particular, such policies shape the development paths of nations, which in turn affect not only the severity of future climate change impacts, but also vulnerability to climate change, as well as adaptive and mitigative capacities.

The AIM approach will help to find 'win-win' policies and projects, which not only achieve conventional macroeconomic objectives (like growth), but also make local and national development efforts more sustainable. With respect to climate change, the approach can identify key linkages between development efforts and climate change issues like vulnerability, impacts (including changes in GHG emission levels), mitigation and adaptation. It would help to identify development paths that embed national climate change policies in the overall sustainable development strategy.

The process of preparing the matrix encourages stakeholder participation in identifying priority issues and relevant data, posing the appropriate questions, interpreting the results, and formulating and implementing policy outcomes. In particular, it facilitates consensus building among the development, climate change, and environmental communities.

The AIM itself promotes an integrated view, meshing development decisions with priority economic, environmental and social impacts. Usually, the rows of the table list the main development interventions (both policies and projects), while the columns indicate key sustainable development issues and impacts (including climate change vulnerability). Thus the elements or cells in the matrix help to:

- identify explicitly the key issues and linkages;
- focus the analysis on the most important vulnerabilities and issues; and
- suggest action priorities and remedies.

At the same time, the organisation of the overall matrix facilitates the tracing of impacts via complex pathways, as well as the coherent articulation of the links among a range of development actions - both policies and projects. More details are provided in Example 2.

4.2 Indicators

It will be important to monitor if and how climate change or climate change policies may affect stocks of natural, social and economic capital in different regions of the world. The risks to natural and economic capital are well documented in the recent IPCC Third Assessment Report (IPCC 2001a - Ch.19 of WGII; IPCC 2001b - Section 3), whereas the social dimension is more difficult to measure and has only received attention in the past few years. For example, recent OECD work advances definitions of human capital to encompass human well-being -- measured through education and health indicators and social capital as networks of shared norms, values and understanding that facilitates co-operation within and between groups (OECD 2001). However these concepts of social capital have not yet been systematically applied in the assessment of climate change impacts or of climate policies. Nevertheless, these different types of stocks of assets are central to the optimality and durability approaches, as well as to the capacity to adapt to and mitigate climate change, and multi-dimensional indicators could be useful in assessing policy options. Annex 2 (Section A2.1) summarises the literature which describe a wide variety of indicators that are already in use. It may be possible to adapt some of these for use in the assessment of connections between development and climate policies.

4.3 Cost-Benefit Analysis (CBA)

Cost-benefit analysis (CBA) is one well-known example of a single value approach, which seeks to assign economic values to the various consequences of an economic activity. The resulting costs and benefits are combined into a single decision making criterion like the net present value (NPV), internal rate of return (IRR), or benefit-cost ratio (BCR). Useful variants include cost effectiveness, and least cost based methods. Both benefits and costs are defined as the difference between what would occur *with and without* the project being implemented. The economic efficiency viewpoint usually requires that shadow prices (or opportunity costs) be used to measure costs and benefits. All significant impacts and externalities need to be valued as economic benefits and costs. However, since many environmental and social effects may not be easy to value in monetary terms, CBA is used in practice mainly as a tool to assess economic and financial outcomes. Annex 2 (Section A2.2) provides further details.

4.4 Multi-Criteria Analysis (MCA)

Multi-criteria analysis (MCA) or multi-objective decision-making is particularly useful in situations when a single criterion approach like CBA falls short – especially where significant environmental and social impacts cannot be assigned monetary values (see Annex 2, Section A2.3). In MCA, desirable objectives are specified and corresponding attributes or indicators are identified. Unlike in CBA, the actual measurement of indicators does not have to be in monetary terms – *i.e.*, different environmental and social indicators may be developed, side by side with economic costs and benefits. Thus, more explicit recognition is given to the fact that a variety of both monetary and non-monetary objectives and indicators may influence policy decisions. MCA provides techniques for comparing and ranking different outcomes, even though a variety of indicators are used.

4.5 Sustainable Development Assessment (SDA)

Sustainable development assessment (SDA) is an important tool to ensure balanced analysis of both development and sustainability concerns. The 'economic' component of SDA is based on conventional economic and financial analysis (including cost benefit analysis, as described earlier). The other two key components are environmental and social assessment (EA and SA) – *e.g.*, see World Bank 1998. Poverty assessment is often interwoven with SDA. Economic, environmental and social analyses need to be integrated and harmonised within SDA. Since traditional decision making relies heavily on economics, a first step towards such an integration would be the systematic incorporation of environmental and social concerns into the economic policy framework of human society (see Annex 2, Section A2.4).

5. EXAMPLES ANALYSING THE LINKAGES BETWEEN SUSTAINABLE DEVELOPMENT CLIMATE CHANGE

The concepts outlined above are highlighted in practical examples outlined below. These case studies provide additional insights into the potential convergence between optimality and durability approaches, and the practical use of the various analytical tools to make development MORE sustainable at the global-transnational, national, sub-national and local-project scales.

5.1 Global-transnational scale: climate change policy objectives

The climate change problem fits in quite readily within the broad conceptual framework of sustainomics, described above. For a variety of reasons described in the previous section, decision makers are beginning to show more interest in the assessment of how serious a threat climate change poses to the future basis for improving human welfare (Munasinghe 2000; Munasinghe and Swart 2000). Typically, increased GHG emissions and other unsustainable practices are likely to undermine the security of nations and communities, through economic, social and environmental impoverishment, as well as inequitable distribution of adverse impacts – with undesirable consequences such as large numbers of 'environmental' refugees (Lonergan 1993; Ruitenbeek 1996; Westing 1992).

Thus, human-induced climate change is a global environmental problem that will have impacts at the local, regional and (potentially) global levels. Successfully limiting the pace and extent of the harmful effects of climate change will require international co-operation. The first example examines the interplay of impacts, adaptation, and mitigation, with optimality and durability based approaches in determining global GHG emission levels (Munasinghe 2001). GHG concentrations should "be stabilised at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (Article 2, UNFCCC 1993).

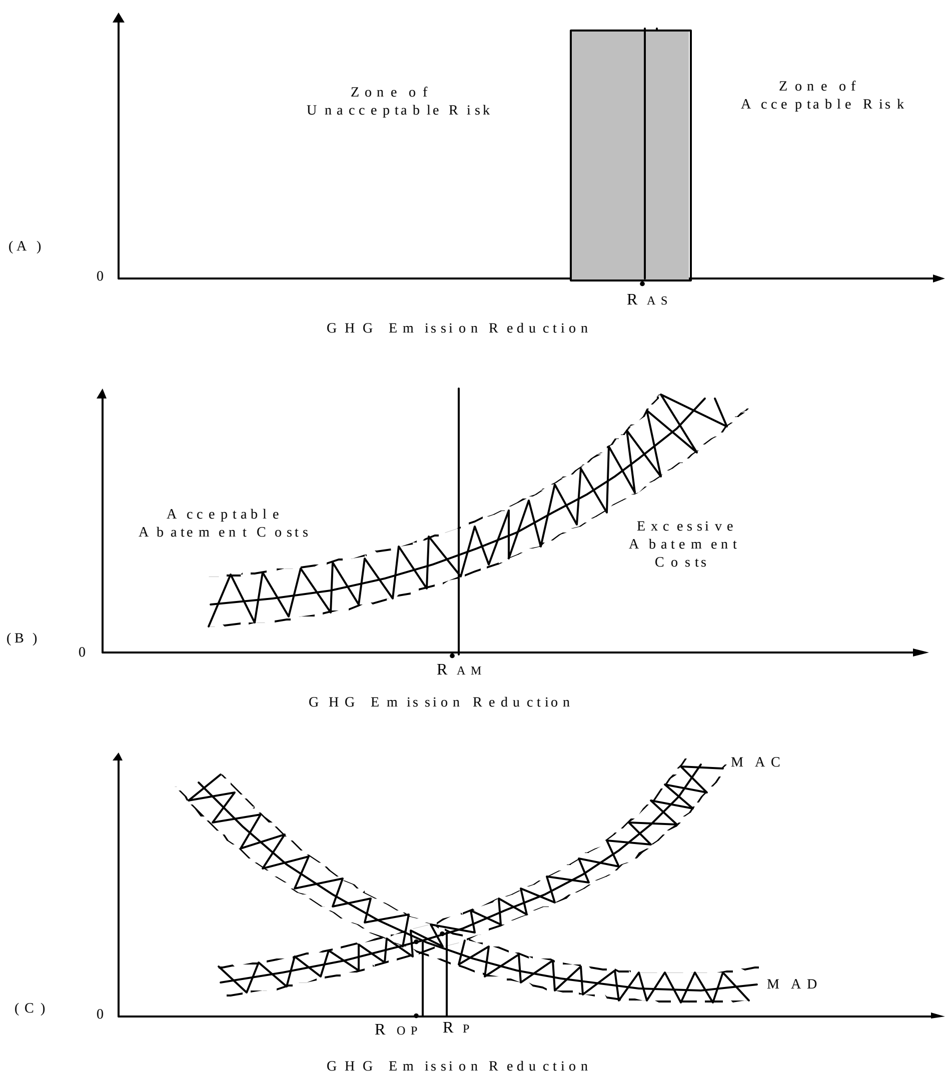
<u>Example 1</u>: Setting global objectives for climate change co-operation

Under an economic optimising framework, the ideal solution would be to estimate two curves associated with different GHG emission profiles:

a) the marginal avoided damages (MAD) which depends on climate change impacts and adaptation costs; and
b) the long-run marginal abatement costs (MAC) based on mitigation efforts.

The MAD and MAC curves are shown in Figure 4(c), where the error bands on the curves indicate measurement uncertainties (IPCC 1996a).

Figure 4. Determining Global Abatement Targets based on different approaches: A) absolute standard; B) affordable standard; C) cost-benefit optimum



Source: Adapted from IPCC 1996a

The optimisation approach indicates that the desirable emission level would be determined at the point where future benefits (in terms of climate change damage avoided by reducing one unit of GHG emissions) are just equal to the corresponding costs (of mitigation measures required to reduce that unit of GHG emissions), *i.e.*, MAD = MAC at point ROP.

"Durable" strategies become more relevant when we recognise that MAC and/or MAD might be poorly quantified and uncertain. Figure 4(b) assumes that MAC is better defined than MAD. Here, MAC is determined using techno-economic least cost analysis – an optimising approach. Next, the target emissions are set on the basis of the affordable safe minimum standard (at R_{AM}), which is the upper limit on costs that will still avoid unacceptable socio-economic disruption. This line of reasoning takes into consideration the capability of social and economic systems to absorb the shock of the financial burden of mitigation, and is closer to the durability approach.

Finally, Figure 4(a) indicates an even more uncertain world, where neither MAC nor MAD is defined. Here, the emission target is established on the basis of an absolute standard (R_{AS}) or safe limit, which would avoid an unacceptably high risk of impact damage to ecological (and/or social) systems. This last approach places greater emphasis on vulnerability, impacts and adaptation, and would be more in line with the durability concept.

5.2 National-economy-wide scale: macroeconomic management

At the project level, conventional economic valuation of environmental impacts is a key step in incorporating the results of environmental assessment into economic decision making – *e.g.*, cost-benefit analysis (see also Annex 2, Section A2.4). Meanwhile, at the macroeconomic level, recent work has focused on incorporating environmental considerations such as depletion of natural resources and pollution damage into the system of national accounts. These efforts have yielded useful new indicators and measures of national product and wealth, including natural resource (stock) accounts, resource and pollutant flow accounts, environmental expenditure accounts, and alternative national accounts aggregates (Atkinson et al. 1997). An important umbrella framework is the United Nations Integrated System of Environmental and Economic Accounting (SEEA), which is the first step towards standardizing the various accounting approaches (UN Statistical Office 1993). The SEEA is designed to be a *satellite* account to the conventional System of National Accounts (SNA), i.e., it is an adjunct to rather than a modification of the core accounts. It is highly complex, involving disaggregation of the standard accounts to highlight environmental relationships, linked physical and monetary accounting, imputations of environmental costs, and extensions of the production boundary of the SNA. A comprehensive framework like the SEEA may be used to estimate various national accounts aggregates such as 'green GNP' and 'genuine savings' -- which are usually adjusted downward to reflect the costs of net resource depletion and environmental pollution (Munasinghe 2002).

Meanwhile, national policy-makers routinely make many key macro-level decisions that could have (often inadvertent) environmental and social impacts, which are far more significant than the effects of local economic activities. These pervasive and powerful measures are aimed at achieving economic development goals like accelerated growth – which invariably have a high priority in national agendas. Typically, many macroeconomic policies seek to induce rapid growth, which in turn could potentially result in greater environmental harm or impoverishment of already disadvantaged groups. In particular, such policies shape the development paths of nations, which in turn affect the vulnerability to climate change, as well as adaptive and mitigative capacities. Therefore, more attention needs to be paid to such economy-wide policies, whose environmental and social linkages have not been adequately explored in the past (Munasinghe and Cruz 1994).

Clearly, sustainable development strategies (including options that reduce vulnerability and strengthen adaptive and mitigative capacities), need to be made more consistent with other national development policies. Such strategies are more likely to be effective than isolated technological or policy options. In particular, the highest priority needs to be given to finding any 'win-win policies', which not only achieve conventional macroeconomic objectives, but also make local and national development efforts more sustainable, and address climate change issues. Such policies could help to build support for sustainable climate change strategies among the traditional decision making community, and conversely make climate specialists more sensitive to shorter term macroeconomic and development goals. They would reduce the potential for conflict between two powerful current trends – the growth oriented, market based economic reform process, and protection of the global environment.

Scope of policies and range of impacts

The most important economic management tools currently in common use are economy-wide reforms, which include structural adjustment packages. Economy-wide (or country-wide) policies consist of both sectoral and macroeconomic policies that have widespread effects throughout the economy. Sectoral measures mainly involve a variety of economic instruments, including pricing in key sectors (for example, energy or agriculture) and broad sector-wide taxation or subsidy programs (for example, agricultural production subsidies, and industrial investment incentives). Macroeconomic measures are even more sweeping, ranging from exchange rate, interest rate, and wage policies, to trade liberalisation, privatisation, and similar programs. Since space limitations preclude a comprehensive review of interactions between economy-wide policies and sustainable development, we briefly examine several examples that provide a flavour of the possibilities involved (for details, see Munasinghe 1996; Jepma and Munasinghe 1998).

On the positive side, liberalising policies such as the removal of price distortions and promotion of market incentives have the potential to improve economic growth rates, while increasing the value of output per unit of pollution emitted (*i.e.,* so called 'win-win' outcomes). For example, improving property rights and strengthening incentives for better land management not only yield economic gains and reduce deforestation of open access lands (*e.g.*, due to 'slash and burn' agriculture), but also help to reduce vulnerability, improve the adaptive capacity of ecosystems, and mitigate greenhouse gas emissions.

At the same time, growth-inducing economy-wide policies could lead to increased environmental damages and greater vulnerability to climate change, unless the macro-reforms are complemented by additional environmental and social measures. Such negative impacts are invariably unintended and occur when some broad policy changes are undertaken while other hidden or neglected economic and institutional imperfections persist (Munasinghe and Cruz 1994). In general, the remedy does not require reversal of the original reforms, but rather the implementation of additional complementary measures (both economic and non-economic) that reduce climate change vulnerability and increase adaptive and mitigative capacities. For example, export promotion measures and currency devaluation might increase the profitability of timber exports (see the example below). This in turn, could further accelerate deforestation that was already under way due to low stumpage fees and open access to forest lands. Establishing property rights and increasing timber charges would reduce deforestation, thereby diminishing vulnerability to climate change and improving both adaptation and mitigation prospects, without interrupting the macroeconomic benefits of trade liberalisation.

Similarly, market-oriented liberalisation in a country could lead to economic expansion and the growth of wasteful resource-intensive activities in certain sectors – if such growth was associated with subsidised resource prices. Such a situation is reported in a case study of Morocco, where irrigation water is the scarce resource affected by economic expansion (Munasinghe 1996). Eliminating the relevant resource price subsidy could help to reduce local water scarcities and reduce vulnerability to future climate change, while enhancing macroeconomic gains. Other countrywide policies could influence adaptation to climate change, negatively or positively. For example, national policies that encouraged population movement into low-lying coastal areas might increase their vulnerability to future impacts of sea level rise. On the other hand, government actions to protect citizens from natural disasters – such as investing in safer physical infrastructure or strengthening the social resilience of poorer communities – could reduce vulnerability to extreme weather events associated with future climate change (Clarke and Munasinghe 1995).

In this context, systematic assessment of economic-environmental-social interactions helps to formulate effective sustainable development policies, by linking and articulating these activities explicitly. In particular, it is important to identify those systems, sectors and communities that are likely to be the most vulnerable to climate change, especially if they are already under threat due to existing national policies. Implementation of such an approach would be facilitated by constructing a simple Action Impact Matrix or AIM, as described below in Example 2 (Munasinghe and Cruz 1994).

***Example 2*: Action impact matrix (AIM) for policy analysis**

A simple example of the Action Impact Matrix (AIM) – is shown in Table 1, although an actual AIM would be very much larger and more detailed (Munasinghe 1992, 1996). The far left column of the Table lists examples of the main development interventions (both policies and projects), while the top row indicates some typical sustainable development issues -- including climate change vulnerability and adaptive and mitigative capacity.

Table 1. A simplified preliminary Action Impact Matrix (AIM).[1]

Activity/Policy	*Main (Economic) Objective*	***Impacts On Key Sustainable Development Issues*** *Land Degradation & Biodiversity Loss*	*Water Scarcity & Pollution*	*Resettlement & Social Effects*	*Climate Change Effects (eg, vulnerability, impacts and adaptation; and mitigation)*
	(A)	**(B)**	**(C)**	**(D)**	**(E)**
Macro-economic & Sectoral Policies	Macroeconomic and sectoral improvements	Positive impacts due to removal of distortions Negative impacts mainly due to remaining constraints			
Exchange Rate **(1)**	Improve trade balance and economic growth	(-H) (deforest open-access areas)			(-M) (more vulnerable, less adaptive & mitigative capacity)
Water Pricing **(2)**	More efficient water use and economic efficiency		(+M) (water use efficiency)		(+M) (less vulnerable, better adaptive capacity)
Others **(3)**					
Complementary Measures and Remedies[2]	Specific socio-economic and environmental gains	Enhance positive impacts and mitigate negative impacts (above) of broader macroeconomic and sectoral policies			
Market Based **(4)**			(+M) (pollution tax)		(+L) (less vulnerable)
Non-Market Based **(5)**		(+H) (property rights)	(+M) (public sector accountability)		
Investment Projects	Improve effectiveness of investments	Investment decisions made more consistent with broader policy and institutional framework			
Project 1 (*Hydro Dam*) **(6)**		(-H) (inundate forests)		(-M) (displace people)	(+M, -L) (less fossil fuel use, more vulnerable)
Project 2 *(Re-afforest and relocate)* **(7)**		(+H) (replant forests)		(+M) (relocate people)	(+M) (absorb carbon, less vulnerable)
Other Projects					

Source : adapted from Munasinghe and Cruz (1994)

Notes:

1. A few examples of typical policies and projects as well as illustrative impact assessments are indicated. + and - signify beneficial and harmful impacts, while H and M indicate high and moderate intensity. The AIM process helps to focus on the highest priority economicsocial and environmental issues.

2. Commonly used market-based measures include effluent charges, tradable emission permits, emission taxes or subsidies, bubbles and offsets (emission banking), stumpage fees, royalties, user fees, deposit-refund schemes, performance bonds, and taxes on products (such as fuel taxes). Non-market based measures comprise regulations and laws specifying environmental standard (such as ambient standards, emission standards, and technology standards) which permit or limit certain actions ('dos' and 'don'ts').

As indicated earlier, the elements or cells in the matrix help to explicitly identify the key issues and linkages, focus the analysis on the most important vulnerabilities and adaptation issues, and suggest action priorities and remedies. At the same time, the organisation of the overall matrix facilitates the tracing of impacts, as well as the coherent articulation of the links among development policies and projects.

Table 2. Typical Elements from a Vulnerabilities Table

ISSUE	BIO-PHYSICAL IMPACTS	SOCIO-ECONOMIC IMPACTS	CAUSES AND DRIVERS
Deforestation and Biodiversity Loss	Area under forest cover, threatened species, etc.	Stakeholder income levels, livelihoods at risk, value of forest loss, etc.	Landless population, open access to forests, lack of stumpage fees, etc.

The next task would be the preparation of a ***'development activities table'*** (Table 3). The first column of this table would contain major development goals and policies, such as an exchange rate devaluation (to improve the balance of payments). The second column might indicate the current status from a development perspective – in the forest sector, typical effects might include balance of payments improvement due to greater timber exports, increased timber demand for exports and local construction, higher deforestation rate, illegal felling, and 'slash and burn' agriculture. The third column could contain environmental and climate related implications, such as threats to the adaptive capacity of forest areas, soil erosion, and loss of watersheds. The fourth column would set out ongoing or proposed remedies, including restricted access to forests, better enforcement, higher stumpage fees, and re-afforestation. A normal development activities table would summarise information on many such major policy areas, dealing with acceleration of economic growth, import substitution, fiscal and monetary balance, industrialisation, agricultural self-sufficiency, energy development, etc.

Table 3. Typical Elements from a Development Activities Table

DEVELOPMENT GOALS AND POLICIES	DEVELOPMENT IMPACTS	ENVIRONMENT AND CLIMATE IMPACTS	REMEDIES
Exchange rate devaluation to improve balance of payments	**Forest Sector** Higher timber demand for exports and local construction, increased deforestation, illegal timber felling, 'slash and burn' agriculture, etc.	Adaptive capacity of forests, watershed loss, soil erosion, etc.	Restrict forest access, better enforcement, higher stumpage fees, more re-afforestation, etc.

The AIM would be put together by bringing all stakeholders together, to integrate the information in the two tables prepared earlier. Table 3 shows how a simple AIM might be organised, by combining information on development activities and vulnerabilities.

Screening and problem identification

One of the early objectives of the AIM-based process is to help in *screening and problem identification* – by preparing a preliminary matrix that identifies broad relationships, and provides a qualitative idea of the magnitudes of the impacts. Thus, the preliminary AIM would be used to prioritise the most important links between policies and their sustainability impacts (especially climate effects). As mentioned earlier, row (1) of Table 3 shows how a currency devaluation aimed at improving the trade balance, may make timber exports more profitable and lead to deforestation of open access forests. Column (A) indicates a negative local environmental side effect involving severe land degradation and biodiversity loss. In the same row, column (D) shows negative climate change effects, including greater vulnerability etc. Some air pollution and GHG emissions due to burning of wood might also occur, although this is not indicated here. Potential remedial policies are shown lower down in column (A) – *e.g.*, complementary measures to strengthen property rights and restrict access to forest areas, which would prevent the deforestation. As shown in column (D), such steps would reverse the negative climate change effects.

A second example shown in row (2) involves raising (subsidised) water prices to reflect marginal supply costs -- to improve the efficiency of water use, and thereby have the additional positive effect of decreasing water scarcity [column (B)] and reducing vulnerability to future climate change [column (D)]. A complementary measure indicated in row (4), column (B) consists of adding water pollution taxes to water supply costs, which will help to reduce both water pollution and damage to human and ecological health, while reducing vulnerability to climate change. As shown in row (5), column (B), improving competition and public sector accountability will reinforce favourable responses to these price incentives, by reducing the ability of inefficient firms to pass on the increased costs of water to consumers or to transfer their losses to the government.

The third example involves a major hydroelectric project, shown in row (6), which has two adverse impacts (inundation of forested areas and village dwellings), as well as one net positive impact (the replacement of thermal power generation, which would reduce air pollution and GHG emissions – despite potential methane emissions from inundated vegetation). A re-afforestation project coupled with resettlement schemes, as indicated in row (7), would help to address the negative impacts.

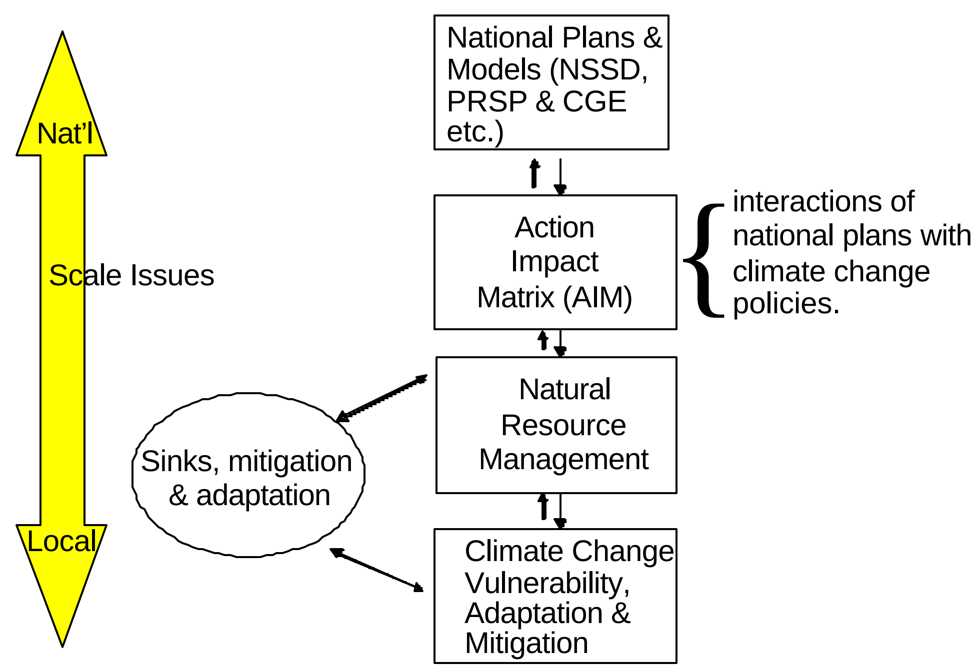
This matrix-based approach therefore encourages the systematic articulation and co-ordination of policies and projects to make development more sustainable. Based on readily available data, it would be possible to develop such an initial matrix as the organising framework for case studies in the OECD project.

Analysis and remediation

This process may be developed further to assist in *analysis* and *remediation*. For example, more detailed analyses and modelling may be carried out for those matrix elements in the preliminary AIM that had been already identified as representing high priority linkages between development activities and climate change vulnerabilities, impacts and adaptation. This, in turn, would lead to a more refined and updated AIM, which would help to quantify impacts and formulate additional policy measures to enhance positive linkages and mitigate negative ones.

The types of more detailed analyses, which could be applied to the high priority matrix elements in the AIM, would be case specific and depend on planning goals, available data and resources. They may range from the application of conventional sectoral economic analysis methods (appropriately modified in scope to incorporate environmental impacts), to fairly comprehensive system or multisector modelling efforts – including computable general equilibrium (CGE) models that include both conventional economic, as well as environmental or resource variables. Sectoral and partial equilibrium analyses are more useful to trace details of direct impacts, whereas CGE modeling provides a more comprehensive but aggregate view, and insights into indirect linkages (Munasinghe 1996, 2002). Often, such models are built around an expanded input-output (I-O) table or social accounting matrix (SAM), which includes information based on an integrated system of environmental and economic accounts (SEEA – discussed earlier). The expanded I-O, SAM and SEEA framework helps to incorporate environmental and social considerations into sectoral and macroeconomic analysis. As a typical example Figure 5 summarises the flow of the analytical process linking broad national-level development plans and models, to detailed climate change vulnerabilities, impacts, adaptation, and mitigation at the local level.

Figure 5. Assessing the linkages between national development plans and climate policy (adaptation and mitigation) using the Action Impact Matrix (AIM)



Source: OECD (2002).

5.3 Sub-national scale: energy sector planning and policy analysis

At the sub-national scale, sustainable development issues arise in various forms. In this section, we consider an example dealing with issues in the important energy sector of the Sri Lankan economy.

***Example 3*: Improving energy sector decision-making in Sri Lanka**

Actions that affect an entire economic sector or region of a country can have significant and pervasive environmental and social impacts. Thus typically, policies in a given sector like energy have widespread impacts on other sectors of the economy. This requires an integrated, multi-sectoral analytic framework (Munasinghe 1990).

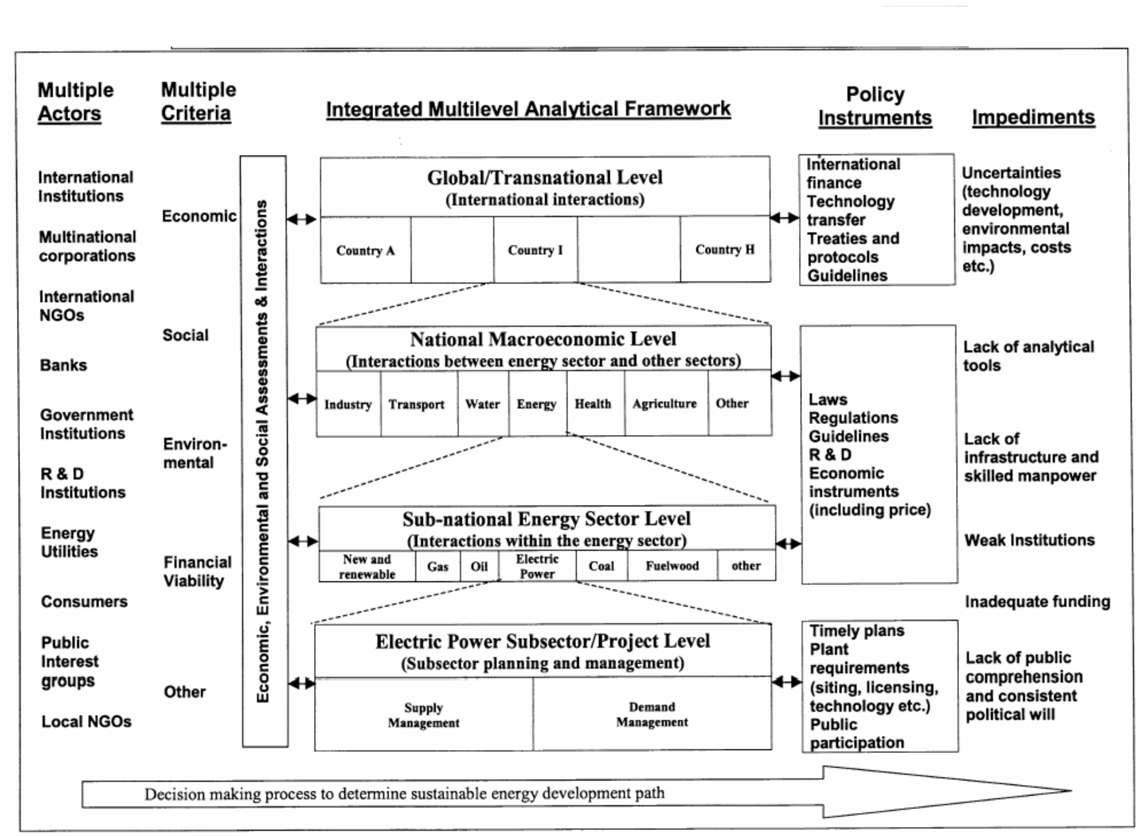
Sustainable energy development framework

A framework for sustainable energy decision making is depicted in Figure 6. The middle column of the Figure shows the core of the framework comprising an integrated multilevel analysis that can accommodate issues ranging from the global scale down to the local or project level. At the top level, individual countries constitute elements of an international matrix. Economic and environmental conditions imposed at this global level constitute exogenous inputs or constraints on national level decision-makers. Typical examples of such external constraints include emerging agreements under the UNFCCC, which have implications for both adaptation and mitigation.

The next level in the hierarchy focuses on the multi-sectoral national economy, of which the energy sector is one element. This level of the framework recognises that planning within the energy sector requires analysis of the links between that sector and the rest of the economy. At the third or sub-national level, we focus on the energy sector as a separate entity composed of sub-sectors such as electricity, petroleum products and so on. This permits detailed analysis, with special emphasis on interactions among different energy sub-sectors. Finally, the most disaggregate and lowest hierarchical level pertains to energy analysis within each of the energy sub-sectors. At this level, most of the detailed energy planning and implementation of projects is carried out by line institutions (both public and private).

In practice, the various levels of analysis merge and overlap considerably, requiring that inter-sectoral linkages should be carefully examined. Energy-economic-environmental-social interactions (represented by the vertical bar) tend to cut across all levels and need to be incorporated into the analysis as far as possible. Such interactions also provide important paths for incorporating environmental and social considerations into sustainable energy development policies.

Figure 6 Framework for sustainable energy development



Source: adapted from Munasinghe (1990)

Methodology

The incorporation of environmental and social externalities into decision making is particularly important in the electric power sector (see also Annex 2, Section A2.4). It is also clear that in order for environmental and social concerns to play a real role in power sector decision making, one must address these issues early -- at the sectoral and regional planning stages, rather than later at the stage of environmental and social assessment of individual projects. Many of the valuation techniques discussed earlier are most appropriate at the micro-level, and may therefore be very difficult to apply in situations involving choices among a potentially large number of technology, site, and mitigation options. Therefore, multi-criteria analysis (MCA) may be applied, since it allows for the appraisal of alternatives with differing objectives and varied costs and benefits, which are often assessed in differing units of measurement.

Such an approach was used by Meier and Munasinghe (1994) in a study of Sri Lanka, to demonstrate how externalities could be incorporated into power system planning in a systematic manner. Sri Lanka presently depends largely on hydro power for electricity generation, but over the next decade the main choices seem to be large coal- or oil-fired stations, or hydro plants whose economic returns and environmental impacts are increasingly unfavourable. In addition, there is a wide range of other options (such as wind power, increasing use of demand side management, and system efficiency improvements), that make decision making quite difficult -- even in the absence of the environmental concerns. The study is relatively unique in its focus on system wide planning issues, as opposed to the more usual policy of assessing environmental concerns only at the project level after the strategic sectoral development decisions have already been made.

The methodology involves the following steps: (a) definition of the generation options and their analysis using sophisticated least-cost system planning models; (b) selection and definition of the attributes, selected to reflect planning objectives; (c) explicit economic valuation of those impacts for which valuation techniques can be applied with confidence -- the resultant values are then added to the system costs to define the overall attribute relating to economic cost; (d) quantification of those attributes for which explicit economic valuation is inappropriate, but for which suitable quantitative impact scales can be defined; (e) translation of attribute value levels into value functions (known as "scaling"); (f) display of the trade-off space, to facilitate understanding of the trade-offs to be made in decision making; and (g) definition of a candidate list of options for further study; this also involves the important step of eliminating inferior options from further consideration.

Main results of Example 3

The main set of sectoral policy options examined included: (a) variations in the currently available mix of hydro, and thermal (coal and oil) plants, included; (b) demand side management (using the illustrative example of compact fluorescent lighting); (c) renewable energy options (using the illustrative technology of wind generation); (d) improvements in system efficiency (using more ambitious targets for transmission and distribution losses than the base case assumption of 12% by 1997); (e) clean coal technology (using pressurised fluidised bed combustion (PFBC) in a combined cycle mode as the illustrative technology); and (f) pollution control technology options (illustrated by a variety of fuel switching and pollution control options such as using imported low sulphur oil for diesels, and fitting coal burning power plants with flue gas desulphurisation (FGD) systems).

Great care needs to be exercised in selecting a limited number of key criteria or attributes, which normally reflect issues of national as well as local project level significance, and have implications for both adaptation and mitigation policies. To capture the potential impact on global warming, CO_2 emissions were defined as the appropriate proxy. Three key indicators based on impacts on human beings, social systems, and ecological systems, were identified. Human health impacts were measured through population-weighted increments in both fine particulates and NO_x attributable to each source. As an illustrative social impact, employment creation was used. To capture the potential biodiversity impacts, a composite biodiversity loss index was derived (Table 4).

Table 4. Deriving a preliminary biodiversity index

Rank	**Ecosystem**	**Relative biodiversity value (w)**
1	Lowland wet evergreen forest	0.98
2	Lowland moist evergreen forest	0.98
3	Lower montane forest	0.90
4	Upper montane forest	0.90
5	Riverrine forest	0.75
6	Dry mixed evergreen forest	0.5
7	Villus	0.4
8	Mangroves	0.4
9	Thorn forest	0.3
10	Grasslands	0.3
11	Rubber lands	0.2
12	Home gardens	0.2
13	Salt marshes	0.1
14	Sand dunes	0.1
15	Coconut lands	0.01

Source: adapted from Meier and Munasinghe (1994)

We define Gi as the average biodiversity loss index value per unit of energy produced per year at hydro site i.

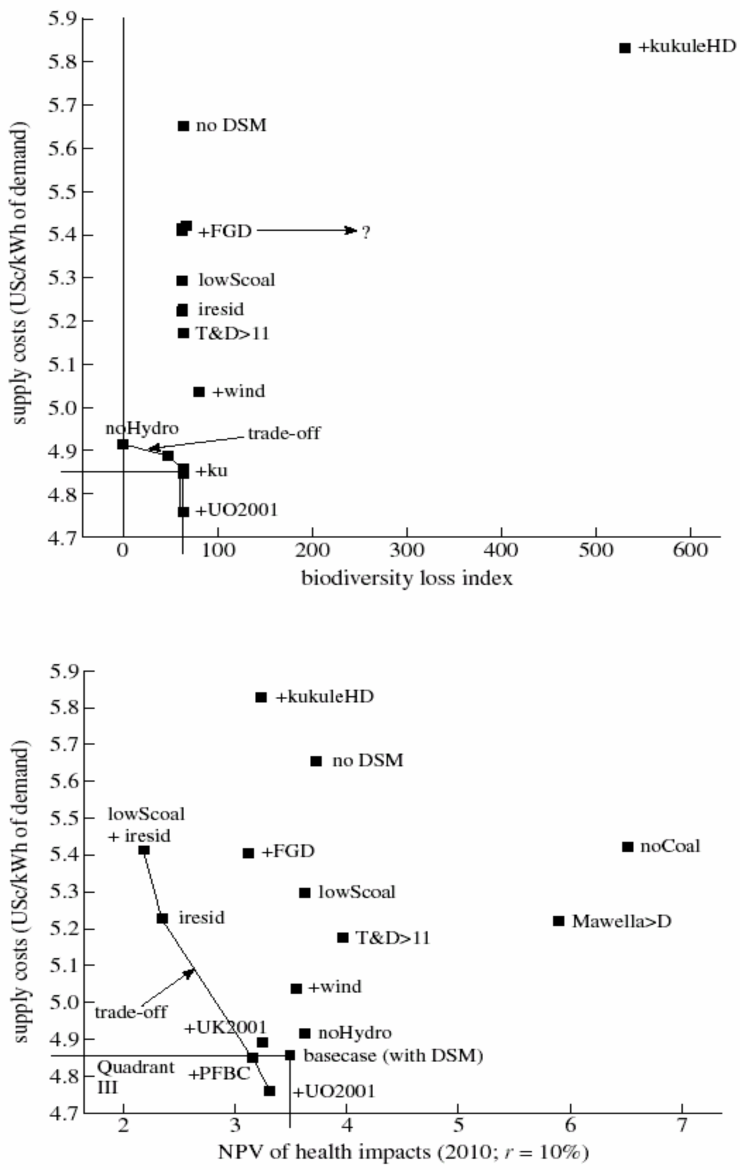
$$G_i = \sum_j (w_j).(A_{ij}) / \text{[Hydroelectric energy generated per year at site i]}$$

where A_{ij} is the area of ecosystem type j at hydro site i, and w_j is relative biodiversity value of ecosystem type j (as defined in Table 4).

Figure 7(a) illustrates a typical trade-off curve for biodiversity loss (see also, the earlier discussion on MCA in Annex 2, Section 1.3). The "best" solutions lie closest to the origin. The so-called trade-off curve is defined by the set of "non-inferior" solutions, representing the set of options that are better, regardless of the weights assigned to the different objectives. For example, on this curve, the option called “no hydro” is better than the option “wind”, in terms of both economic cost and biodiversity loss.

While most of the options have an index value that falls in the range of 50-100, the no hydro option has an essentially zero value, because the thermal projects that replace hydro plants in this option tend to lie at sites of poor bio-diversity value (either close to load centres or on the coast). Meanwhile, wind plants would require rather large land area, and their biodiversity loss index is higher. However, the vegetation in the area on the south coast (where the wind power plants would be located) has relatively low bio-diversity value, and therefore the overall bio-diversity impact of this option is small. In summary, the best options (on the trade-off curve) include the no hydro, and run-of-river hydro options that require essentially zero inundation. Note the extreme outlier at the top right hand corner, which is the Kukule hydro dam -- it has a bio-diversity loss index (B = 530) that is an order of magnitude larger than for other options (B = 50 to 70).

Figure 7 Trade-off curves for economic costs versus (a) biodiversity loss; and (b) health impacts



Source: Meier and Munasinghe 1994

A quite different trade-off curve was derived between health impacts and average incremental cost, as illustrated in Figure 7 (b). Note that the point "iresid" on the trade-off curve (which calls for the use of low sulphur imported fuel oil at diesel plants), is better than the use of flue gas desulphurisation systems (point "FGD") -- in terms of both economic cost and environment.

Conclusions of Example 3

This example draws several useful conclusions. First, the results indicate that those impacts for which valuation techniques are relatively straightforward and well-established -- such as valuing the opportunity costs of lost production from inundated land, or estimating the benefits of establishing fisheries in a reservoir -- tend to be quite small in comparison to overall system costs, and their inclusion into the benefit-cost analysis does not materially change results. Second, even in the case where explicit valuation may be difficult, such as in the case of mortality and morbidity effects of air pollution, implicit valuation based on analysis of the trade-off curve can provide important guidance to decision-makers. Third, the example indicated that certain options were in fact clearly inferior, or clearly superior, to all other options when one examines all impacts simultaneously. For example, the high dam version of the Kukule hydro project can be safely excluded from all further consideration here, as a result of poor performance on all attribute scales (including the economic one). Fourth, the results indicate that it is possible to derive attribute scales that can be useful proxies for impacts that may be difficult to value. For example, use of the biodiversity loss index, and the population-weighted incremental ambient air pollution scale as a proxy for health impacts permitted a number of important conclusions that are independent of the specific economic value assigned to biodiversity loss and health effects, respectively.

Finally, with respect to the practical implications for planning, the study identified several specific recommendations on priority options, including (i) the need to systematically examine demand side management options, especially fluorescent lighting; (ii) the need to examine whether the present transmission and distribution loss reduction target of 12% ought to be further reduced; (iii) the need to examine the possibilities of pressurised fluidised bed combustion (PFBC) technology for coal power; (iv) replacement of some coal-fired power plants (on the South coast) by diesel units; and (v) the need to re-examine cooling system options for coal plants.

5.4 Local-project scale: Hydroelectric power

The procedures for conventional environmental and social assessment at the project/local level (which are now well accepted world wide), may be readily adapted to assess the environmental and social effects of micro-level activities (World Bank 1998). The OECD (1994) has pioneered the 'Pressure-State-Response' framework to trace socio-economic-environment linkages. This P-S-R approach begins with the pressure (*e.g.*, population growth), then seeks to determine the state of the environment (*e.g.*, ambient pollutant concentration), and ends by identifying the policy response (*e.g.*, pollution taxes). The focus here is on local pressures, but bearing in mind that climate change impacts would eventually exacerbate the local impacts – the examples are useful because the same analytical techniques may be applied to deal with the impacts of both local and global environmental drivers on key sustainable development indicators.

Specific methods for economic valuation of environmental and social impacts are described in Annex 2. The practical application of such techniques were illustrated in the previous example. When valuation is not feasible for certain impacts, MCA may be used.

Example 4: ***Comparison of hydroelectric power projects***

In this example, multi-criteria analysis (MCA) is used to compare hydroelectric power schemes (for details, see Morimoto et al.2000). The three main sustainable development issues that are considered comprise the economic costs of power generation, ecological costs of biodiversity loss, and social costs of resettlement.

The principal objective is to generate additional kilowatt-hours (kWh) of electricity to meet the growing demand for power in Sri Lanka. As explained earlier in the section on cost-benefit analysis (CBA), we assume that the benefits from each additional kWh are the same. Therefore, the analysis seeks to minimise the economic, social and environmental costs of generating one unit of electricity from different hydropower sites. Following the MCA approach, environmental and social impacts are measured in different (non-monetary) units, instead of attempting to economically value and incorporate them within the single-valued CBA framework.

Environmental, social and economic indicators

Sri Lanka has many varieties of fauna and flora, many of which are endemic or endangered. Often large hydro projects destroy wildlife at the dam sites and the downstream areas. Hence, biodiversity loss was used as the main ecological objective. A biodiversity loss index, as outlined above, was estimated for each hydroelectric site.

Although dam sites are usually in less densely populated rural areas, resettlement is still a serious problem in most cases. In general, people are relocated from the wet to the dry zone where soils are less rich, and therefore the same level of agricultural productivity cannot be maintained. In the wet zone, multiple crops including paddy rice, tobacco, coconuts, mangoes, onions, and chilies can be grown. However, these crops cannot be cultivated as successfully in the dry zone, due to limited access to water and poor soil quality. Living standards often become worse and several problems (like malnutrition) could occur. Moreover, other social issues such as erosion of community cohesion and psychological distress due to change in the living environment might arise. Hence, limiting the number of people resettled due to dam construction is one important social objective.

The project costs are available for each site, from which the critical economic indicator – average cost per kWh per year – may be estimated (for details, see Ceylon Electricity Board (CEB) 1987, 1988, 1989). The annual energy generation potential at the various sites ranges from about 11 to 210 GWh (see Table 5). All three variables, the biodiversity loss index, number of people resettled, and generation costs, are divided by the amount of electrical energy generated. This scaling removes the influence of project size and makes them more comparable.

Table 5. Multi-criteria indexing of hydropower project options[1]

Hydro Site	Annual Generation	Generation cost		Persons Resettled		Biodiversity loss	
	Gwh	AVC/KWh/yr	Rank	RE/KWh/yr	Rank	BDI/KWh/yr	Rank
1. AGRA003	28	12.1	16	11.07	22	0.86	12
2. DIYA008	11	15.8	18	2.39	15	1.74	15
3. GING052	159	12	15	0.6	9	3.71	20
4. GING053	210	16.4	19	5.77	20	4.71	21
5. GING074	209	4.3	1	0.74	10	0.2	7
6. HEEN009	20	17.7	21	1.31	12	7.09	22
7. KALU075	149	9.7	11	3.36	17	0	1
8. KRLA071	114	6.8	3	4.56	18	3.51	19
9. KOTM033	390	7.3	5	0.44	8	0.01	3
10. KUKU022	512	7.5	7	1.78	13	2.3	17
11. LOGG011	22	12.6	17	5	19	2.14	16
12. MAGA029	78	8.5	9	0	1	0.14	6
13. MAGU043	161	9.9	12	0.25	7	2.37	18
14. MAHA096	34	18.4	22	8.06	21	1.64	14
15. MAHO007	50	16.5	20	0	1	0.02	4
16. MAHW235	83	7.3	5	0	1	0.78	11
17. MAHW287	42	11.1	14	0	1	0.09	5
18. NALA004	18	7.1	4	0	1	0	1
19. SITA014	123	8.8	10	2.93	16	0.57	9
20. SUDU009	79	9.9	12	1.27	11	0.72	10
21. SUDU017	113	7.9	8	2.3	14	0.88	13
22. UMAO008	143	5.1	2	0	1	0.54	8

Source: CEB (1987); CEB (1988); Meier and Munasinghe (1994)

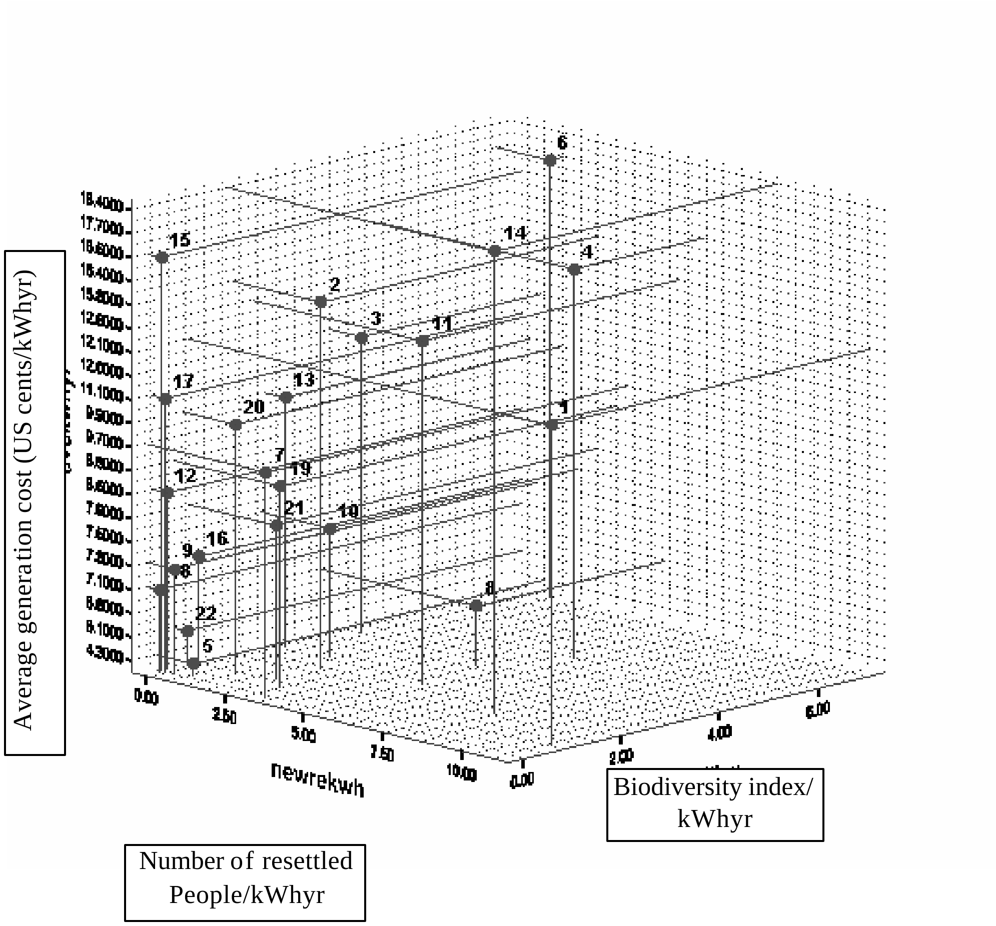
Notes: Average generation costs (AVC), biodiversity loss index (BDI), and number of resettled people (RE) by hydroelectricity project. All indices are per kWh per year. Numbers of people resettled and biodiversity loss index are scaled for convenience (by multipliers 10^{-5} and 10^{-9} respectively).

Conclusions of Example 4

A simple statistical analysis shows that pair-wise, there is a little correlation between the quantity of electricity generated, average generation cost, number of people resettled, and biodiversity loss index

From the table, it is clear that on a per kWh per year basis, the projects named AGRA003 and KALU075 have the highest and lowest biodiversity loss index, HEEN009 and MAGA029 have the highest and lowest numbers of resettled people, and MAHA096 and GING074 have the highest and lowest average generation costs, respectively. Some important comparisons may be made. For example, KALU075 is a relatively large project where the costs are low, whereas MAHA096 is a smaller scheme with much higher costs with respect to all three indices. Another simple observation is that a project like KELA071 fully dominates GING053, since the former is superior in terms of all three indicators. Similar comparisons may be made between other projects.

This type of analysis gives policymakers some idea about which project is more favourable from a sustainable energy development perspective. Suppose we arbitrarily give all the three objectives an equal weight. Then, each project may be ranked according to its absolute distance from the origin of the three axes, as shown in Figure 8. For example, rank 1 is given to the one that is closest to the origin, rank 2 to the second closest and so on. On this overall basis, from a sustainable energy development perspective, project no.5 (GING074) is the most favourable one, whereas the least favourable one is project no.14 (MAHA096).



Source: Morimoto, Munasinghe and Meier (2000)

Figure 8 Three dimensional MCA of sustainable development indicators for various hydro power options

The strength of this approach lies in its ability to help policy-makers in comparing project alternatives more easily and effectively. The simple graphical presentations are readily comprehensible, and indicate the sustainable development characteristics of each scheme quite clearly. The multi-dimensional analysis supplements the more conventional CBA, based on economic analysis alone. Since each project has different features, assessing them by looking at only one aspect (e.g., generation costs, effects on biodiversity, or impacts on resettlement) could be misleading.

There are some weaknesses in the MCA approach used here. First, for simplicity each major objective is represented by only one variable, assuming that all the other impacts are minor. In reality, there may be more than one variable that can describe the economic, social and environmental aspects of sustainable development. Further analysis that includes other variables may provide important new insights. Second, this study could be extended, for example, to include other renewable sources of energy in the analysis. Finally, improved 3D-graphic techniques could yield a better and clearer representation of these multi-criteria outcomes (Tufte 1992).

6. CONCLUDING REMARKS

Sustainable development and climate change are two important and interlinked challenges facing humankind, in the 21st century. Therefore, they merit careful joint analysis. In this context, many relevant findings emerged form the IPCC TAR process, as documented in the three working group reports, special reports, and other documents like the guidance paper on development, equity and sustainability and proceedings of two expert meetings on climate change and sustainable development. Building on this base, the present paper has sought to provide a starting point for preparations for the fourth assessment report (AR4), by analysing key issues linking sustainable development and climate change, using the sustainomics framework.

While no universally acceptable practical definition of SD exists as yet, the concept has evolved to encompass three major points of view: economic, social and environmental. Each viewpoint corresponds to a domain or system, which has its own distinct driving forces and objectives. The economic system is geared mainly towards improving human welfare (primarily through increases in the consumption of goods and services). The environmental domain focuses on protection of the integrity and resilience of ecological systems. The social system seeks to enrich human relationships and achieve individual and group aspirations.

There is no single overarching framework for sustainable development, but sustainomics attempts to describe ‘a trans-disciplinary, integrative, balanced, heuristic and practical meta-framework for making development more sustainable’. This paper has set out the basic elements of such a framework and applied it to several illustrative, practical case studies involving climate change.

Sustainomics recognizes that the precise definition of sustainable development remains an elusive (and perhaps unreachable) goal. Thus, it pursues the less ambitious strategy of simply seeking to make development more sustainable, which offers greater promise. Such an incremental (or gradient-based) method is more practical, because many unsustainable activities are often easier to recognize and eliminate. The approach seeks to synthesize key elements from a wide range of disciplines. Methods that cross the economy-society-environment interfaces are also important, including environmental and resource economics, ecological economics, sustainability science, conservation ecology, social capital and inclusion, energetics and energy economics, sociological economics, environmental sociology, cultural economics, economics of sociology, and sociology of the environment. While building on earlier work, sustainomics constitutes a more neutral expression which focuses attention explicitly on sustainable development, and especially issues of concern to the developing world.

Comprehensiveness is an important requirement because both sustainable development and climate change involve every aspect of human activity, including complex interactions among socioeconomic, ecological and physical systems. The scope of analysis needs to extend from the global to the local scale, cover time spans extending to centuries (for example, in the case of climate change), and deal with problems of uncertainty, irreversibility, and non-linearity. The approach must not only integrate the economic, social and environmental dimensions of sustainable development, as well as related methodologies and paradigms in a consistent manner, but also provide balanced treatment of all these elements. Balance is also needed in the relative emphasis placed on traditional development *versus* sustainability. No single discipline could cope with the multiplicity of issues involved, and therefore a trans-disciplinary framework is required which would address the many facets, from concept to actual practice. Although the current state of knowledge makes it rather difficult to provide a complete definition of sustainomics, this paper has identified some of its key constituent elements and how they might fit together. The basic intention was to sketch out preliminary ideas which would help to stimulate discussion and encouraging further contributions that are needed to flesh out the initial framework.

The environmental, social and economic criteria for sustainability play an important role in the sustainomics framework. The environmental interpretation of sustainability focuses on the overall viability and health of ecological systems – defined in terms of a comprehensive, multiscale, dynamic, hierarchical measure of resilience, vigour and organization. Natural resource degradation, pollution and loss of biodiversity are detrimental because they increase vulnerability, undermine system health, and reduce resilience. The notion of a safe threshold (and the related concept of carrying capacity) are important – often to avoid catastrophic ecosystem collapse. The nested hierarchy of ecological and social systems across scales and their adaptive cycles constitute a 'panarchy'. A system at a given level is able to operate in its stable (sustainable) mode, because of the continuity provided by the slower and more conservative changes in the super-system above it, while being simultaneously invigorated and energized by the faster cycles of change taking place in the sub-systems below it.

Social sustainability seeks to reduce the vulnerability and maintain the health (i.e., resilience, vigour and organization) of social and cultural systems, and their ability to withstand shocks. Enhancing human capital (through education) and strengthening social values and institutions (like trust and behavioural norms) are key aspects. Weakening social values, institutions and equity will reduce the resilience of social systems and undermine governance. Preserving cultural diversity and cultural capital across the globe, strengthening social cohesion and networks of relationships, and reducing destructive conflicts, are integral elements of this approach. In summary, for both ecological and socioeconomic systems, the emphasis is on improving system health and their dynamic ability to adapt to change across a range of spatial and temporal scales, rather than the conservation of some 'ideal' static state.

The modern concept underlying economic sustainability seeks to maximize the flow of income that could be generated while at least maintaining the stock of assets (or capital), which yield these beneficial outputs. Economic efficiency plays a key role – in ensuring both efficient allocation of resources in production, and efficient consumption choices that maximize utility. Problems of interpretation arise in identifying the kinds of capital to be maintained (for example, manufactured, natural, human and social capital stocks have been identified) and their substitutability. Often, it is difficult to value these assets and the services they provide, particularly in the case of ecological and social resources. The issues of uncertainty, irreversibility and catastrophic collapse pose additional difficulties, in determining dynamically efficient development paths.

Equity and poverty play an important role in the sustainomics framework. Both issues have not only economic, but also social and environmental dimensions, and therefore, they need to be assessed using a more comprehensive set of indicators (rather than income distribution alone).

Several analytical techniques have sought to provide integrated and balanced treatment of the economic, social and environmental viewpoints. If material growth is the main issue, while uncertainty is not a serious problem, and relevant data are available, then the focus is more likely to be on optimizing economic output, subject to (secondary) constraints that ensure social and environmental sustainability. Alternatively, if sustainability is the primary objective, conditions are chaotic, and data are rather weak, then the emphasis would be on paths which are economically, socially and environmentally durable or resilient, but not necessarily growth optimizing. Sustainomics attempts to use both optimal and durable approaches, by developing their potential to yield consistent and complementary results. In the same vein, sustainomics could also better reconcile the natural science view which relies more on flows of energy and matter, with the sociological and economic approaches that focus on human activities and behaviour. One potential area of application involves integrated assessment models or IAMs, which contain a variety of submodels that represent ecological, geophysical and socioeconomic systems. Cost-benefit analysis and multi-criteria analysis are useful tools for analyzing sustainable development issues.

The sustainomics framework would encourage crucial changes in the mindset of decision makers, by helping them to focus on the structure of development, rather than just the magnitude of economic growth (conventionally measured). This process would make development more sustainable, through the adoption of environmentally- and socially-friendly strategies that enable us to use natural resource inputs more frugally and efficiently, reduce polluting emissions, and facilitate public participation in social decisions. Sustainomics serves as an essential bridge between the traditional techniques of decision making and modern environmental and social analysis, by helping to incorporate ecological and social concerns into the decision making framework of human society. Operationally, it plays this bridging role by helping to map the results of environmental and social assessments (EA and SA) onto the framework of conventional economic analysis of projects. Thus, the approach identifies practical social and natural resource management options that facilitate sustainable development.

The climate change problem fits in quite readily within the broad conceptual framework of sustainomics. Alternative development paths will certainly affect future climate change, and in turn, climate change will have an impact on prospects for sustainable development. This full cycle of cause and effect may be considered within an integrated assessment modelling (IAM) framework -- starting from alternative socio-economic development paths (driven by the underlying forces of population, economy, technology, and governance), through GHG and other emissions, to changes in the physical climate system, to biophysical and human impacts, and back to the socio-economic development paths. Development paths strongly affect the capacity to both adapt to and mitigate climate change in any region. Adaptation reduces the impact of climate stresses on human and natural systems, while mitigation lowers potential greenhouse gas emissions. To summarise, both the climate and sustainable development domains interact in a dynamic cycle, characterized by significant time delays. Thus climate change impacts are part of the larger question of how complex social, economic, and environmental subsystems interact and shape prospects for sustainable development.

Decision makers are beginning to show more interest in the assessment of how serious a threat climate change poses to the future basis for improving human welfare. First, global warming poses a significant potential threat to the future *economic well-being* of large numbers of human beings. Second, climate change could also undermine *social welfare and equity* in an unprecedented manner. In particular, more attention needs to be paid to the vulnerability of social values and institutions, which are already stressed due to rapid technological changes. Furthermore, both intra- and inter-generational equity are likely to be worsened. Although relevant information is unavailable, on global scale phenomena like climate change, some historical evidence based on large scale disasters like El Nino provide useful insights. Inequitable distributions are not only ethically unappealing, but also may be unsustainable in the long run. Third, the *environmental viewpoint* draws attention to the fact that increasing anthropogenic emissions and accumulations of GHGs might significantly perturb a critical global subsystem – the atmosphere. Changes in the global climate (e.g., mean temperature, precipitation, etc.) could also threaten the stability of a range of critical, interlinked physical, ecological and social systems and subsystems.

When considering climate change response options, several principles and ideas from environmental economics would be useful – these include the polluter pays principle, economic valuation, internalization of externalities, and property rights. From the social equity viewpoint, the polluter pays principle (mentioned above) is based not only on economic efficiency, but also on fairness. An extension of this idea is the principle of recompensing victims – ideally by using the revenues collected from polluters. There is also the moral/equity issue concerning the extent of the polluters' obligation to compensate for past emissions (i.e., a form of environmental debt). Several concepts from contemporary environmental and social analysis are also relevant for developing climate change response options, including the concepts of durability, optimality, safe limits, carrying capacity, irreversibility, non-linear responses, and the precautionary principle.

Integrated sustainable development and climate change policies must take into account, the powerful economywide reforms in common use – including both sectoral and macroeconomic adjustment policies which have widespread effects throughout the economy. The highest priority needs to be given to finding 'win-win policies', which promote all three elements of sustainable development (economic, social and environmental). With other policies, trade-offs among different objectives need to be analysed. Economywide policies that successfully induce growth, could also lead to environmental and social harm, unless the macro-reforms are complemented by additional environmental and social measures. The sustainomics approach helps to identify and analyse economic-environmental-social interactions, and formulate integrated sustainable development and climate change policies, by linking and articulating these activities explicitly through the action impact matrix (AIM) method.

From a policy perspective, the effectiveness of climate policies can be enhanced when they are integrated with broader strategies designed to make national and regional development paths more sustainable. This occurs because climate impacts, climate policy responses, and associated socio-economic development will affect the ability of countries to achieve sustainable development goals, while the pursuit of those goals will in turn affect the opportunities for, and success of, climate policies. In particular, the socio-economic and technological characteristics of different development paths will strongly affect emissions, the rate and magnitude of climate change, climate change impacts, the capability to adapt, and the capacity to mitigate climate. There are opportunities for countries acting individually, or in cooperation with others, to reduce costs of mitigation and adaptation and realize benefits associated with achieving sustainable development.

The paper also illustrates these concepts, by applying them to case studies involving climate change and energy problems across the full range of spatial scales. At the global-transnational level, the first example examines the interplay of optimality and durability in determining appropriate global GHG emission target levels. At the level of national-economywide policies, the second case study describes how the action impact matrix (AIM) may be used for policy analysis, while the fourth sets out approaches for restructuring growth to make long term development more sustainable. On the subnational-sectoral scale, the third case outlines methods for improving energy sector decision making (including GHG mitigation) in Sri Lanka. Finally, at the project-local level, multi-criteria analysis is applied to compare small hydroelectric power projects, using relevant economic, social and environmental indicators.

ANNEX 1
Climate Change and Sustainable Development Linkages: Extracts from the IPCC Third Assessment Report

A1.1. Conceptual overview of linkages between climate change and sustainable development

- Climate change and sustainable development interact in a complex, dynamic cycle, characterised by significant time delays and feedbacks (SYR, Fig.1.1)
- The three major dimensions of sustainable development are economic, social and environmental. Key issues such as climate change, poverty, equity, and sustainability, can be related to all three dimensions (SYR, Fig. 8.3, and Section 8.26)
- Climate change impacts and responses are part of the larger question of how complex social, economic, and environmental sub-systems interact and shape prospects for sustainable development. There are multiple links (SYR, Section 1.9)
- In a broader context, equity and fairness are important elements of the social dimension, while efficiency is a crucial factor in the economic dimension of sustainable development. The impetus of sustainable development provides a crucial reason for finding efficient and equitable solutions to the problem of global warming, especially with regard to future generations (WG3/TAR, Section 10.4.5).
- Climate change and sustainable development have largely separate scientific discourses which need to be brought together (WG3/TAR, Section 2.2, Section 10.3)
- The effectiveness of climate policies can be enhanced when they are integrated with broader strategies designed to make national and regional paths more sustainable (SYR, Fig.1.10)
- Enhancement of adaptive capacity involves similar requirements as promotion of sustainable development (WG2/TAR, Section 18.6).
- Climate mitigation policies may promote sustainable development when they are consistent with broader societal objectives, e.g. those relating to development, sustainability and equity (WG3/TAR, SPM, Chapter 2, SYR 3.37).

A1.2. Consequences of climate change impacts for sustainable development prospects, in various sectors, systems, and regions.

Food and water

- Climate change may lead to impacts on forestry by changes in forest and species distribution and in productivity due to changes in temperature and extreme weather events, and carbon dioxide concentrations. Climate change is likely to increase global timber supply and enhance existing market trends towards rising market share in developing countries (WG2/TAR, Section 5.6.3).
- Even though increased CO_2 concentration can stimulate crop growth and yields that benefit may not always overcome the adverse effects of excessive heat and drought (WG2/TAR, TS).
- Food security in some countries may be worsened by climate change while it may be improved in others (WG2/TAR, Chapter 7, SYR 3.21).

- Projected climate change could further decrease streamflow and groundwater recharge and water quality in many water-stressed countries – e.g., in central Asia, southern africa, and countries around the Meditarranean Sea – but may increase it in some others. Climate change complicates existing water resources management practices by adding uncertainty (WG2/TAR, TS, SYR 2.24, 3.22, 8.19).

Energy, industry and transportation

- Hydropower generation is the energy source most likely to be impacted, since it is sensitive to the amount, timing, and geographical pattern of precipitation as well as temperature (rain or snow, timing of melting). Where they occur, reduced stream flows are expected to negatively impact hydropower production; while greater stream flows, if timed correctly, might help hydroelectric production. (WG2/TAR, Section 7.3)
- Increased cloudiness can reduce energy production from some solar energy facilities. Wind energy production would be reduced if wind speeds increase above or fall below the acceptable operating range of the technology. Changes in growing conditions could affect production of biomass, as well as prospects for carbon sequestration in soils and forest resources. (WG2/TAR, Section 7.3)
- Climate change may have (local and regional) impacts on availability of resources to industry as a result of changes in average temperature, precipitation patterns and weather disaster frequencies, in particular, availability of water (as a resource, energy source or for cooling) and renewable inputs (industrial and food crops) may be affected. (WG3/SRTT, Section9.2).
- A future climate with more summer rain days, somewhat higher rain rates, and more rainstorms would increase total vehicular accidents and total injuries in vehic ular accidents, reduce travel on public transportation systems, and cause more aircraft accidents and delays (WG2/TAR, Section 7.3)
- Coastal transport infrastructure can be damaged by a combination of sea-level rise and increased storminess (WG2/TAR, Section 13.2)
- Fluctuating water levels at sea or rivers may also affect the steady supply of resources to industrial facilities, as evidenced by the impact of extremely high water levels on river bulk transport on the Rhine river system. (WG3/SRTT, Section 9.2)

Human settlements

- Human settlements have been affected by recent increases in floods, droughts, rising socio-economic costs related to weather damage an d regional variation in climate. This suggests the increasing vulnerability of human settlements to climate change (SYR 2.25-27)
- The ability to cope with negative impacts or to take advantage of positive impacts is likely to be greater among advantaged groups than among disadvantaged groups, both within regions and between regions. As a result, climate change has the potential to enlarge equity-related gaps in human settlements and systems. (WG2/TAR, Chapter 7)
- Physical infrastructure or services may be directly affected by flooding, sea level rise (WG2/TAR, Chapter 7), permafrost melting.

- Although most indigenous peoples are highly resilient, the combined impacts of climate change and globalisation create new and unexpected challenges.(WG2/TAR, Section 16.2.8)
- The capacity of permafrost to support buildings, pipelines and roads decreases with atmospheric warming, so that pilings fail to support even insulated structures (WG2/TAR Section 16.2.8)
- Degradation of coral reefs, including coral bleaching, due to climate impacts can have long-term socioeconomic consequences due to changed fish species mix and decreased fish stocks, and negative effects on tourism as a result of degraded reefs. Degradation of reefs will also lead to diminished natural protection of coastal infrastructure against high waves and storm surges on low-lying atolls (WG2/TAR, Section 6.5.4)

Human health

- Overall climate change is projected to increase threats to human health, access to adequate food, clean water and other resources, particularly in lower income population's predominantly within tropical/sub tropical countries (SYR 3.17, 3.33)
- Some health impacts would result from changes in the frequencies and intensities of extremes of heat and cold, of floods and droughts. Other health impacts would result from the impacts of climate change upon ecological and social systems, and would include changes in infectious disease occurrence, in local food production and nutritional adequacy, in concentrations of local air pollutants and aeroallergens, and the various health consequences of population displacement and economic disruption (WG2/TAR, Chapter 9, SYR 2.28).
- Flooding may become more frequent with climate change and can affect health through the spread of disease (WG3/SRTT, Section 14.4.1).
- Health impacts will tend to occur unevenly in the world - and the impacts in poorer populations, especially in the least developed countries, will often be augmented by the heightened vulnerability of those populations (WG2/ TAR, Section 9.14)

Natural ecosystems (terrestrial, freshwater and marine systems)

- Changes in terrestrial and marine ecosystems are closely linked to changes in climate and vice versa (SR 8.13-16)
- Studies have shown that, in the event of an adverse impact on vegetation due to climate change, the forest dependent communities will be adversely affected through loss or change in forest area and diversity, and through forest dieback. (WG3/SRTT, Section 12.7, SR 3.18).
- Climate change would exacerbate the continuation of land degradation and desertification in many areas (SYR 8.18)
- Solar radiation, temperature and available water affect photosynthesis, plant respiration and decomposition, thus climate change can lead to changes in net ecosystem productivity (WG1/TAR, Section 3.2.2, SYR 3.19)
- Natural ecosystems provide many goods and services which relate to sustainable development, such as wildlife (e.g. pest control, pollinators, seed dispersal, soil maintainers, subsistence hunting, recreation, non-market values), rangelands, forests (e.g. timber, tourism, carbon storage, non-wood products), lakes, streams and wetlands (e.g. food and fiber, carbon sink), etc.(WG2/TAR, Chapter 5, SYR 3.20)

- Large-scale impacts of global warming on the oceans will include increases in sea level and sea-surface temperature; decreases in sea-ice cover; and changes in salinity, alkalinity, wave climate and ocean circulation. Collectively these changes will have profound impacts on the status, sustainability, productivity and biodiversity (e.g. coral reefs and fish population's) of the coastal zone and marine ecosystems.(WG2/TAR, Chapter 6, SYR 2.22-23)
- Climate change represents an additional stress on systems already affected by increased resource demands. In coastal areas, where a large part of the global population lives, climate change can cause inundation of wetlands and lowlands, erosion and degradation of shorelines and coral reefs, increased flooding and salinisation of estuaries and freshwater aquifers. (WG3/SRTT, Section 6.1, SYR 3.23-24)

Aggregate socio-economic impacts
- Most coastal impacts of climate change will impinge on collective goods and systems, such as food and water security, biodiversity and human health and safety. These impacts could affect commercial interests indirectly, but usually the strongest and most direct incentives to adapt are with the public sector (WG3/SRTT, Section 15.4)
- With a small temperature increase, there is medium confidence that aggregate market sector impacts would amount to plus or minus a few percent of world GDP, while there is low confidence that aggregate nonmarket impacts would be negative. Most studies of aggregate impacts find that there are net damages at the global scale beyond a medium temperature increase, and that damages increase from there with further temperature increases. (WG2/TAR, Section 19.4, SYR 3.25).
- Hazards associated with climate change can undermine progress toward sustainable development (SYR 3.35)

A1.3. Consequences of climate change response actions (mitigation, adaptation, and vulnerability reduction) for sustainable development prospects in various sectors, systems, and regions

Food and water
- Appropriately designed forestry mitigation and adaptation projects contribute to other environmental impacts as biodiversity conservation, watershed protection, and socio-economic benefits to urban and rural populations through access to forest products and creation of jobs, especially in rural areas ultimately promoting sustainable development. (WG3/SRTT, Executive Summary, Chapter 12)
- Although plantations usually have lower biodiversity than natural forest, they can reduce pressure on natural forests, leaving greater areas to provide for biodiversity and other environmental services (WG3/TAR, Section 4.4); Promotion of forestry-sector mitigation projects and the accompanying technology component would require careful attention as its adoption could impact biodiversity and the watershed role of forests and further affect the poorest and indigenous communities. (WG3/SRTT, Section 12.5)
- A range of adaptation options can be employed in the agricultural sector to increase the flexibility and adaptability of vulnerable systems, and reverse trends that increase

vulnerability. Many of these attempts to abate climate change will be of immediate benefit, and can therefore be considered "no-regret" technologies. (WG3/SRTT, Section 11.2)

- Options to reduce vulnerability of agriculture to climate change (e.g. drought resistent varieties) can have multiple benefits, e.g. reducing vulnerability to current climate variability (WG2/TAR, Chapter 5)
- Technology transfer strategies in the forestry sector for promoting mitigation options, apart from reducing greenhouse gas (GHG) emissions or enhancing carbon sinks, have the potential to provide other tangible socio-economic and local and global environmental benefits, contributing to sustainable development. (WG3/SRTT, Section 12.1)
- Adaptations in agriculture are possible, but they will not happen without considerable transition costs and equilibrium (or residual) costs.(WG2/TAR, Section 18.6)
- The effectiveness of technology transfer in the agricultural sector in the context of climate change response strategies would depend to a great extent on the suitability of transferred technologies to the socio-economic and cultural context of the recipients, considering development, equity, and sustainability issues. This is particularly relevant when applied to North-South technology transfers in this sector (WG3/SRTT, Executive Summary, Chapter 1)

Energy, industry and transportation

- The very likely direct costs for fossil fuel consumption are accompanied by very likely environmental and public health benefits associated with a reduction in the extraction and burning of the fuels. GHG mitigation policies reducing [the growth in] demand for fossil fuels could result in several ancillary benefits: slower rate of depletion, less air and water pollution, reduced import dependency; Uptake of new, high-efficiency technologies could lead to enhanced skills levels and technological capacity in developing countries (WG3/TAR, Chapter 9)
- Successful technology transfer strategies link climate change goals with measures that produce these companion benefits (WG3/SRTT, Section 7.1). While the primary emphasis is on increased efficiency, fuel switching also can lead to lower GHG emissions (WG3/SRTT, Section 7.1). Many of the technologies that mitigate GHG emissions also help adapt to the potential effects of climate change (WG3/SRTT, Section 7.2.3).
- Energy resource development and increase in energy R&D to assist accelerating development and deployment of advanced environmentally friendly sound energy technologies is needed (SYR 9.33)
- Certain climate-change-related actions can be beneficial to developing countries. For example, measures to improve energy efficiency could support their economic growth, and widen the opportunities for transferring more advanced energy technologies that could bring multiple benefits, while also limiting their greenhouse gas emissions. (WG3/SRTT, Section 3.2)
- Adaptation to reduced navigation opportunities can be realised through enhanced water-level managements, increased dredging, or smaller ships (WG2/TAR, Section 13.3). Such options can have multiple benefits, e.g. reduced vulnerability to natural climate vulnerability.

- Transport policies can have co-benefits in terms of reduced air emissions, reduced congestion, fewer traffic crashes, less noise and less road damage (WG3/TAR, Section 9.2.8).

Human settlements

- Humans have shown a capacity to adapt to long-term mean climate conditions, but there is less success in adapting to extreme and year-to-year variations in climatic conditions (SYR 5.9)
- Adaptation options include improved land-use planning; planning and design of new housing with low environmental impacts and less exposed to flood and other hazards; improving water, sanitation, and electricity supply systems; improving flood control; diversifying economic activities; building efficient environmental institutions. These options are likely to have multiple benefits.(WG2/TAR, Chapter 7)
- A systems, or whole-building approach, can achieve both mitigation and adaptation objectives through the optimal integration of land use, building design, equipment and material choices and recycling strategies. (WG3/SRTT, Section 7.2).
- Adaptation in fishery management such as measures that can promote sustainable fishery (improved and expanded monitoring to obtain information for better management of fisheries, sharing of this information, modification of fishing industry efforts, practices and investment to match biological productivity and responses to climate change, and protection of spawning areas and habitat) (WG2/TAR, Chapter 6) can have multiple benefits.
- Coastal-adaptation technologies can provide an important contribution to the sustainable development in coastal zones, but their effectiveness depends strongly on the economic, institutional, legal and socio-cultural contexts in which they are implemented. Furthermore, climate change is but one of the many interacting stresses in coastal zones (WG3/SRTT, Section 15.7.2).

Human health

- Adaptation options include: investments in public health training programmes, disease surveillance, sanitaiton systems, disease vector control, immunizations, resources to respond to disease outbreaks and resources to diagnose and treat disease are important components of efforts to (re-)build public health infrastructure (WG2/TAR, Chapter 9). Such health adaptation options to climate change would promote health generally, regardless of the effects of climate change.
- Ancillary benefits [of GHG mitigation actions] related to public health accrue over the short term, and under some circumstances can be a significant fraction of private (direct) mitigation costs (WG3/TAR , Section 8.2.4).

Natural ecosystems (terrestrial, freshwater and marine systems)

- Greenhouse gas emissions reduction (mitigation) actions would lessen the pressures on natural and human systems for climate change (SYR 6.10)
- Adaptation options [in ecosystem management] could produce multiple benefits in the form of reduced climate change vulnerability and promotion of sustainable development (WG2/TAR, Chapter 5).

- Some options for adaptation (e.g. in the areas of wood product supply, and water use and management) may have adverse effects on natural ecosystems.(WG/TAR, Chapter 5)

Aggregate socio-economic impacts

- Adaptation is a necessary strategy at all scales to complement climate change mitigation efforts. Together they can contribute to sustainable development objectives (SYR 6.13-18, 9.40)
- Adaptation measures to changing climatic conditions are more likely to be implemented if they are consistent with or integrated with decisions or programmes addressing non-climatic stresses. Vulnerabilities associated with climate change are rarely experienced independently of non-climatic conditions. (WG2/TAR, Section 18.8)
- In the absence of emissions trading between Annex B countries, the majority of global studies show reductions in projected GDP of about 0.2 to 2% in 2010 for different Annex II regions. With full emissions trading between Annex B countries, the estimated reductions in 2010 are between 0.1 and 1.1% of projected GDP.(WG3/TAR, SPM)
- Emission constraints in Annex I countries have well established, albeit varied "spillover" effects on non-Annex I countries. Oil-exporting, non-Annex I countries: Analyses report costs differently, including, inter alia, reductions in projected GDP and reductions in projected oil revenues. Other non-Annex I countries may be adversely affected by reductions in demand for their exports to OECD nations and by the price increase of those carbon-intensive and other products they continue to import. These countries may benefit from the reduction in fuel prices, increased exports of carbon-intensive products and the transfer of environmentally sound technologies and know-how. (WG3/TAR, SPM)
- Mitigation actions to stabilise atmospheric concentrations of greenhouse gases at lower levels would generate greater benefits in terms of less damage (SYR 6.11)

A1.4. Synergies and tradeoffs between different sustainable development strategies, and options for increasing adaptive capacity and reducing vulnerability to climate change, in various sectors, systems and regions

Food and water

- A majority of these [adaptation/mitigation technology transfer] efforts [in forestry] have emerged independently of the climate change-related debates.(WG3/SRTT, Section 12.3.2)
- An analysis of the literature suggests that C mitigation strategies can be pursued as one element of more comprehensive strategies aimed at sustainable development, where increasing C stocks is but one of many objectives. (WG3/TAR, Chapter 4)
- Development of drought resistent varieties can reduce vulnerability to natural climate variability as well as change (WG2/TAR, Chapter 5)
- Adaptation technologies which involve institutional infrastructures (for example in agriculture, health and human settlement planning) could be integrated with other

parts of efforts to alleviate poverty and promote development (WG3/SRTT, Section 4.10.1)

- Ability to adapt is affected by institutional capacity, wealth, management philosophy, planning time scale, organizational and legal framework, technology, and population mobility.(WG2/TAR, Section 18.6). These factors also determine the efectiveness of water management regardless of climate change.
- There are numerous “no regrets” water policy changes, which would provide benefits by addressing growing water demands and reducing risks associated with hydrological variability, which in turn would reduce vulnerability to climate change (WG2/TAR, Chapter 4)

Energy, industry and transportation

- Recent major innovations in infrastructure design such as linking urban transport to land-use patterns, zoning, increase access to jobs and shops, comprehensive and integrated planning strategies have lead to reduction of urban pollution with possible climate change benefits as they reduce the reliance on automobile transportation (WG3/SRTT, Section 8.2.4).

Human settlements

- Local capacity to limit environmental hazards or their health consequences in any settlement generally implies local capacity to adapt to climate change, unless adaptation implies particularly expensive infrastructure investment. There are many techniques that can contribute towards better environmental planning and management including: market-based tools for pollution control, demand management and waste reduction, mixed-use zoning and transport planning (with appropriate provision for pedestrians and cyclists), environmental impact assessments, capacity studies, strategic environmental plans, environmental audit procedures and state of the environment reports (WG2/TAR, Section 7.5.2)
- Lessons from “Sustainable cities” activities may be applicable to future climate change adaptation responses (WG2/TAR, Section 7.5.3).
- Adaptation options are more acceptable and effective when incorporated into coastal zone management, disaster mitigation programs, land use planning, and sustainable development strategies.(WG2/TAR, Section 18.6). Conversely, such strategies can enhance adaptive capacity.
- Socio-economic factors such as technical and institutional abilities, economic wealth, and cultural characteristics determine a society’s adaptive capacity in coastal areas (WG2/TAR, Chapter 6, WG3/SRTT, Section 15.7). Hence, strategies pursuing sustainable development in these areas can also enhance adaptive capacity.
- Policies and practices that are unrelated to climate but which do increase a system’s vulnerability to climate change are termed “maladaptation”. Examples of maladaptation in coastal zones include investments in hazardous zones, inappropriate coastal-defence schemes, sand or coral mining and coastal-habitat conversions. (WG3 SRTT Section 15.2.2)

Human health

- Public health structure, water and sanitation infrastructure, nutritional status of the population, local food supplies and distribution systems, education levels and access to information, exposure to disease vectors, air quality, urban heat island effects, existence of early warning systems for extreme weather events, concentration of people in high risk areas, flood control emasures, poverty are all determinants of health (WG2/TAR, Chapter 9). Addressing these issues will also reduce vulnerability to climate change.

Natural ecosystems (terrestrial, freshwater and marine systems)

- Adapting to declines in wildlife populations by establishing parks, refuges, and reserves rarely takes into account potential climate change [and associated migration needs] (WG2/TAR, Chapter 5)
- Resilience to climate change is but one of many considerations influencing decisions on forestry next to biodiversity and other ecological benefits such as watershed protection, soil erosion protection, and prevention of desertification. (WG3/SRTT, 12.2.1)

Aggregate issues

- Various development paths, sustainable or otherwise, will shape future vulnerability to climate change and climate impacts may affect prospects for sustainable development in different parts of the world (WG2/TAR, TS, Section 7.2.3).
- Population living in poverty have relatively low capacity to adapt to, and cope with climate change impacts such as those on water, and hence poverty eradication can reduce vulnerability to these impacts (WG2/TAR, Chapter 7)

A1.5. Synergies and tradeoffs between different sustainable development strategies, and options for increasing mitigative capacity and mitigating GHG emissions, in various sectors, systems and regions

Food and water

- Improvements in agricultural yields, dietary changes that influence meat production, cattle population, and in turn, grassland cover in combination with demographic changes can lead in some scenarios to a considerable “greening” of the planet, without climate change concerns taken into account. (WG3, SRES, Chapter 4)
- Possible conflicts of land use for sustainable food production, soil nutrient depletion, water availability, and biodiversity need to be addressed.(WG3/TAR, Section 3.6.1)
- Agriculture will be heavily influenced by climate change. Sustainable agricultural development is an ongoing priority for all countries. Transfer of adaptation and mitigation technologies has significant benefits independent of climate change consideration, but is even more relevant, now climate change will offer greater challenges and development opportunities for agricultural systems (WG3/SRTT, Section 11.6)
- Reducing nitrogen losses from fertilisation (e.g. slow release fertilisers, organic manures, nitrification inhibitors) would improve nitrogen availability for crops, but also reduce nitrous oxide emissions (WG3/TAR, Section 3.6.4)
- In order for agricultural production to be undertaken in a more sustainable manner, one can use husbandry methods and management techniques to minimize the inputs

of energy, synthetic fertilizers and agri-chemicals on which present industrialized farming methods depend. (WG3/TAR, Section 3.6.1)

- Hydropower remains the most developed renewable resource worldwide…. Large-scale hydropower plant developments can have high environmental and social costs such as loss of fertile land, methane generation from flooded vegetation, and displacement of local communities. (WG3 TAR Section 3.8.3)
- Methane emissions from domestic and industrial wastewater disposal contribute about 10% of global anthropogenic methane sources (30-40 Mt annually). Industrial wastewater, mainly from pulp and paper and food processing industries, contributes more than 90% of these emissions, whereas domestic and commercial wastewater disposal contributes about 2 Mt annually. (WG3/TAR, Section 3.7.2.5)

Energy, industry and transportation

- In some long-term scenarios (e.g. SRES B1, A1T) GHG emissions from the energy sector are eventually declining on the basis of technological innovation, economic structural changes and demographic developments unrelated to climate change (WG3, SRES, Chapter 4)
- In many places, renewable energy technologies seem to offer some of the best prospects for providing needed energy services while addressing the multiple challenges of sustainable development, including air pollution, mining, transport, and energy security. (WG3/TAR, Section 1.4.2.1)
- Efforts mainly driven by other concerns than climate change have led to technological options (improved technology design and maintenance, alternative fuels, vehicle use change, and modal shifts) and non-technical options (transport reduction, and improved management systems) that can reduce GHG emissions significantly (WG3/SRTT, Executive Summary, Chapter 8).
- Adoption of opportunities including greenhouse gas reducing technologies and measures may require overcoming barriers through the implementation of policy measures (SYR 7.5-7.8, 8.24)
- Current energy supply technology transfer is primarily driven by objectives of economic development and international competitiveness. Climate change objectives and in particular the reduction of CO_2 emissions do not play a significant role. This does not imply that energy supply technology transfer has no effect on climate change, but that such effects are coincidental rather than intended. (WG3/SRTT, Section 10.3.1)
- There is scope where infrastructure is developing rapidly to implement planning measures that encourage more sustainable transport patterns, avoiding the pollution , congestion, higher accident rates, and also GHG emissions associated with cars (WG3/TAR Section 5.3.2).
- Three policy strands intend to lead from the status quo to sustainability: (a) "best practice" in urban transport policy, combining combining land-use management strategies with advanced road traffic management strategies, environmental protection strategies and pricing mechanisms, (b) in addition investments in transit, pedestrian and bicycle infrastructure, and (c) steep year-by-year increases in fuel prices, full-cost externality pricing for motor vehicles, and ensuring use of high-efficiency, low-weight and low-pollution vehicles in cities (WG3/ TAR, Section 3.4.4)

- Significant achievements have been made in developing transport systems that reduce GHG emissions though the development of other concerns such as performance gains, safety, and energy intensity improvements has been paramount in their development. Introducing various options to mitigate GHG emissions may require justification of other objectives other than GHG mitigation such as competitiveness, security concerns, and improvement of quality of life or local environment improvement. (WG3/SRTT, Section 8.2).

Human settlements

- Hundreds of technologies and measures exist in buildings, households and services that can improve the energy efficiency of appliances and equipment as well as building structures in all regions of the world (WG3/TAR, TS). Improving energy efficiency can be pursued independent of climate change concerns, in order to reduce energy costs.

Human health

- Public health concerns related to urban air pollution increasingly lead to abatement of sulfur emissions, also in developing countries. If, in addition to desulfurisation of flue gases, this is achieved by energy conservation, interfuel substitution from high to low sulfur gases, associated GHG emissions reductions will be achieved (WG3, SRES, Chapters 3, 4 and 5).
- The formal health sector is not substantively involved in the reduction of greenhouse gas emissions – other than incidentally via participation in society-wide improved energy efficiency (hospital building design, institutional energy-use policies, etc.), and by promoting alternative energy-saving systems of transport and mobility to increase physical activity levels. (WG3/SRTT, Section 14.1)

Natural ecosystems (terrestrial, freshwater and marine systems)

- High incomes in some scenarios also increase the demand for environmental amenities. Hence, “demand” for forests also increases with economic growth, and the expected rent of forest land is assumed to increase. These rising rents eventually reduce the rate of deforestation and increase the area of managed tree-covered land (WG3, SRES, Section 4.4.9.1).

Aggregate socio-economic changes and strategies

- Climate policy, and the impacts of climate change, will have significant implications for sustainable development at both the global and sub-global levels. In addition, policy and behavioural responses to sustainable development issues may affect both our ability to develop and successfully implement climate policies, and our ability to respond effectively to climate change. In this way, climate policy response will affect the ability of countries to achieve sustainable development goals, while the pursuit of those goals will in turn affect the opportunities for, and success of, climate policy responses. (WG3/TAR, Section 2.2.3)
- GHG emissions are likely to be reduced by other policies for the sustainable use of resources, such as land, forest ecosystems, mineral resources, water, and soil. Instruments may include direct planning, regulations, establishing property rights and

obligations, information, education, and persuasion, and a broad range of prices to support or influence the innovation process to encourage dematerialization (SRES 3.7.2).

- Decisions about technology, investment, trade, poverty, biodiversity, community rights, social policies, or governance, which may seem unrelated to climate policy, may have profound impacts upon emissions, the extent of mitigation required, and the cost and benefits that result. Conversely, climate policies that implicitly address social, environmental, economic, and security issues may turn out to be important levers for creating a sustainable world (WG3/TAR, Section 1.4.1)
- Alternative pathways could be considered to pursue global sustainability and address issues like decoupling growth from resource flows, for example through eco-intelligent production systems, resource light infrastructure and appropriate technologies, and decoupling well being from production, for example through intermediate performance levels, regionalization of production systems, and changing lifestyles.(WG3/TAR, TS). Such developments have important GHG implications.
- Sustainable development is a context-driven concept and each society may define it differently. Technologies that may be suitable in each of such contexts may differ considerably. This makes it important to ensure that transferred [mitigation] technologies meet local needs and priorities, thus increasing the likelihood that they will be effective. (WG3,SRTT, Section 1.2)
- Approaches that exploit synergies between environmental policies and key notional socio-economic objectives like growth and equity could help to mitigate and reduce vulnerability to climate change as well as promote sustainable development (SYR 8.26)

A1.6. Mutual interlinkages between different overall development paths (that cut across various sectors and systems), including strategies for technology development, diffusion and transfer processes, and climate change responses

Synergies and trade-offs in sectoral policies

- Policies governing agriculture and land use and energy systems need to be linked for climate change mitigation. There is a latent demand for low-cost housing, small hydropower units, low-input organic agriculture, local non-grid power stations, and biomass-based small industries. Sustainable agriculture can benefit both the environment and food production. Biomass-based energy plants could produce electricity from local waste materials in an efficient, low-cost, and carbon-free manner. Each of these options needs to be evaluated alongside conventional energy supply and demand alternatives in terms of the impacts and contribution to sustainable development. (WG3/TAR, Section 1.4.2, Chapter 2)
- Trends in inequality, resource consumption and depletion, environmental degradation, population growth and ill-health are closely interrelated and will strongly interact with potential climate change impacts. Such problems cannot be effectively addressed solely by implementing improved intersectoral (energy, agriculture) or public health technologies. Cross-sectoral policies that promote ecologically sustainable development and address underlying driving forces will be essential. (WG3/SRTT, Section 14.4.3)

Role of alternative socio-economic development pathways and system inertia

- Development paths that meet sustainable development objectives may result in lower levels of greenhouse gas emissions (WG3/TAR, SPM, Chapter 2, SYR 9.41).
- [This] comparisons of SRES scenario characteristics imply that similar future emissions can result from very different socio-economic developments, and similar developments of driving forces can result in different future emissions. Uncertainties in future development of key emissions driving forces create large uncertainties in future emissions even with the same socio-economic development paths. (SRES TS 9.1.3).
- Particular sets of technological and behavioral options can be clustered into alternative, internally consistent packages to represent different choices over time and so define different development paths for any economy. Such clusters can give rise to self-reinforcing loops between technical choices, consumer demand, and geographic distributions, which create "lock-in" effects and foreclosures of options in technology and socio-institutional innovations. The time-dependent nature of these choices gives rise to bifurcations and irreversibilities in which the shift from one development path to another entails important economic and political costs. (SRES 3.3.5.)
- The existence of time lags, inertia and irreversibility in the Earth system means that a mitigation action or technology development can have different outcomes, depending on when it is taken (SYR, Chapter 5)
- Technological inertia in less developed countries can be reduced through "leapfrogging"(i.e. adopting anticipative strategies to avoid the problems faced today by industrial societies). (SYR, Chapter 5)
- The challenge of addressing climate change raises an important issue of equity, namely the extent to which the impacts of climate change or mitigation policies ameliorate or exacerbate inequities both within and across nations and regions, and between generations. (SYR Chapter 7)

Synergies in transfer of environmentally sound technologies

- Environmental sustainability, including mitigating and adapting to climate change, can be seen not as a barrier to growth, but as a boundary condition that could stimulate the emergence of a sustainable industrial economy, a process in which technology transfer is likely to play a major role. (WG3/SRTT, Section 5.4.1)
- To the extent that the transfer of technology is seen as an important operational tool for addressing the global climate change problem, it will also have a serious impact on distribution issues. Technology transfer within countries is likely to affect some groups positively at the cost of other groups so clear distribution issues will become evident. If they are ignored there could be negative consequences on achieving technology transfer. (WG3/SRTT, Section 4.10) However, the international equity aspect of climate change impacts and adaptation have received relatively little attention so far.
- Past experience with technology transfer in a variety of sectors can be used to suggest policy tools for providing enabling environments for the transfer of technologies for mitigation and adaptation to climate change that is supportive and sustainable. Evidence exists both of barriers and ways in which barriers can be avoided and overcome. Experience also shows that technology transfer offers many opportunities for sustainable economic and social development. The sustainable use of environmentally sound technologies (ESTs) for climate change has to fulfill not only

social but also economic and development objectives through a complex process of technological change (WG3/SRTT Section 4.1).

Abbreviations (for IPCC publications)

SPM	-	Summary for Policymakers
SRES	-	Special Report on Emissions Scenarios
SRTT	-	Special Report on Technology Transfer
SYR	-	Synthesis Report
TAR	-	Third Assessment Report
TS	-	Technical Summary
WG2	-	Working Group 2
WG3	-	Working Group 3

ANNEX 2
Tools for Analysis and Assessment

A2.1 Indicators

A wide variety of indicators relating to the social, economic and environmental dimensions of sustainable development have been discussed in the literature [e.g., Munasinghe and Shearer 1995; UNDP 1998; World Bank 1998; Liverman et al. 1988; Kuik and Verbruggen 1991; Opschoor and Reijnders 1991; Holmberg and Karlsson 1992; Adriaanse 1993; Alfsen and Saebo 1993; Bergstrom 1993; Gilbert and Feenstra 1994; Moffat 1994; OECD 1994; Azar 1996; UN 1996; Commission on Sustainable Development (CSD) 1998; World Bank 1997). In particular, we note that measuring the stocks of economic, environmental (natural), human and social capital raises various problems.

Manufactured capital may be estimated using conventional neo-classical economic analysis. As described later in the section on cost-benefit analysis, market prices are useful when economic distortions are relatively low, and shadow prices could be applied in cases where market prices are unreliable (e.g., Squire and van der Tak 1975).

Natural capital needs to be quantified first in terms of key physical attributes. Typically, damage to natural capital may be assessed by the level of air pollution (*e.g.*, concentrations of suspended particulate, sulphur dioxide or GHGs), water pollution (*e.g.*, BOD or COD), and land degradation (*e.g.*, soil erosion or deforestation). Then the physical damage could be valued using a variety of techniques based on environmental and resource economics (e.g., Munasinghe 1992; Freeman 1993; Teitenberg 1992).

Social capital is the one that is most difficult to assess (Grootaert 1998). Putnam (1993) described it as ‘horizontal associations’ among people, or social networks and associated behavioural norms and values, which affect the productivity of communities. A somewhat broader view was offered by Coleman (1990), who viewed social capital in terms of social structures, which facilitate the activities of agents in society – this permitted both horizontal and vertical associations (like firms). An even wider definition is implied by the institutional approach espoused by North (1990) and Olson (1982), that includes not only the mainly informal relationships implied by the earlier two views, but also the more formal frameworks provided by governments, political systems, legal and constitutional provisions etc. Recent work has sought to distinguish between social and political capital (*i.e.*, the networks of power and influence that link individuals and communities to the higher levels of decisionmaking). Human resource stocks are often measured in terms of the value of educational levels, productivity and earning potential of individuals.

A2.2 Cost-Benefit Analysis (CBA)

Cost-benefit analysis is an important tool in the economic and financial analysis of projects and for determining their viability. The basic criterion for accepting a project is that the net present value (NPV) of benefits is positive. Typically, NPV = PVB – PVC,

where $PVB = \sum_{t=0}^{T} B_t / (1 + r)^t$; and $PVC = \sum_{t=0}^{T} C_t / (1 + r)^t$.

B_t and C_t are the project benefits and costs in year t, r is the discount rate, and T is the time horizon. Both benefits and costs are defined as the difference between what would occur *with and without* the project being implemented.

When two projects are compared, the one with the higher NPV is deemed superior. Furthermore, if both projects yield the same benefits (PVB), then it is possible to derive the least cost criterion -- where the project with the lower PVC is preferred. The IRR is defined as that value of the discount rate for which PVB = PVC, while BCR = PVB/PVC. The BCR may be interpreted as a measure of 'cost effectiveness', *e.g.*, even if the benefits are not measurable in monetary terms, BCR indicates the gain derived per unit of investment in a project. Further details of these criteria, as well as their relative merits in the context of sustainable development, are provided in (Munasinghe 1992).

If a purely financial analysis is required from the private entrepreneurs viewpoint, then B, C, and r are defined in terms of market or financial prices, and NPV yields the discounted monetary profit. This situation corresponds to the economist's ideal world of perfect competition, where numerous profit-maximising producers and utility-maximising consumers achieve a Pareto-optimal outcome. However, conditions in the real world are far from perfect, due to monopoly practices, externalities (such as environmental impacts which are not internalised in the private market), and interference in the market process (*e.g.*, taxes). Such distortions cause market (or financial) prices for goods and services to diverge from their economically efficient values. Therefore, the economic efficiency viewpoint usually requires that shadow prices (or opportunity costs) be used to measure B, C and r. In simple terms, the shadow price of a given scarce economic resource is given by the change in value of economic output caused by a unit change in the availability of that resource. In practice, there are many techniques for measuring shadow prices – *e.g.*, removing taxes, duties and subsidies from market prices (for details, see Munasinghe 1992; Squire and van der Tak 1975).

The incorporation of environmental considerations into the economist's single valued CBA criterion requires further adjustments. All significant environmental impacts and externalities need to be valued as economic benefits and costs. As explained earlier in the section on indicators, environmental assets may be quantified in physical or biological units. Recent techniques for economically valuing environmental impacts are summarised in Box A.1. However, many of them (such as biodiversity) cannot be accurately valued in monetary terms, despite the progress that has been made in recent years (Munasinghe 1992; Freeman 1993). Therefore, criteria like NPV often fail to adequately represent the environmental aspect of sustainable development.

Capturing the social dimension of sustainable development within CBA is even more problematic. Some attempts have been made to attach 'social weights' to costs and benefits so that the resultant NPV favours poorer groups. However, such adjustments (or preferential treatment for the poor) are rather arbitrary, and have weak foundations in economic theory. Other key social considerations like empowerment and participation are hardly represented within CBA. In summary, the conventional CBA methodology would tend to favour the market-based economic viewpoint, although environmental and social considerations might be introduced in the form of side constraints.

Box A.1. Techniques for economically valuing environmental impacts

	TYPE OF MARKET		
BEHAVIOUR TYPE	**Conventional market**	**Implicit market**	**Constructed market**
Actual Behaviour	Effect on Production Effect on Health Defensive or Preventive Costs	Travel Cost Wage Differences Property Values Proxy Marketed Goods	Artificial Market
Intended Behaviour	Replacement Cost Shadow Project		Contingent Valuation

Box A.1. Techniques for economically valuing environmental impacts

Effect on Production. An investment decision often has environmental impacts, which in turn affect the quantity, quality or production costs of a range of productive outputs that may be valued readily in economic terms.

Effect on Health. This approach is based on health impacts caused by pollution and environmental degradation. One practical measure related to the effect on production is the value of human output lost due to ill health or premature death. The loss of potential net earnings (called the human capital technique) is one proxy for foregone output, to which the costs of health care or prevention may be added.

Defensive or Preventive Costs. Often, costs may be incurred to mitigate the damage caused by an adverse environmental impact. For example, if the drinking water is polluted, extra purification may be needed. Then, such additional defensive or preventive expenditures (ex-post) could be taken as a minimum estimate of the benefits of mitigation.

Replacement Cost and Shadow Project. If an environmental resource that has been impaired is likely to be replaced in the future by another asset that provides equivalent services, then the costs of replacement may be used as a proxy for the environmental damage -- assuming that the benefits from the original resource are at least as valuable as the replacement expenses. A shadow project is usually designed specifically to offset the environmental damage caused by another project. For example, if the original project was a dam that inundated some forest land, then the shadow project might involve the replanting of an equivalent area of forest, elsewhere.

Travel Cost. This method seeks to determine the demand for a recreational site (*e.g.*, number of visits per year to a park), as a function of variables like price, visitor income, and socio-economic characteristics. The price is usually the sum of entry fees to the site, costs of travel, and opportunity cost of time spent. The consumer surplus associated with the demand curve provides an estimate of the value of the recreational site in question.

Property Value. In areas where relatively competitive markets exist for land, it is possible to decompose real estate prices into components attributable to different characteristics like house and lot size, air and water quality. The marginal willing-to-pay (WTP) for improved local environmental quality is reflected in the increased price of housing in cleaner neighborhoods. This method has limited application in developing countries, since it requires a competitive housing market, as well as sophisticated data and tools of statistical analysis.

Wage Differences. As in the case of property values, the wage differential method attempts to relate changes in the wage rate to environmental conditions, after accounting for the effects of all factors other than environment (*e.g.*, age, skill level, job responsibility, etc.) that might influence wages.

Proxy Marketed Goods. This method is useful when an environmental good or service has no readily determined market value, but a close substitute exists which does have a competitively determined price. In such a case, the market price of the substitute may be used as a proxy for the value of the environmental resource.

Artificial Market. Such markets are constructed for experimental purposes, to determine consumer WTP for a good or service. For example, a home water purification kit might be marketed at various price levels, or access to a game reserve may be offered on the basis of different admission fees, thereby facilitating the estimation of values.

Contingent Valuation. This method puts direct questions to individuals to determine how much they might be willingness to pay (WTP) for an environmental resource, or how much compensation they would be willing-to-accept (WTA) if they were deprived of the same resource. The contingent valuation method (CVM) is more effective when the respondents are familiar with the environmental good or service (*e.g.*, water quality) and have adequate information on which to base their preferences. Recent studies indicate that CVM, cautiously and rigorously applied, could provide rough estimates of value that would be helpful in economic decision making, especially when other valuation methods were unavailable.

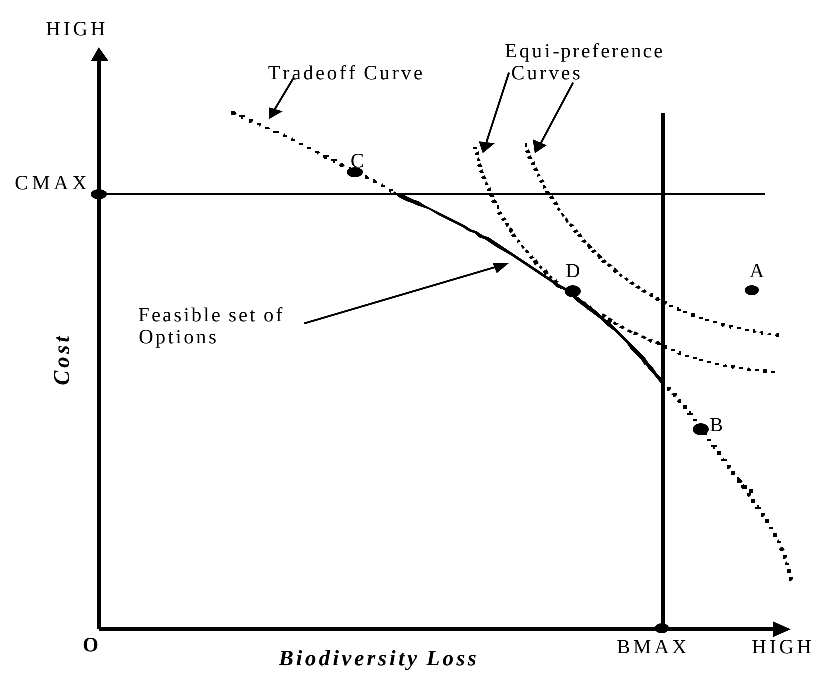
Source : adapted from Munasinghe (1992)

A2.3 Multi-Criteria Analysis (MCA)

This technique is particularly useful in situations where a single criterion approach like CBA falls short – especially when significant environmental and social impacts cannot be assigned monetary values. MCA is implemented usually within a hierarchical structure. The highest level represents the broad overall objectives (for example, improving the quality of life), which are often vaguely stated. However, they can be broken down -- usually into more comprehensible, operationally relevant and easily measurable lower level objectives (*e.g.*, increased income). Sometimes only proxies are available – *e.g.*, if the objective is to preserve biological diversity in a rainforest, the practically available attribute may be the number of hectares of rainforest remaining. Although value judgements may be required in choosing the proper attribute (especially if proxies are used), actual measurement does not have to be in monetary terms – unlike CBA. More explicit recognition is given to the fact that a variety of objectives and indicators may influence planning decisions.

Figure A2.1 is a two dimensional representation of the basic concepts underlying MCA. Consider an electricity supplier, who is evaluating a hydroelectric project that could potentially cause biodiversity loss. Objective Z_1 is the additional project cost required to protect biodiversity, and Z_2 is an index indicating the loss of biodiversity. The points A, B, C and D in the figure represent alternative projects (*e.g.*, different designs for the dam). In this case, project B is superior to (or dominates) A in terms of both Z_1 and Z_2 – because B exhibits lower costs as well as less bio-diversity loss relative to A. Thus, alternative A may be discarded. However, when we compare B and C, the choice is more complicated since the former is better than the latter with respect to costs but worse with respect to biodiversity loss. Proceeding in this fashion, a trade-off curve (or *locus* of best options) may be defined by all the non-dominated feasible project alternatives such as B, C and D. Such a curve implicitly places both economic and environmental attributes on a more equal footing.

Figure A1.1. Simple Two-Dimensional Example of Multi-criteria Analysis.



Source: adapted from (Munasinghe 1992)

Further ranking of alternatives is not possible without the introduction of value judgements (for an unconstrained problem). Typically, additional information may be provided by a family of equi-preference curves that indicate the way in which the decision maker or society trades off one objective against the other (see the figure). Each such equi-preference curve indicates the *locus* of points along which society is indifferent to the trade-off between the two objectives. The preferred alternative is the one that yields the greatest utility – *i.e.*, at the point of tangency D of the trade-off curve with the best equi-preference curve (*i.e.*, the one closest to the origin).

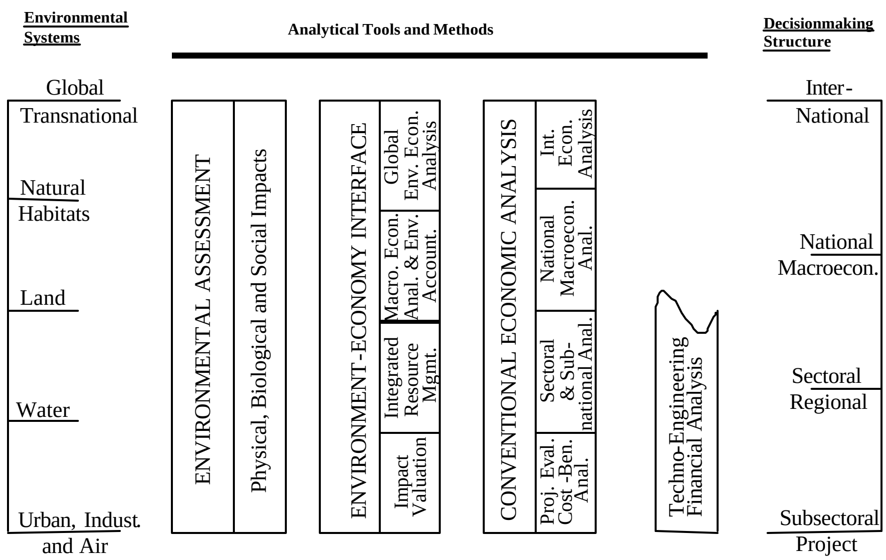
Since equi-preference curves are usually not measurable, other practical techniques may be used to narrow down the set of feasible choices on the trade-off curve. One approach uses limits on objectives or 'exclusionary screening'. For example, the decision maker may face an upper bound on costs (*i.e.*, a budgetary constraint), depicted by CMAX in the figure. Similarly, ecological experts might set a maximum value of bio-diversity loss BMAX (*e.g.*, a level beyond which the ecosystem suffers catastrophic collapse). These two constraints may be interpreted in the context of durability considerations, mentioned earlier. Thus, exceeding CMAX is likely to threaten the viability of the electricity supplier, with ensuing social and economic consequences (*e.g.*, jobs, incomes, returns to investors etc.). Similarly, violating the biodiversity constraint will undermine the resilience and sustainability of the forest ecosystem. In a more practical sense, CMAX and BMAX help to define a more restricted portion of the trade-off curve (darker line) – thereby narrowing and simplifying the choices available to the single alternative D, in the figure.

This type of analysis may be expanded to include other dimensions and attributes. For example, in our hydroelectric dam case, the number of people displaced (or resettled) could be represented by another social variable Z_3.

A2.4 Linking sustainable development issues with conventional decision making

Figure A2.2 provides an example of how environmental assessment is combined with economic analysis. The right-hand side of the diagram indicates the hierarchical nature of conventional decision making in a modern society. The global and international level consists of sovereign nation states. In the next level are individual countries, each with a multi-sectored macro-economy. Various economic sectors (like industry and agriculture) exist in each country. Finally, each sector consists of different sub-sectors and projects. The conventional decision making process in a modern economy is shown on the right side of Figure A2.2. It relies on techno-engineering, financial and economic analyses of projects and policies. In particular, conventional economic analysis has been well developed in the past, and uses techniques such as project evaluation/cost-benefit analysis (CBA), sectoral/regional studies, multi-sectoral macroeconomic analysis, and international economic analysis (finance, trade, etc.) at the various hierarchic levels.

Figure A2.2. Incorporating Environmental Concerns into Decisionmaking



Source: adapted from Munasinghe (1992)

Unfortunately, environmental and social analysis cannot be carried out readily using the above process (*i.e.*, economic, financial and techno-engineering analyses). We examine how environmental issues might be incorporated into this framework (with the understanding that similar arguments may be made with regard to social issues). The left side of Figure A2.2 shows one convenient breakdown of environmental issues:

- global and transnational (*e.g.*, climate change, ozone layer depletion);
- natural habitat (*e.g.*, forests and other ecosystems);
- land (*e.g.*, agricultural zone);
- water resource (*e.g.*, river basin, aquifer, watershed); and
- urban-industrial (*e.g.*, metropolitan area, airshed).

In each case, a holistic environmental analysis would seek to study a physical or ecological system in its entirety. Complications arise when such natural systems cut across the structure of human society. For example, a large and complex forest ecosystem (like the Amazon) could span several countries, and also interact with many economic sectors (*e.g.*, agriculture, energy, etc.) within each country.

The causes of environmental degradation arise from human activity (ignoring natural disasters and other events of non-human origin), and therefore, we begin on the right side of the figure. The ecological effects of economic decisions must then be traced through to the left side. The techniques of environmental assessment (EA) have been developed to facilitate this analysis (World Bank 1998). For example, destruction of a primary moist tropical forest may be caused by activities in many different sectors of the economy. Slash and burn agriculture often exacerbates forest depletion. Land clearing could be encouraged by land-tax incentives arising from fiscal policy. Hydroelectric dams will inundate large tracks of forest. The construction of rural roads may cause significant forest cutting. Mining in remote areas also could cause large-scale depletion of forests. Disentangling and prioritising these multiple causes (right side) and their impacts (left side) will involve a complex analysis.

Figure A2.2 also shows to bridge the ecology-economy interface, by mapping the EA results (measured in physical or ecological units) onto the framework of conventional economic analysis. A variety of environmental and economic techniques facilitate this process of incorporating environmental issues into traditional decision making. These include valuation of environmental impacts (at the local/project level), integrated resource management (at the sector/regional level), environmental macroeconomic analysis and environmental accounting (at the economy-wide level), and global/transnational environmental economic analysis (at the international level). Since there is considerable overlap among the analytical techniques described above, this conceptual categorisation should not be interpreted too rigidly. Furthermore, when economic valuation of environmental impacts is difficult, techniques such as multi-criteria analysis (MCA) would be useful (see Section A2.3).

Once the foregoing steps are completed, projects and policies must be redesigned to reduce their environmental impacts and shift the development process towards a more sustainable path. Clearly, the formulation and implementation of such policies is itself a difficult task. In the deforestation example described earlier, protecting this ecosystem is likely to raise problems of co-ordinating policies in a large number of disparate and (usually) uncoordinated ministries and line institutions (*i.e.*, energy, transport, agriculture, industry, finance, forestry, etc.).

Analogous reasoning may be readily applied to social assessment (SA) at the society-economy interface, in order to incorporate social considerations more effectively into the conventional economic decision making framework. In this case, the left side of Figure A2.2 would include key elements of SA, such as asset distribution, inclusion, cultural considerations, values and institutions. Impacts on human society (*i.e.*, beliefs, values, knowledge and activities), and on the bio-geophysical environment (*i.e.*, both living and non-living resources) are often inter-linked via second and higher order paths, requiring integrated application of SA and EA. For example, economic theory emphasises the importance of pricing policy to provide incentives that will influence rational consumer behaviour. However, cases of seemingly irrational or perverse behaviour abound, which might be better understood through findings in areas like behavioural and social psychology, and market research.

Such work has identified basic principles that help to influence society and modify human actions, including reciprocity (or repaying favours), behaving consistently, following the lead of others, responding to those we like, obeying legitimate authorities, and valuing scarce resources (Cialdini 2001). These insights reflect current thinking on the co-evolution of socio-economic and ecological systems.

REFERENCES

Adger, W.N. (1999) 'Social vulnerability to climate change and extremes in coastal Vietnam', *World Development*, February, pp.1–21.

Adriaanse, A. (1993) *Environmental Policy Performance Indicators*, Sdu, Den Haag.

Alfsen, K. H., and H.V. Saebo. (1993) 'Environmental quality indicators: background, principles and examples from Norway', *Environmental and Resource Economics*, October, Vol. 3, pp.415–35.

Arrow, K.J., Cline, W., Maler, K.G., Munasinghe, M. and Stiglitz, J. (1995) 'Intertemporal equity, discounting, and economic efficiency', in *Global Climate Change: Economic and Policy Issues*, M. Munasinghe (Ed.), World Bank, Washington, DC.

Atkinson, G., Dubourg R., Hamilton, K., Munasinghe, M., Pearce, D.W. and Young, C. (1997) *Measuring Sustainable Development: Macroeconomics and the Environment*, Edward Elgar, Cheltenham, UK.

Azar, C., Homberg, J. and Lindgren, K. (1996) 'Socio-ecological indicators for sustainability', *Ecological Economics*, Vol. 18, August, pp.89–112.

Banuri, T. (1998) 'Human and environmental security', *Policy Matters*, Vol. 3, Autumn.

Banuri, T., Hyden, G. Juma,, C. and Rivera, M. (1994) Sustainable Human Development: From Concept To Operation: A Guide For The Practitioner, UNDP, New York.

Bennet, R. (2000) 'Risky business', *Science News*, Vol. 158, pp.190-1, September.

Bergstrom, S. (1993) 'Value standards in sub-sustainable development: On limits of ecological economics', *Ecological Economics*, Vol. 7, pp.1–18, February.

Bohle, H.G., Downing, T.E. and Watts, M.J. (1994) 'Climate change and social vulnerability: toward a sociology and geography of food insecurity', *Global Environmental Change*, Vol. 4, No. 1, pp.37–48.

Brown, P.G. (1998) 'Towards an economics of stewardship: the case of climate', *Ecological Economics*, Vol. 26 July, pp. 11–21.

Burton, I. (1997) 'Vulnerability and adaptive response in the context of climate and climate change', *Climatic Change*, Vol. 36, Nos. 1–2, pp.185–196.

Ceylon Electricity Board (CEB) (1987) *Masterplan for electricity supply in Sri Lanka, Vol 1*, CEB, Colombo, Sri Lanka.

Ceylon Electricity Board (CEB) (1988) *Masterplan for electricity supply in Sri Lanka, Vol 2*, CEB, Colombo, Sri Lanka.

Ceylon Electricity Board (CEB) (1989) *Long Term Generation Expansion Plan 1999-2013*, CEB, Colombo, Sri Lanka.

Chambers, R. (1989) 'Vulnerability, coping and policy', *IDS Bulletin*, Vol. 20, No. 2, pp.1–7.

Chenery, H. and Srinivasan, T.N. (Eds.) (1988 and 1989) *Handbook of Development Economics*, i and ii, North-Holland, Amsterdam.

Cialdini, R.B. (2001) *Influence: Science and Practice*, Fourth Edition, Allyn and Bacon, London, UK.

Clark, W.C. (1998) "Visions of the 21st century: Conventional wisdom and other surprises in the global interactions of population, technology and environment," in K. Newton, T. Schweitzer, J. P. Voyer, eds., *Perspective 2000: Proceedings of a conference sponsored by the Economic Council of Canada, December*, Economic Council of Canada, Ottawa, Canada, pp. 7-32.

Clarke, C. and Munasinghe, M. (1995) 'Economic aspects of disasters and sustainable development', in M. Munasinghe and C. Clarke (Eds.) *Disaster Prevention for Sustainable Development*, Int. Decade of Natural Disaster Reduction (IDNDR) and World Bank, Geneva and Wash. DC.

Colding, J. and Folke, C. (1997) 'The relations among threatened species, their protection, and taboos', *Conservation Ecology*, Vol.1, No.1, p.6. Available from: http://www.consecol.org /vol1/iss1/art6.

Cole, M.A., Rayner, A.J. and Bates, J.M. (1997) 'Environmental quality and economic growth', University of Nottingham, Department of Economics *Discussion Paper; 96/20*, pp.1–33, December.

Coleman, J. (1990) *Foundations of Social Theory*, Harvard Univ. Press, Cambridge MA.

Commission on Sustainable Development (CSD) (1998) *Indicators of Sustainable Development*, New York, NY, USA.

Costanza, R. (2000) 'Ecological sustainability, indicators and climate change', in *Climate Change and its Linkages with Development, Equity and Sustainability*, M. Munasinghe and R. Swart (Eds.), IPCC, Geneva.

Costanza, R., Cumberland J., Daly, H., Goodland, R. and Norgaard, R. (1997) *An Introduction to Ecological Economics*, St. Lucia's Press, Boca Raton FL, USA.

Daly, H.E. and Cobb, J.B. Jr. (1989) *For the Common Good*, Beacon Press, Boston MA.

Dasgupta, P. and Maler, K.G. (1997) 'The resource basis of production and consumption: an economic analysis', in *The Environment and Emerging Development Issues*, Vol. 1, P. Dasgupta and K.G. Maler (Eds.), Clarendon Press, Oxford.

Dreze, J. and Sen, A. (1990) *Hunger and Public Action*, Clarendon Press, Oxford.

Ecological Economics (2000) Special Issue on the Human Actor in Ecological-Economic Models, Vol.35, No.3, December.

Faucheux, S., Pearce, D. and Proops, J. (Eds.) (1996) *Models of Sustainable Development*, Edward Elgar, Cheltenham.

Freeman, A.M., (1993) 'The Measurement of Environmental and Resource Values: Theory and Methods', *Resources for the Future*, Washington DC.

Georgescu-Roegen, N. (1971) *The Entropy Law and the Economic Process*, Harvard University Press, Cambridge, MA.

Gilbert, A. and Feenstra, J. (1994) 'Sustainability indicators for the Dutch environmental policy theme 'diffusion' cadmium accumulation in soil', *Ecological Economics*, Vol. 9, pp.253–65, April.

Gintis, H. (2000) 'Beyond homo economicus: evidence from experimental economics', *Ecological Economics*, Vol.35, No.3, pp.311-23, December.

Grootaert, C. (1998) 'Social capital: the missing link', *Social Capital Initiative Working Paper No. 3*, World Bank, Washington DC.

Gunderson, L., and Holling, C.S. (2001) *Panarchy: understanding transformations in human and natural systems*. Island Press, New York, NY, USA.

Hall, C. (Ed.) (1995) *Maximum Power: The Ideas and Applications of H.T.Odum*, Colorado University Press, Niwot, CO.

Hanna, S. and Munasinghe, M. (1995) *Property Rights in Social and Ecological Context*, Beijer Institute and World Bank, Stockholm and Washington, DC.

Hicks, J. (1946) *Value and Capital*, 2nd edition, Oxford University Press, Oxford, UK.

Holling, C.S. (1973) 'Resilience and stability of ecological systems', *Annual Review of Ecology and Systematics*, Vol. 4, pp. 1–23.

Holling, C.S. (1986) 'The resilience of terrestrial ecosystems: local surprises and global change', in W.C.Clark and R.E.Munn (Eds.), *Sustainable Development of the Biosphere*, Cambridge University Press, Cambridge, UK, pp.292-317.

Holling, C.S. (1992) 'Cross scale morphology, geometry and dynamics of ecosystems', *Ecological Mornographs*, Vol. 62, pp. 447–502.

Holmberg, J., and Karlsson, S. (1992) 'On designing socio-ecological indicators', in U. Svedin and Bhagerhall-Aniansson (Eds.) *Society and Environment: A Swedish Research Perspective*, Kluwer Academic, Boston.

Holtz-Eakin, D. and Selden, T.M. (1995) 'Stoking the fires? CO_2 emissions and economic growth', *National Bureau of Economic Research*, Working Paper Series, 4248, pp.1–38. December

IPCC (1996a) *Climate Change 1995: Economic and Social Dimensions of Climate Change*, J.P. Bruce, *et al.*, (Eds.) Cambridge University Press, London, UK.

IPCC (1996b) *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change*, Watson, R.T., *et al.*, (Eds.) Cambridge University Press, London, UK.

IPCC (1997) *Climate Change and Integrated Assessment Models (IAMs)*, Geneva, Switzerland.

IPCC (1999) *Special Report on Technology Transfer* , IPCC, Geneva.

IPCC (2000), *IPCC Special Report: Emissions Scenarios*, Nebojsa Nakicenovic and Rob Swart (Eds), Special Report of IPCC Working Group III, Geneva, Switzerland.

IPCC (2001a) *Climate Change 2001*, Third Assessment Report, Cambridge University Press, London, UK.

IPCC (2001b) *Climate Change, Synthesis Report*, A Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, and New York, USA

Islam, Sardar M.N. (2001) 'Ecology and optimal economic growth: an optimal ecological economic growth model and its sustainability implications', in *The Sustainability of Long Term Growth*, M. Munasinghe, O. Sunkel and C. de Miguel (Eds.), Edward Elgar, Cheltenham.

Jepma, C. and Munasinghe, M. (1998) *Climate Change Policy*, Cambridge Univ. Press, Cambridge, UK.

Kuik, O. and Verbruggen, H. (Eds.) (1991) *In Search of Indicators of Sustainable Development*, Kluwer, Boston.

Kverndokk, S. (1995) 'Tradeable CO_2 emission permits: initial distribution as a justice problem', *Environmental Values*, Vol. 4, pp.129–48.

Liverman, D., Hanson, M., Brown, B.J. and Meredith, R. Jr. (1988) 'Global sustainability: towards measurement', *Environmental Management*, Vol. 12, pp.133–143.

Lonergan, S.L. (1993) 'Impoverishment, population and environmental degradation: the case for equity', *Environmental Conservation*, Vol. 20, No. 4, pp.328–334.

Ludwig, D., Walker, B. and Holling, C.S. (1997) 'Sustainability, stability, and resilience', *Conservation Ecology* [online] Vol. 1, No. 1, p. 7. Available from: http://www.consecol.org/vol1/iss1/art7

Maler, K.G. (1990) 'Economic theory and environmental degradation: a survey of some problems', *Revista de Analisis Economico*, Vol. 5, November pp. 7–17.

Maslow, A.H. (1970) *Motivation and Personality*, Harper and Row, New York.

Meier, P., and Munasinghe, M. (1994) *Incorporating Environmental Concerns in to Power Sector Decision Making*, The World Bank, Washington DC.

Moffat, I. (1994) 'On measuring sustainable development indicators', *International Journal of Sustainable Development and World Ecology*, Vol. 1, pp.97–109.

Morimoto, R., M. Munasinghe and P.M. Meier (2000) 'Sustainable energy development: assessing the economic, social and environmental implications of hydropower projects in Sri Lanka', *MIND Research-Discussion Paper No.2*, Munasinghe Institute For Development (MIND), Colombo, Sri Lanka.

Moser, C. (1998) "The asset vulnerability framework: reassessing urban poverty reduction strategies", *World Development*, Vol.26, No.1, p.1-19.

Munasinghe, M. (1990) *Energy Analysis and Policy*, Butterworth-Heinemann, London, UK.

Munasinghe, M. (1992) *Environmental Economics and Sustainable Development*, Paper presented at the UN Earth Summit, Rio de Janeiro, Brazil, and reproduced as Environment Paper No. 3, World Bank, Wash. DC, USA.

Munasinghe, M. (1993) *Environmental Economics and Sustainable Development*, World Bank, Washington, DC.

Munasinghe, M. (1994) 'Sustainomics: a transdisciplinary framework for sustainable development', *Keynote Paper, Proc. 50th Anniversary Sessions of the Sri Lanka Assoc. for the Adv. of Science* (SLAAS), Colombo, Sri Lanka.

Munasinghe, M. (1995) 'Making growth more sustainable', *Ecological Economics*, Vol. 15, pp.121-4.

Munasinghe, M. (1998a). 'Climate change decision-making: science, policy and economics', *International Journal of Environment and Pollution*, Vol. 10, No. 2, pp.188–239.

Munasinghe, M. (1998b) 'Countrywide policies and sustainable development: are the linkages perverse?', in T. Teitenberg and H. Folmer (Eds.) *The International Yearbook of International and Resource Economics*, Edward Elgar Publ., London, UK.

Munasinghe, M. (1998c). 'Is environmental degradation an inevitable consequence of economic growth', *Ecological Economics*, December.

Munasinghe, M. (2000) 'Development, equity and sustainability in the context of climate change', *IPCC Guidance Paper*, Intergovernmental Panel on Climate Change, Geneva.

Munasinghe, M. (2001) 'Sustainable development and climate change: applying the sustainomics transdisciplinary meta-framework', *International Journal of Global Environmental Issues*, Vol. 5, No. 1, pp. 13-55.

Munasinghe, M. (2002) *Macroeconomics and the Environment*, The International Library of Critical Writings in Economics, Edward Elgar Publ., London, UK.

Munasinghe, M. (Ed.) (1996) *Environmental Impacts of Macroeconomic and Sectoral Policies*, International Society for Ecological Economics and World Bank, Solomons, MD and Wash. DC.

Munasinghe, M. and Cruz, W. (1994) *Economywide Policies and the Environment*, The World Bank, Washington DC, USA.

Munasinghe, M., and Shearer, W. (Eds.) (1995) *Defining and Measuring Sustainability: The Biogeophysical Foundations*, UN University and World Bank, Tokyo and Washington, DC, USA.

Munasinghe, M., and Swart, R. (Eds.) (2000) *Climate Change and its Linkages with Development, Equity and Sustainability*, Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland.

Munasinghe, M., O. Sunkel and C. de Miguel (Eds.) (2001) *The Sustainability of Long Term Growth*, Edward Elgar Publ., London, UK.

Nordhaus, W., and Tobin, J. (1972) 'Is growth obsolete?', *Economic Growth*, National Bureau of Economic Research (NBER), Columbia University Press, New York, NY, USA.

North, D. (1990) *Institutions, Institutional Change and Economic Performance*, Cambridge Univ. Press, Cambridge, UK.

OECD (1994) *Environmental Indicators*, OECD, Paris, France.

OECD (2001) *Sustainable Development: Critical Issues*, Paris, France

OECD (2002) 'Results of expert meeting and next steps', *Environment Directorate*, OECD, Paris, April.

Olson, M. (1982) *The Rise and Decline of Nations*, Yale Univ. Press, New Haven, CN, USA.

Opschoor, H. and Reijnders, L. (1991) 'Towards sustainable development indicators', in O. Kuik and H. Verbruggen (Eds.) *In Search of Indicators of Sustainable Development*, Kluwer, Boston, MA, USA.

Parris, T.M. and Kates R.W. (2001) 'Characterizing a Sustainability Transition: The International Consensus', *Research and Assessment Systems for Sustainability Discussion Paper*, Environment and Natural Resources Program, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, Cambridge, MA, USA.

Pearce, D.W., and Turner, R.K. (1990) *Economics of Natural Resources and the Environment*, Harvester Wheatsheaf, London, UK.

Perrings, C. and Opschoor, H. (1994) *Environmental and Resource Economics*, Edward Elgar Publ., Cheltenham, UK.

Perrings, C., Maler, K.G. and Folke, C. (1995) *Biodiversity Loss: Economic and Ecological Issues*, Cambridge University Press, Cambridge, UK.

Petersen, G.D., Allen, C.R. and Holling, C.S. (1998) 'Diversity, ecological function, and scale: resilience within and across scales', *Ecosystems*, Vol. 1.

Pezzey, J. (1992) 'Sustainable development concepts: an economic analysis', *Environment Paper No. 2*, World Bank, Washington, DC.

Pigou, A.C. (1932) *The Economics of Welfare*, Macmillan, London, UK

Pimm, S.L. (1991) *The Balance of Nature*?, University of Chicago Press, Chicago, IL.

Pinguelli-Rosa, L., and Munasinghe, M. (Eds) (2002) *Ethics, Equity and International Negotiations on Climate Change*, Edward Elgar Publ., London, UK.

Putnam, R.D. (1993) *Making Democracy Work: Civic Traditions in Modern Italy*, Princeton Univ. Press, Princeton.

Rayner, S. and Malone, E. (Eds.) (1998) *Human Choice and Climate Change*, Batelle Press, Columbus, OH, pp.1–4,

Ribot, J.C., Najam, A. and Watson, G. (1996) 'Climate variation, vulnerability and sustainable development in the semi-arid tropics', in J.C Ribot, A.R. Magalhaes and S.S. Pangides (Eds), *Climate Variability, Climate Change and Social Vulnerability in the Semi-Arid Tropics*, Cambridge University Press, Cambridge, UK.

Robson, A.J. (2001) "The biological basis of human behavior', *Journal of Economic Literature*, Vol. XXXIX, pp.11-33, March.

Ruitenbeek, H.J. (1996) 'Distribution of ecological entitlements: implications for economic security and population movement', *Ecological Economics*, Vol. 17, pp.49–64.

Schutz, J. (1999) 'The value of systemic reasoning', *Ecological Econ.*, Vol. 31, No. 1, pp.23–29, October.

Sen, A.K. (1987) *On Ethics and Economics*, Basil Blackwell, Cambridge, MA.

Sengupta, R. (1996) *Economic Development and CO_2 Emissions*, Institute for Economic Development, Boston University, Boston MA.

Siebhuner, B. (2000) 'Homo sustinens – towards a new conception of humans for the science of sustainability', *Ecological Economics*, Vol. 32, pp. 15–25.

Smit, B. et al. (2001), "Adaptation to Climate Change in the Context of Sustainable Development and Equity", Intergovernmental Panel on Climate Change, *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge et al., 877–912.

Solow, R. (1986) 'On the intergenerational allocation of natural resources', *Scandinavian Journal of Economics*, Vol. 88, No. 1, pp.141–9.

Squire, L. and van der Tak, H. (1975) *Economic Analysis of Projects*, Johns Hopkins Univ. Press, Baltimore MD, USA.

Stern, N.H. (1989) 'The economics of development: a survey', *Economic Journal*, 99.

Teitenberg, T. (1992) *Environmental and Natural Resource Economics*, Harper Collins Publ., New York NY.

Tellus Institute (2001) *Halfway to the Future: Reflections on the Global Condition*, Tellus Institute, Boston. MA, USA.

Temple, J. (1999) 'The new growth evidence', *Journal of Economics Literature*, Vol. XXXVII March, pp. 112–54.

Toth, F. (1999) 'Decision analysis for climate change', in M. Munasinghe (Ed.), *Climate Change and Its Linkages With Development, Equity and Sustainability*, Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland.

Tufte.E.R. (1992) *The Visual Display of Quantitative Information*, Graphics Press, London UK.

UN (1993) *Agenda 21*, United Nations, New York.

UN (1996) *Indicators of Sustainable Development: Framework and Methodology*, New York, NY, USA.

UN Statistical Office (1993) *Integrated Environmental and Resource Accounting*, Series F, No. 61, United Nations, New York, NY, USA.

UNDP (1998) *Human Development Report*, New York, NY, USA.

UNFCCC (United Nations Framework Convention on Climate Change) (1993) *Framework Convention on Climate Change: Agenda 21*, United Nations, New York, NY, USA.

Unruh, G.C. and Moomaw, W.R. (1998) 'An alternative analysis of apparent EKC-type transitions', *Ecological Economics*, Vol. 25, pp.221–229, May.

WCED (World Commission on Environment and Development) (1987) *Our Common Future*, Oxford University Press, Oxford, UK.

Westing, A. (1992) 'Environmental refugees: a growing category of displaced persons', *Environmental Conservation*, Vol. 19, No. 3, pp.201–207.

Westra, L. (1994) *An Environmental Proposal for Ethics: The Principle of Integrity*, Rowman and Littlefield, Lanham, MA.

World Bank (1997) 'Expanding the measures of wealth: indicators of environmentally sustainable development', *Environment Department, World Bank*, Washington DC, USA.

World Bank (1998) *Environmental Assessment Operational Directive*, (EAOD4.01). Washington DC, USA.

Yohe, G. and Tol, R.S.J., (2001), "Indicators for Social and Economic Coping Capacity – Moving Toward a Working Definition of Adaptive Capacity", *Global Environmental Change*, 2002

Climate Change and Sustainable Development : View from the developing world

Kirit Parikh
JGIDR

Sustainable Development

- Development is
  - Needed
  - Desirable
  - **Environmentally Beneficial**
- The last part is true for **local environment**

  but questionable for **global environment**

  and particularly for **Climate Change**

  UNLESS

  Pattern of Development changes.

SD - The Main Concerns

Air Quality
- DSM
- Renewables
- Public Transport
- Technology

Water Resources
- Recycle, DSM, Ecological Constraints

Land Degradation
- Forests, CPRs, Land Use

Bio Diversity
- Habitat Protection

SD – Oceans: A Global Commons

- Sustainable Fishery
- Cooperative Use Restraints

Policies/Actions for SD

Internalize externalities for Efficiency

- Economic Instruments
    - Taxes
    - Tradable permits
- Property Rights

Empowerment for Equity

Participation for Enforceability

Education and Awareness for Consensus

How CC Affects These

- Threatens Resources
- Deepens the Problems
- Poses New Problems
- Makes Solutions more Difficult and Expensive

Some Questions Related to Climate Change

- **What should be the concentration of GHG that can be tolerated at different times by weaker sections of the world?**
- **By how much should emissions be reduced to achieve these chosen levels of tolerable concentrations?**
- **How should the burden of abatement be distributed, taking into account responsibility for current concentration and development needs?**
- **What kind of global and national policies will achieve the desired reductions of concentrations of GHG, and in turn the emissions?**
- **What should be the precautionary policies?**

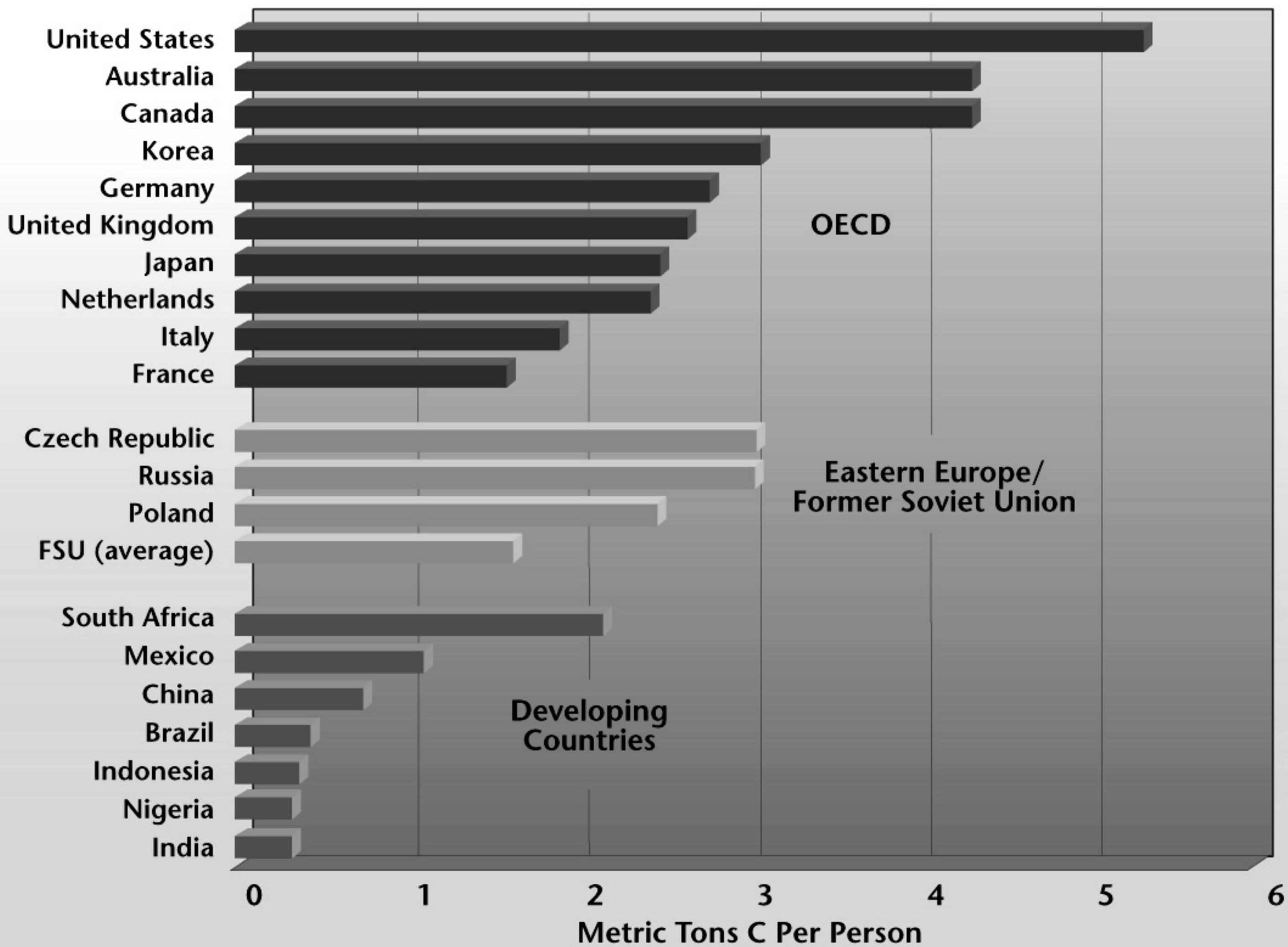
Consumption patterns the driving force

- 75% of energy resources are consumed by 25% of the population in industrialised countries
- They also consume more than
  - 70% of mineral resources (copper, steel, aluminum. Etc)
  - 75% of cars
  - 75% of newsprints, timber, etc.
- 70% of carbon emitted by them
- One american child requires more than 30 times as much resources as an indian child

Consumption patterns the driving force (contd)

- Decarbonisation requires
  - shifts in energy policy
  - dramatic technical progress
  - major changes in consumption patterns of the rich….which the poor aspire to follow tomorrow

Per Capita Carbon Emissions



% Shares in Resources Consumption

Category	Product	Developed Countries	Developing Countries
Population		**25%**	**75%**
Food	Cereals	48	52
	Milk	72	28
	Meat	64	36
Forest	Round Wood	46	54
	Sawn Wood	78	22
	Paper, etc..	81	19
Industry	Fertilisers	60	40
	Cement	52	48
	Cotton, etc..	47	53
Metals	Copper	86	14
	Iron & Steel	80	20
	Aluminium	86	14
Chemicals	Inorganic	87	13
	Organic	85	15
Transport Vehicles	Cars	92	8
	Commrcl Veh.	95	15
Fuel & Electricity	Solid	66	34
	Liquid	75	25
	Gas	85	15
	Electricity	81	19
	Total Energy	75	25
CO_2 Emissions	Total	70	30
	Accumulated (50-89)	77	23

What does it mean in per capita terms?

Compared to an average Indian citizen,

an average USA citizen consumes

			*Equiv. Indian popn. of USA (million)
6	times	Cereal	1470
4	times	Milk	980
52	times	Meat	12740
6	times	Fertilizers	1470
7	times	Cement	1715
6.4	times	Cotton & wood fabrics	1568
245	times	Copper	60025
22	times	Iron and Steel	5390
85	times	Aluminium	20825
54	times	Organic Chemicals	13230
28	times	Inorganic Chemicals	6860

Contd..

What does it mean in per capita terms?

Compared to an average Indian citizen, an average USA citizen consumes

			*Equiv. Indian popn. of USA (million)
320	times	Cars	78400
102	times	Commercial Vehicles	24990
14	times	Solid Fuels	3430
61	times	Liquid Fuels	14945
227	times	Gas	55615
46	times	Electricity	11270
35	times	Total Energy	8575
27	times	Total Carbon dioxide Emissions	6615

*** Equivalent USA population =**

$$\text{population a commodity} \times \frac{\text{Per cap. cons. of USA}}{\text{Per cap. cons. of India}}$$

Why Consumption Patterns Matter ?

- Resource depletion
- Green house gas accumulates
- Ozone depletion
- Polluted Oceans
- Accumulated and transferred hazardous and other wastes
- Cumulated nuclear wastes

Above All – It Sets A Standard for the Global Village

- India if it grows at 8 -10 % for 25 years
- Its 1.4 billion people will have a per capita income of US$ 20000
- With Such growth the Rupee will appreciate
- How they consume will depend on the Standard set by the Rich today

Poverty and global warming

- Poor always more vulnerable
  - deaths due to earthquake ,1993
    - 10,000 in India
    - 100 in California
- Rich can spend more on hedging
  - Netherlands and Bangladesh
- Submergence of island states
  - 35% of Bangladesh under water
  - extreme events
    - increased homelessness and poverty
    - lost livelihoods from fisheries, agriculture
    - large scale migration: 7 million in Indian cities and towns

Impact of Climate Change

- **FCCC** :ensure that food production is not threatened
- **Rosenzweig and Parry** :significant adverse impact on developing countries
- **Parikh J and Kavi Kumar** :a more detailed study of Indian agriculture

d t 2.5º to 4.9ºC

rice yield - 15% to - 42%

wheat yield - 25% to - 55%

(without carbon fertilization effect)

<u>with fertilization</u> - smaller but similar impact

<u>With adaptation</u>

DT + 2°C + 7% Precipitation ▸ $\mathbf{GDP_{Agri}}$ ¯ 7%

DT + 3.5°C + 15% Precipitation ▸ $\mathbf{GDP_{ag}}$ ¯ 25%

Þ Poverty - Þ Hunger -

Agriculture and Climate Change

Indian Agriculture

- GDP from agriculture: 34% , 1994
  42% , 1980
- Area under agriculture: 50% , 760 mha
- Dependent population: 70%
- Average farm size: 1 to 5 ha
- Landless dependent on others

Crop	Area & Irrg., mha	Prod., mt	Rs.	% of Agri. GDP
RICE	42, 20	73	365	22 %
WHEAT	24, 21	57	208	12.6 %

Indian Agriculture contd.

- Pests and diseases always predominant
  - favourable weather in tropics
  - multiple cropping
  - availability of alternative hosts
  - low , but indiscrimate, usage of pesticides
- Disturbance days due to extreme events
  - 17 to 27 ; 10 days increase
- Rise in sea level can

  inundate 1700 km^2 agricultural land

  necessitate 4000 km of dykes and sea walls

  submerge 576 km^2 total land & 4200 km of roads

Adaptation and Damages Vulnerability to

- Frequent storms, floods and other extreme events
- Change in cropping patterns
- Loss of livelihoods from fishing and farming
- Uprooting and migration due to submergence
- Incur increased cooling costs

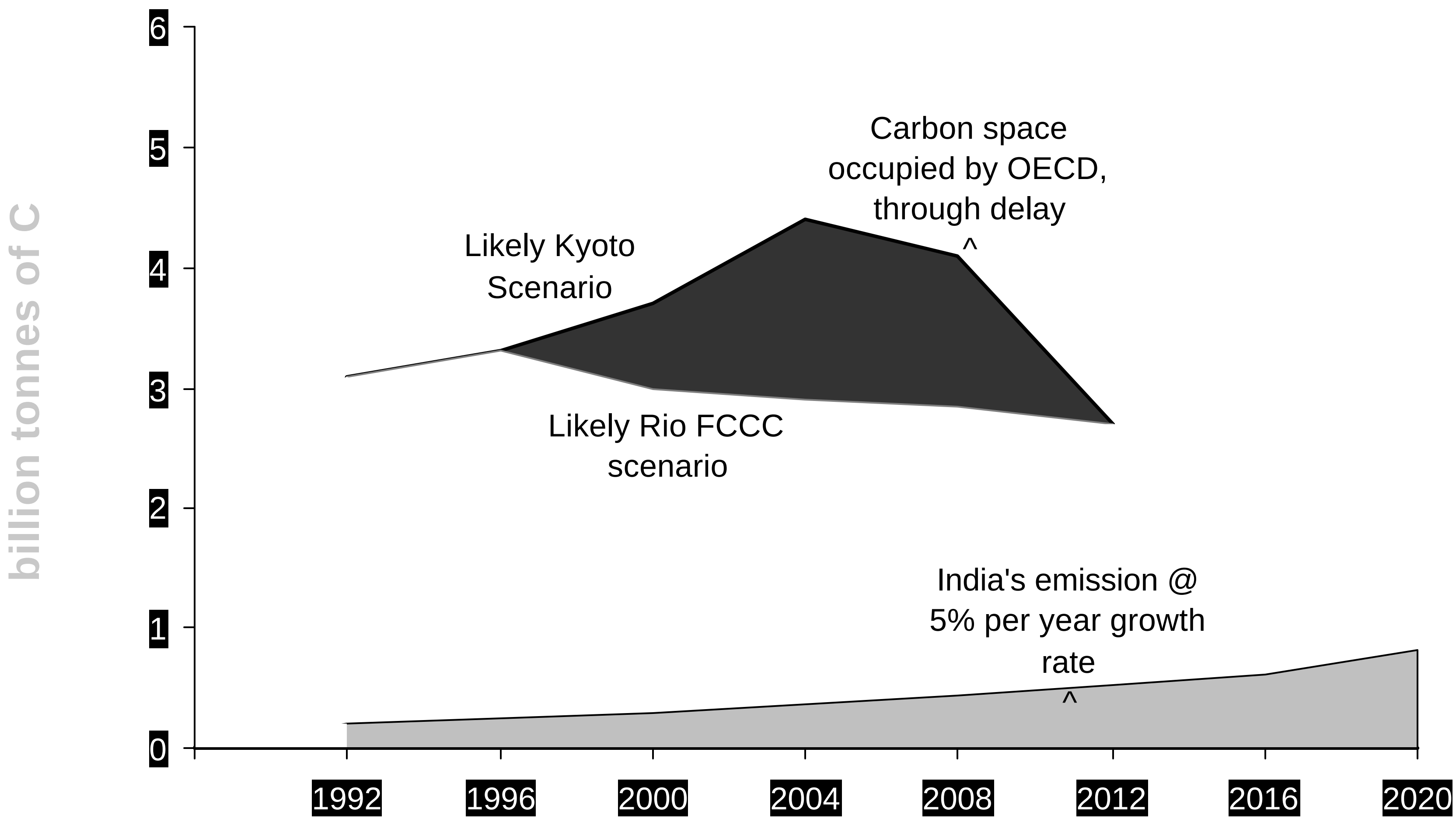
Adaptation

- Is Expensive
- If Indian Farmers can adapt as Americans the loss in Agric GDP will be 5% not 25%
- American farmers adapt better because of public investment in Irrigation, Research and Education

The economic cost of sea level rise: 1m scenarios for India

		Rs Billions	$ bn
Land Loss (km^2)	5763	1527.41	500
Houses	756712	93.98	30
Popl. Displacement ('000)	7100	71.00	230
Loss of Road Network (km)	4245	2.89	1
Dislocation of Jetty/Ore loading points	26	.38	0.15

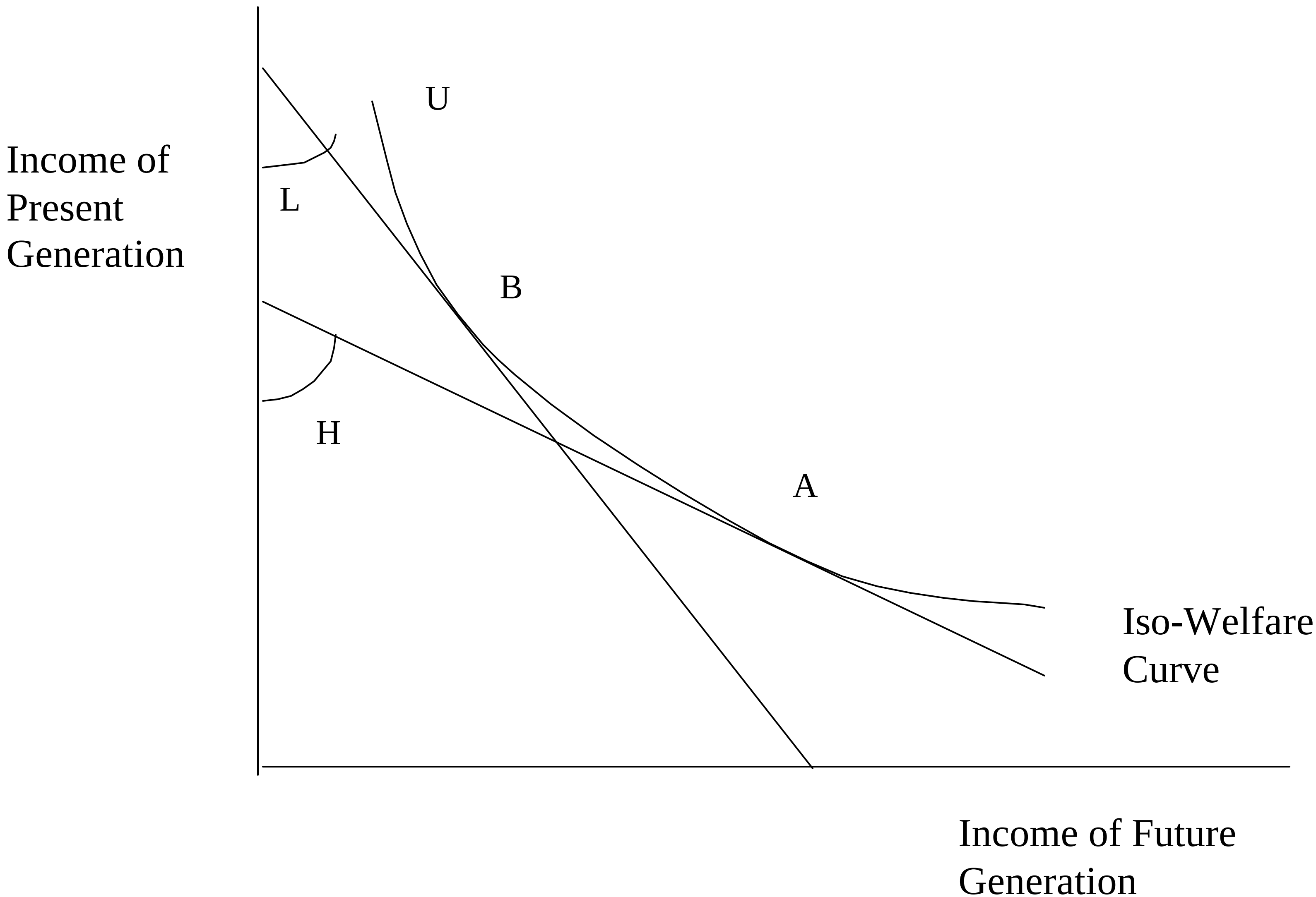
Delay is Free Riding As It Occupies Global Environmental Space



Why the Delay?

- Discount Rate
- Uncertainty
- Burden Sharing

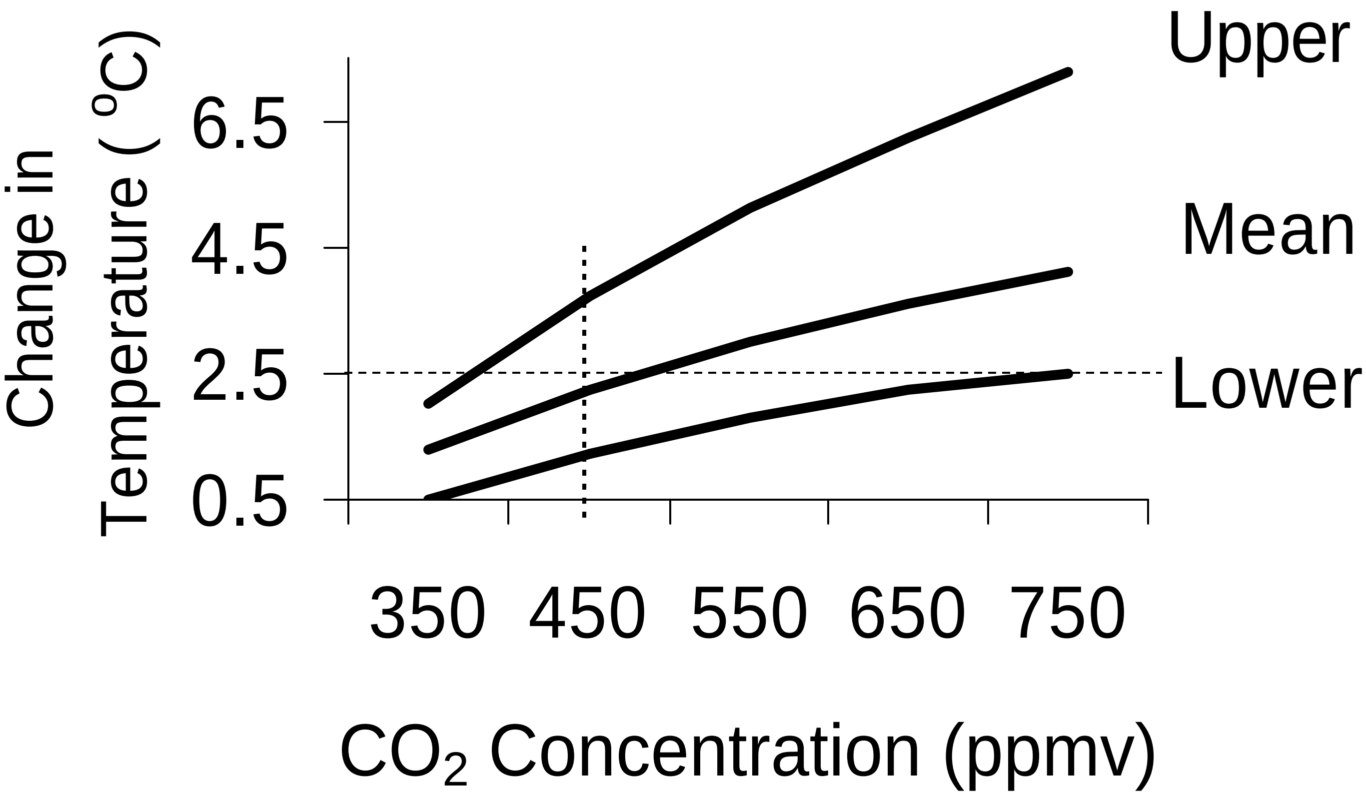
Intergenerational Discount Rate



Considerations for discounting

- Should be considered liability reduction and not as another investment option
- Similarly with local pollution - choice is not with industries who pollute but what is good for society
- “Depends whether the future generation is richer or poorer” - the South in future will be poorer compared to the North at present for nearly a century, though some countries may be richer sooner. <u>Therefore world average as an indicator.</u> Those above this average should consider that future generation will be poorer. South can think that future generation will be richer than at present.

Uncertainty: in temperature rise due to concentration

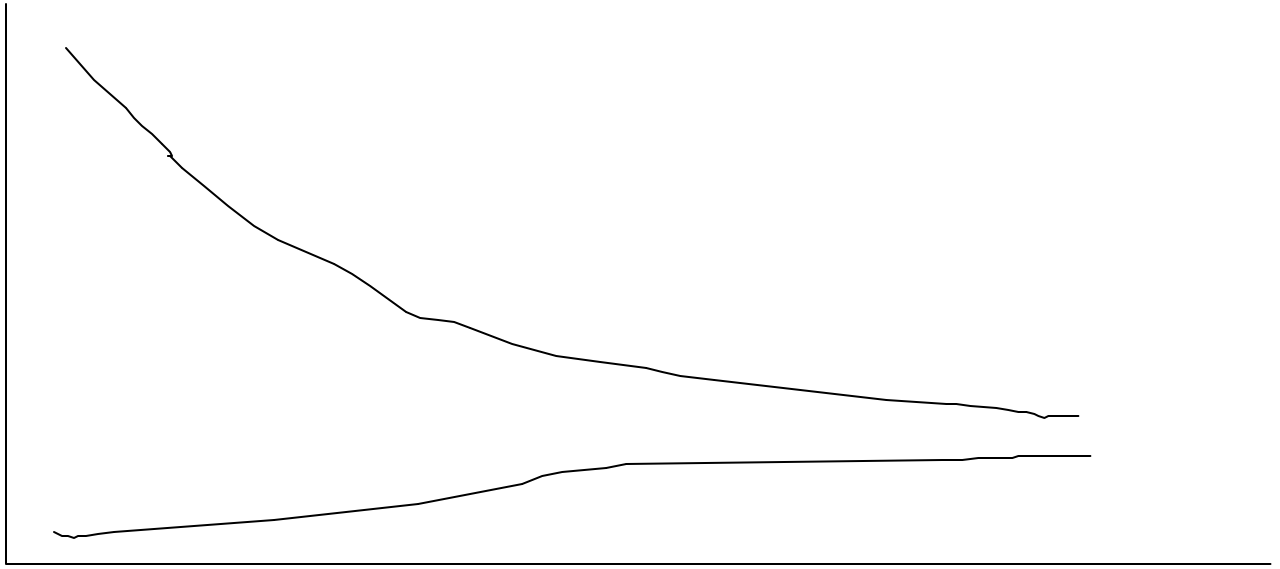


Adaptation should not be an Excuse for Avoiding Mitigation

- “You adopt, I would not Mitigate” is not Acceptable
- Convergence and Contraction in an equitable way

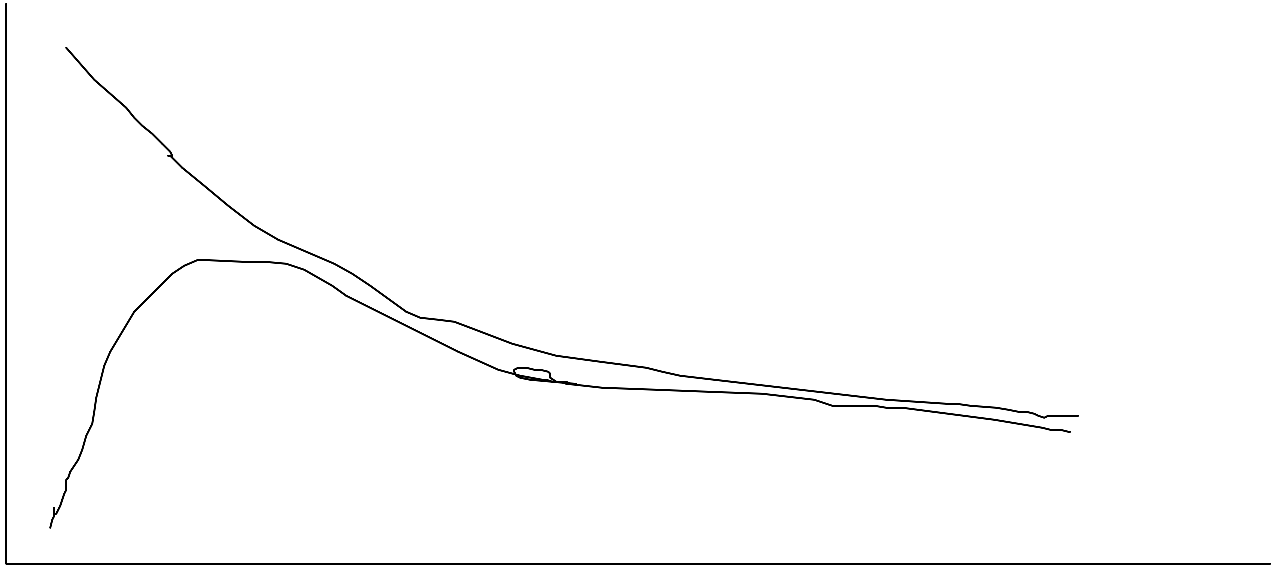
Convergence and Contraction

- Unfair



Convergence and Contraction

Equitable



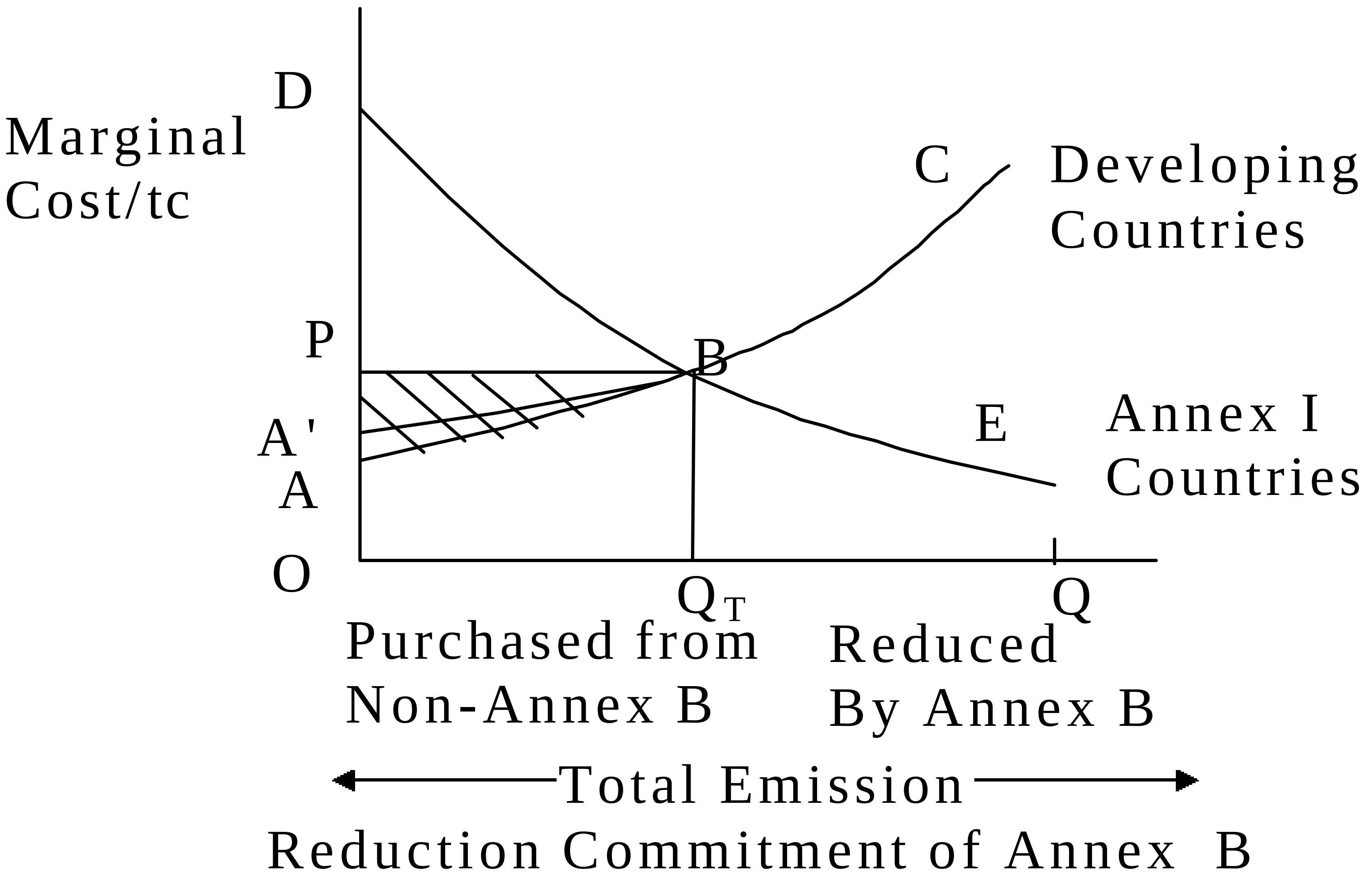
Climate Change And North-South Cooperation

- **CO_2 emissions are not likely to be reduced by merely political and regulatory instruments; need incentives to move away from fossil-fuels**
- **DCs can adopt energy efficient technologies to reduce CO_2 emissions**
- **CDM, JI projects and tradable permits can be established in consonance to help the transition to TEPs in the future**
- **We have to consolidate our international negotiating positions to derive fairer benefits from JI initiatives**

Problems with CDM

- **Base Line**
  - **Perverse Incentives to Inflate**
- **Technology Transfer**
  - **Sequestration Programme**
  - **A Technology Acquisition Fund**
- **Fare Share**

Carbon trading : Who gains what ?



Mitigating Climate Change: What Some Developing Countries Have Done

- Emphasis on energy conservation
- Promotion of renewable energy sources
- Abatement of air pollution
- Afforestation and wasteland development
- Economic reforms, subsidy removal and joint ventures in capital goods
- Fuel substitution policies

Air Pollution Abatement

- Motivation for implementation of energy efficient options
- Afforestation and Wasteland Development
- Programmes of afforestation supported by government
- Rate of deforestation has decreased in the 1990's

Issues to explore

- **The need for an approach to mitigating threat of climate change that is equitable and one that can accommodate differing perspective on risk need to be elaborated. Could we design mechanism that would work?**
- **How can we address the concern of developing countries about an unequal bargain in CDM?**
- **Paradigm shift from abatement cost to risk minimization for everyone.**
- **How can one finance synergistic development in developing countries?**
- **What kind of global regime do we need to monitor emissions trade?**

An Equitable Solution

- Tradable Emission Quotas Over A Long Time Horizon in terms of tonne-years of carbon in the atmosphere
  - Equitably distributed
  - Range specified
  - Range narrows as knowledge firms up
- CDM is a Stop Gap Arrangement
  - Fix a Floor Price
  - A Technology Acquisition Fund

Policies / Actions for SD as Important for CC

- Internalize externalities for Efficiency.
  - Economic Instruments.
    - Taxes.
    - Tradable Permits.
  - Property Rights
- Empowerment for Equity.
- Participation for Enforceability.
- Education and Awareness for Consensus.

Climate Change and Sustainable Development

A view from the developed world

Jan Corfee Morlot

OECD

Overview

Background

1. **OECD on Sustainable Development: Progress, Challenges and Policy Framework**

2. ***Making Markets Work: Subsidy Reform***

3. **Improving Policy Coherence: Climate Change and Development**

4. **Benefits of Climate Policies**

1. Progress and challenges

SD requires maintenance of 4 different types of capital:

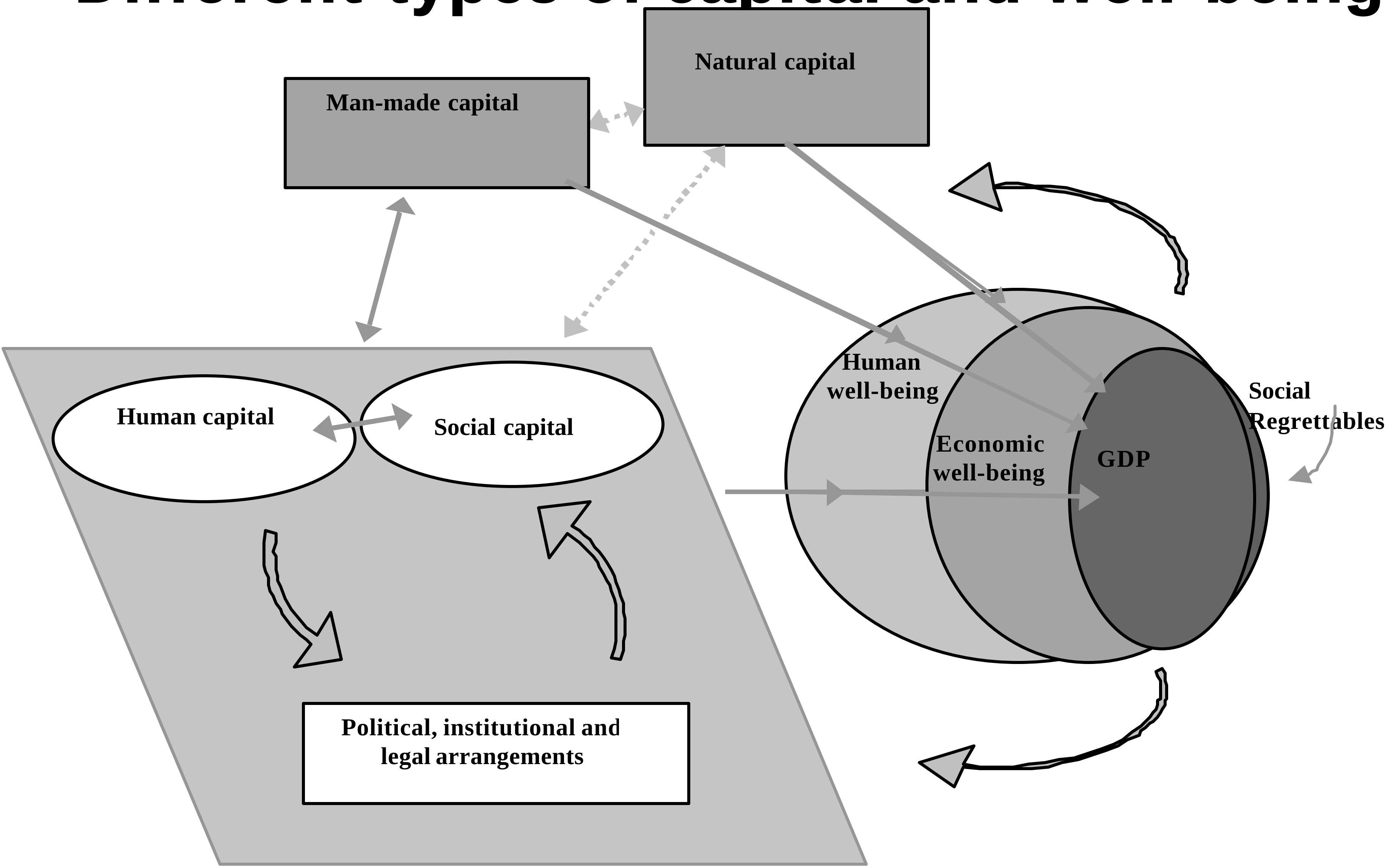
Man-made capital: *the produced means of production (e.g. machinery and equipment), related infrastructure, non-tangibles an financial assets*

Natural capital: *non-renewable and renewable resources, other environmental assets*

Human capital: *knowledge, skills, competencies, education and health*

Social (or institutional) capital: networks of shared norms, values and understanding that facilitate co-operation between groups

Different types of capital and well-being



Source: Adapted from OECD (2001), The Well-Being of Nations: The Role of Human and Social Capital, Paris.

Context: progress and challenges

Sustained economic growth (1970-2000) in OECD countries

1970s : 3 % p.a.

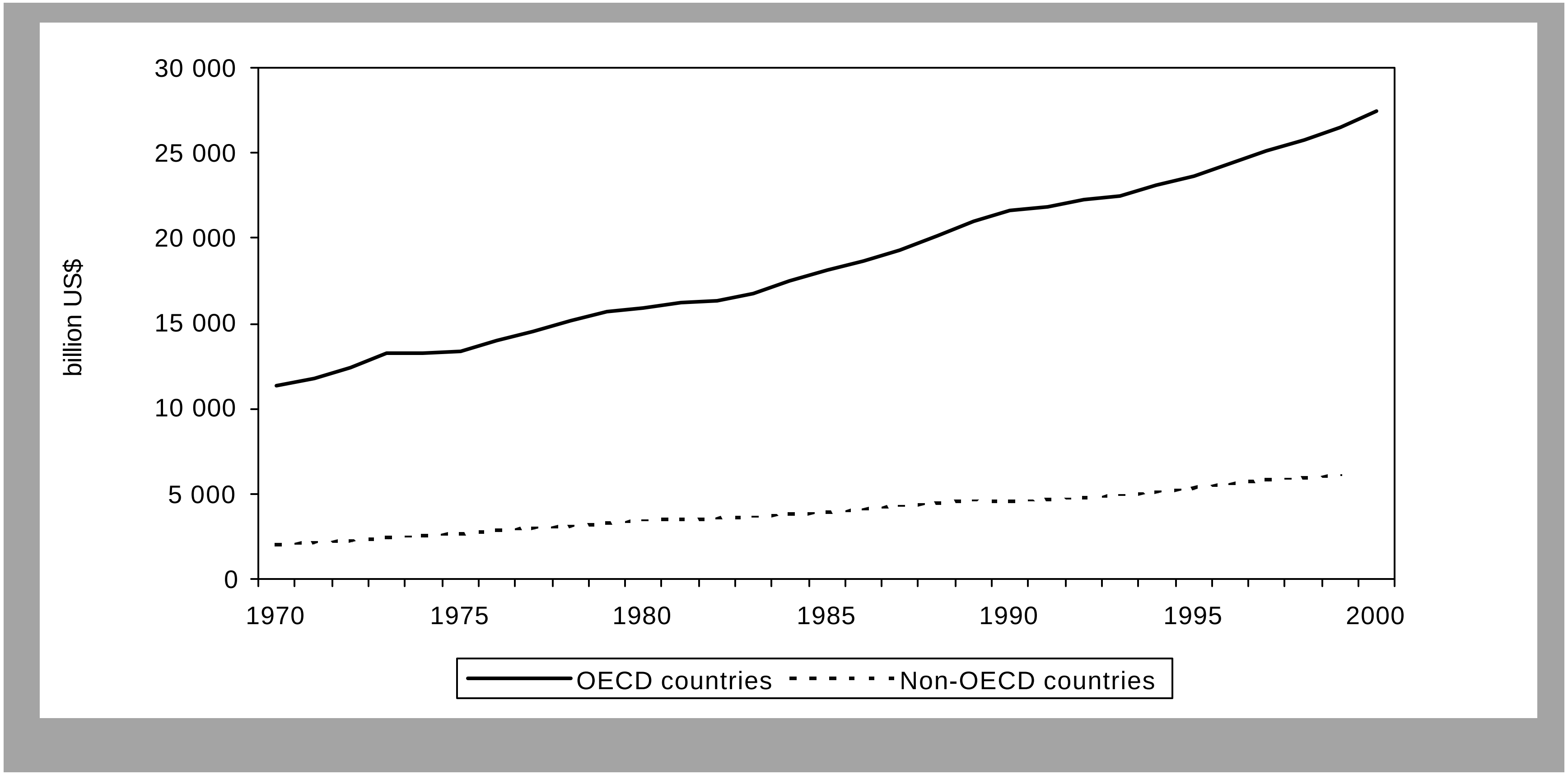
1980s : 2.4 % p.a.

1990s : 2.6 % p.a.

Tripling of per capita income in 26 OECD countries

Non-OECD countries grew by 3.3% in last decade, however, high population growth has led to decline in per capita income

Trends in total gross domestic product, OECD and non-OECD, 1970-2000



Notes: At the price levels and exchange rates of 1995. Data for OECD exclude Czech Republic, Hungary, Poland and Slovak Republic.
Sources: OECD, National Accounts Database; World Bank (2000).

Long term productivity trends are driven by technology changes

Key sectors and technologies driving productivity increases

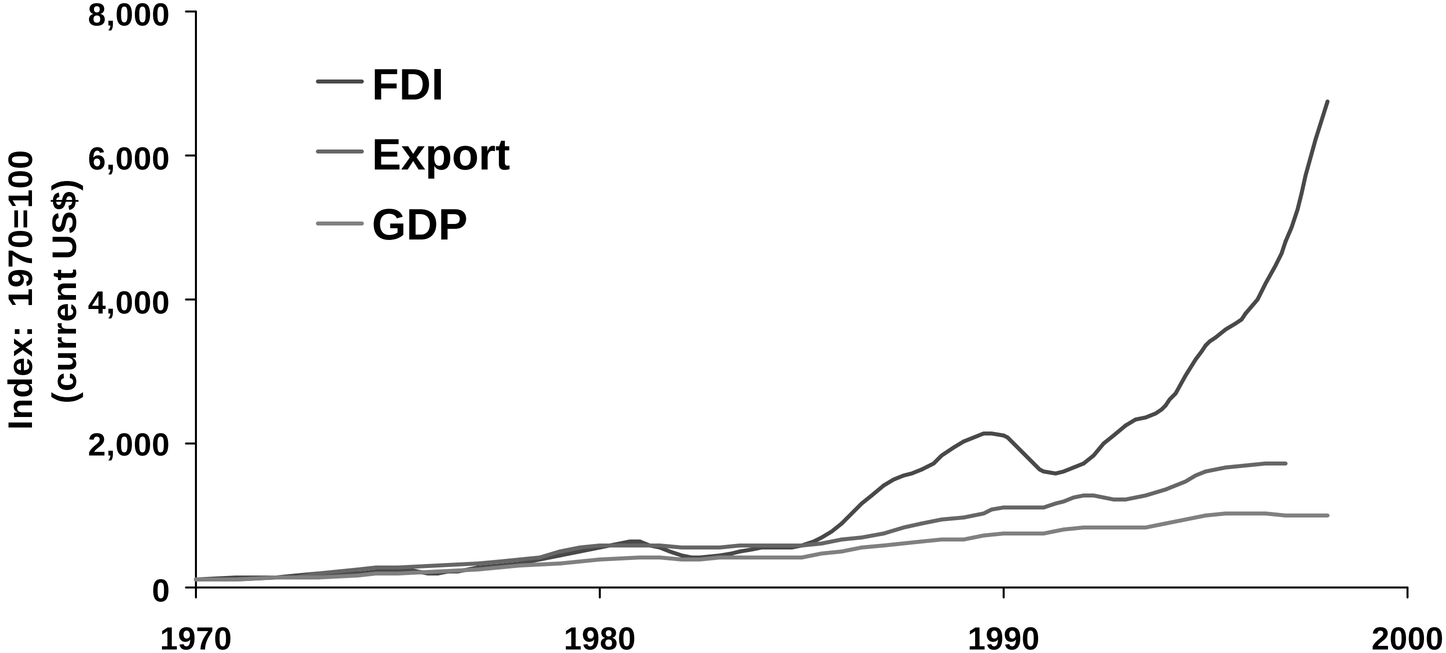
	1820-1890	1880-1945	1935-1995	1985-2050
Key sectors	Coal, railroads, steam power, mech. Equipment	Cars, chemical industry, metallurgical processes	Electric power, oil, aviation, radio and TV, instruments and control	Gas, nuclear, ICT, satellite and laser communications
Key technologies	Electricity, internal combustion, telegraphy, steam building	Electronics, jet engines, air transport	Nuclear, computers, gas, telecommunications	Biotechnology, artificia intelligence, space communications and transport

Sources: Maddison (1995), *Monitoring The World Economy, 1820 – 1992,* OECD Development Centre, Paris; National Research Council (1999), *Our Common Journey: A Transition Toward Sustainability,* National Academy Press, Washington D.C.; and other OECD data.

As cited in OECD, 2001 - Critical Issues, Chapter 1

Markets are globalising...

- **Over last 30 years:**
  - **- 20-fold increase in world exports of goods and services**
  - **- 70-fold increase in FDI flows**



Progress and challenges: trade, FDI and ODA trends

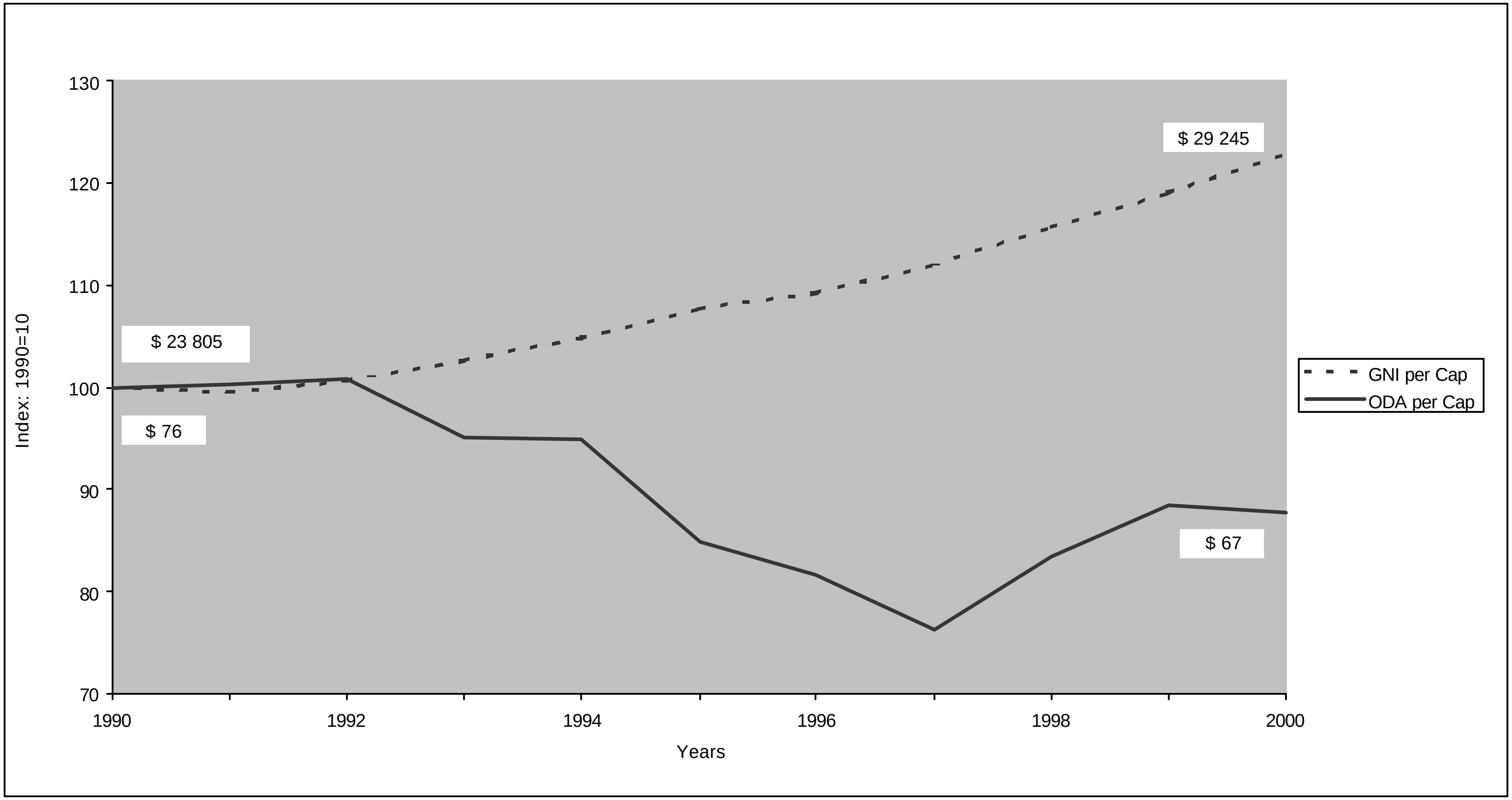
Trade and foreign direct investment have increased relative to GDP and in absolute terms

- Most of this intra-OECD
- Shares going to non-OECD are increasing

Stagnation or decrease of ODA relative to GDP

- Rio/Monterrey objective: 0.7 % of GDP
- OECD - ODA in 1992 : 0.33 % of GDP
- OECD - ODA in 2000 : 0.22 % of GDP

Indexed OECD country per capita income and per capita ODA outflows



Note: USD at 1999 prices and exchange rates.
Source: OECD, DAC Statistics

Progress and challenges: social dimension, poverty reduction in OECD

Increasing life expectancy in all OECD countries

Increasing level of education

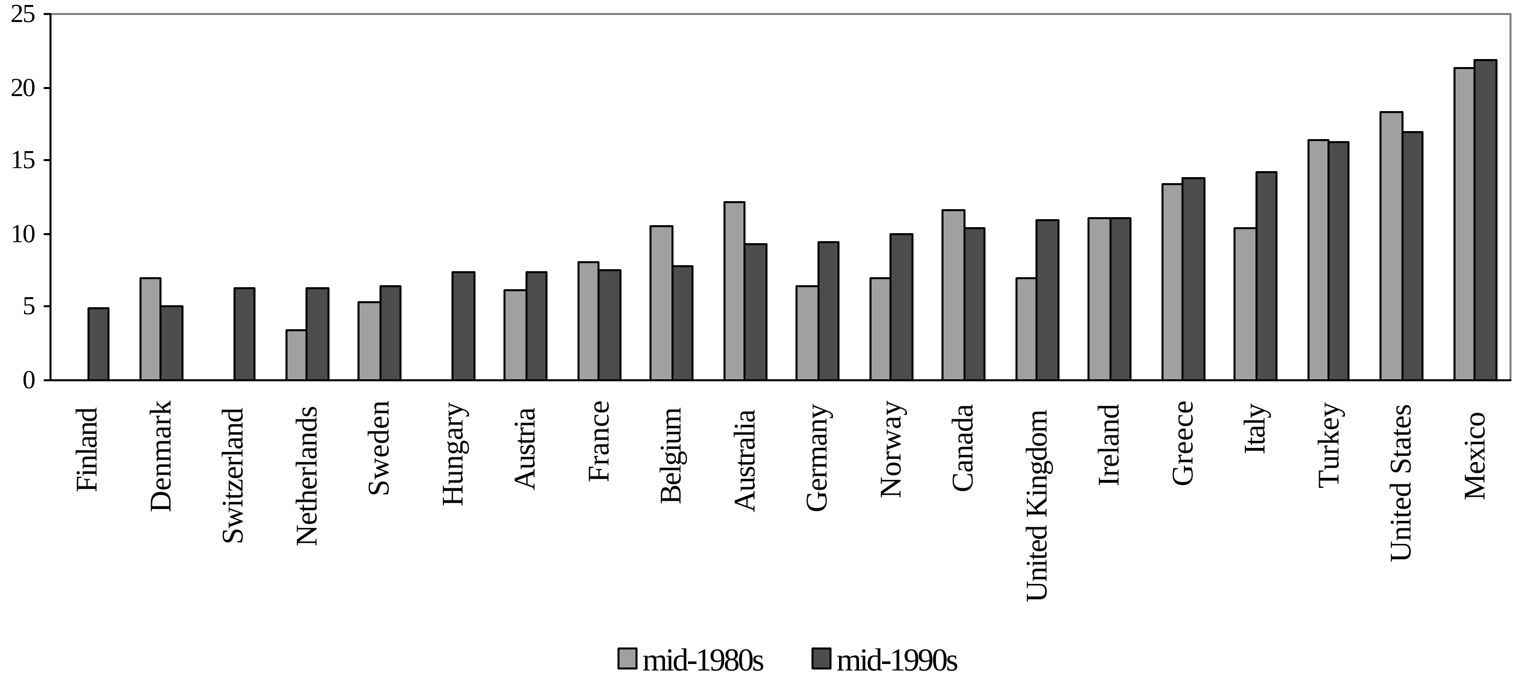
Economic growth has not increased the quality of life for all in the OECD ...

Poverty rates decrease in some countries... but increase in others

– disparity in trends among OECD countries

The OECD context: progress and challenges

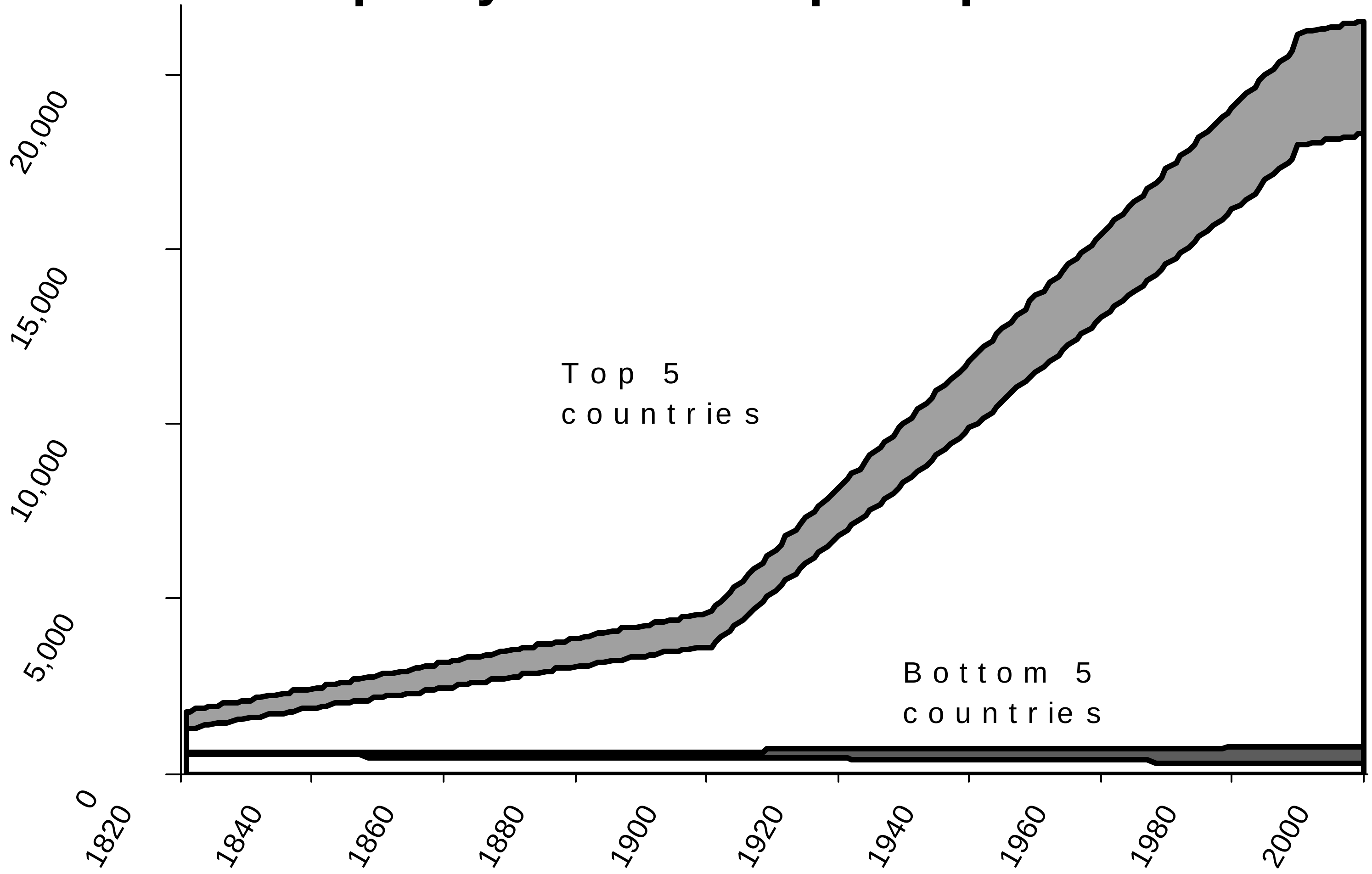
Proportion of people with low income, selected OECD countries, mid-1980s and mid 1990s



Notes : Data for Mexico for the mid-1980s correspond to 1989.
Source: OECD, *Society at a Glance*, 2001.

The global context: progress and challenges

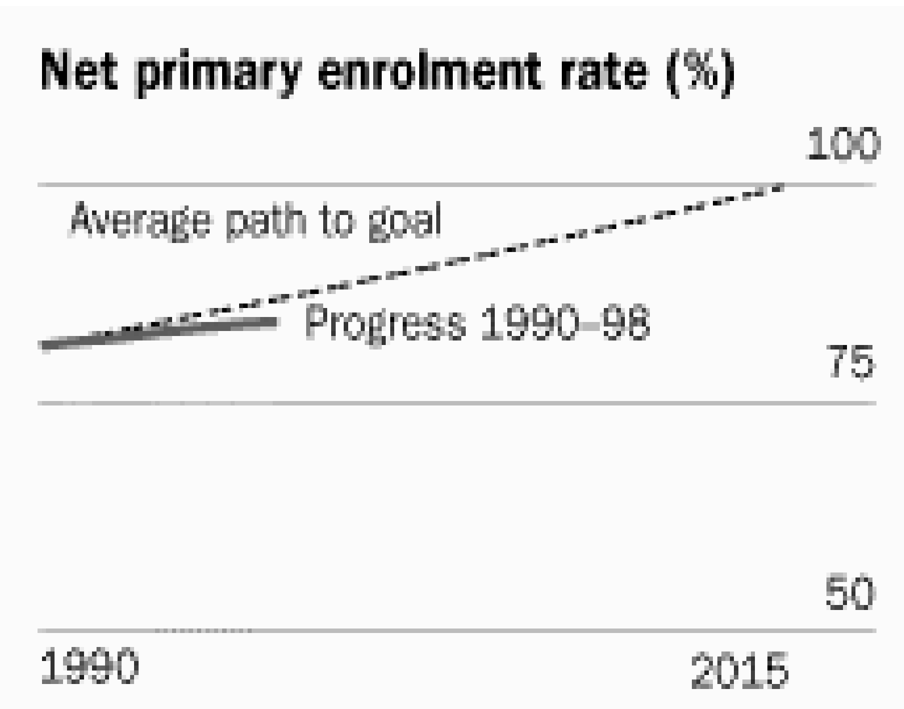
Trends in inequality in real GDP per capita between countries

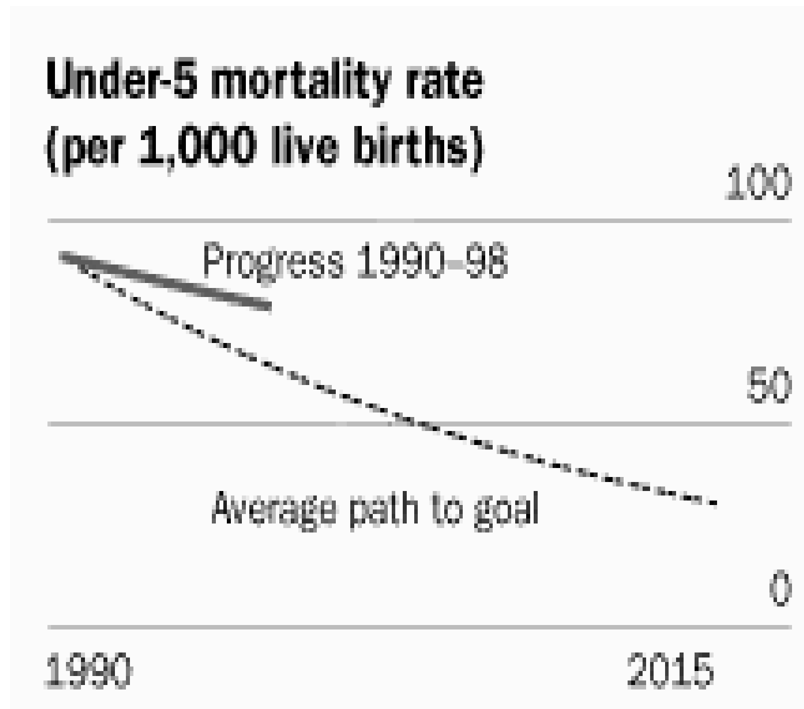


Source: Maddison (1995), Monitoring The World Economy, 1820 – 1992, OECD Development Centre, Paris. Extended to 2000 using projections from the IMF «World Economic Outlook» as cited in OECD 2001.

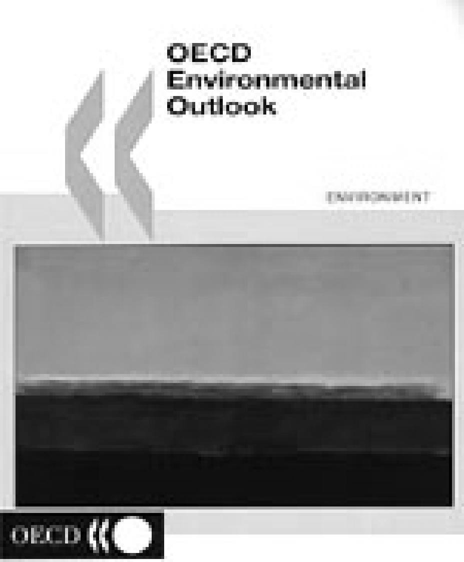
The global context: progress and challenges

Monitoring Millennium Development Goals: Education, Health





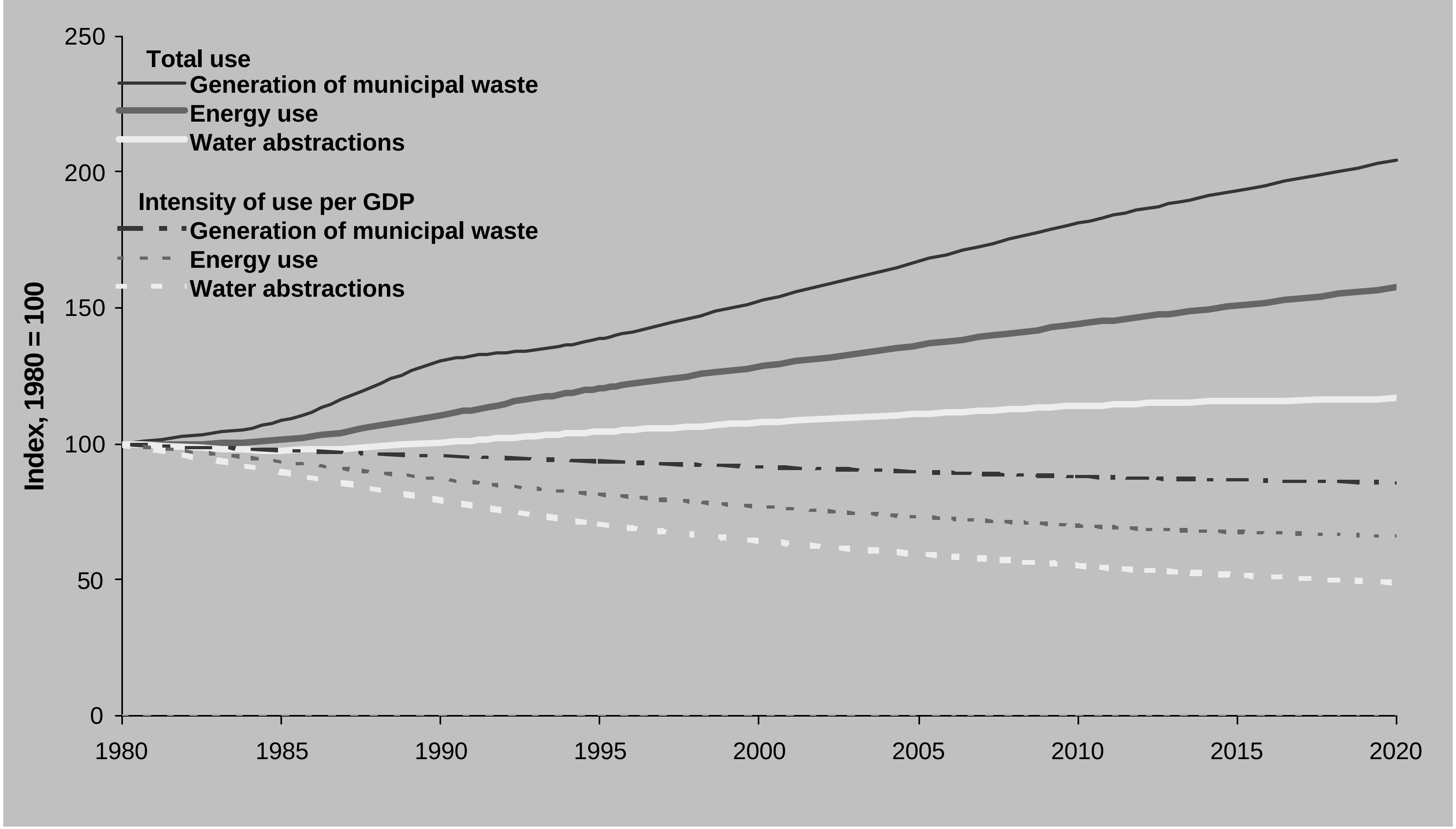
Source: IMF *et al.* (2000), *A Better World for All*, Paris



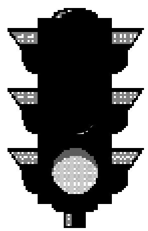
Progress and challenges: environmental outlook

Accumulation of various forms of capital has contributed to economic growth in OECD countries, but natural capital has declined…

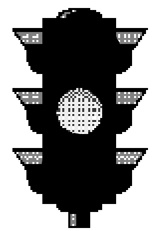
Resource and material intensity of OECD economies, 1980-2020



OECD Environmental Outlook: the traffic lights....



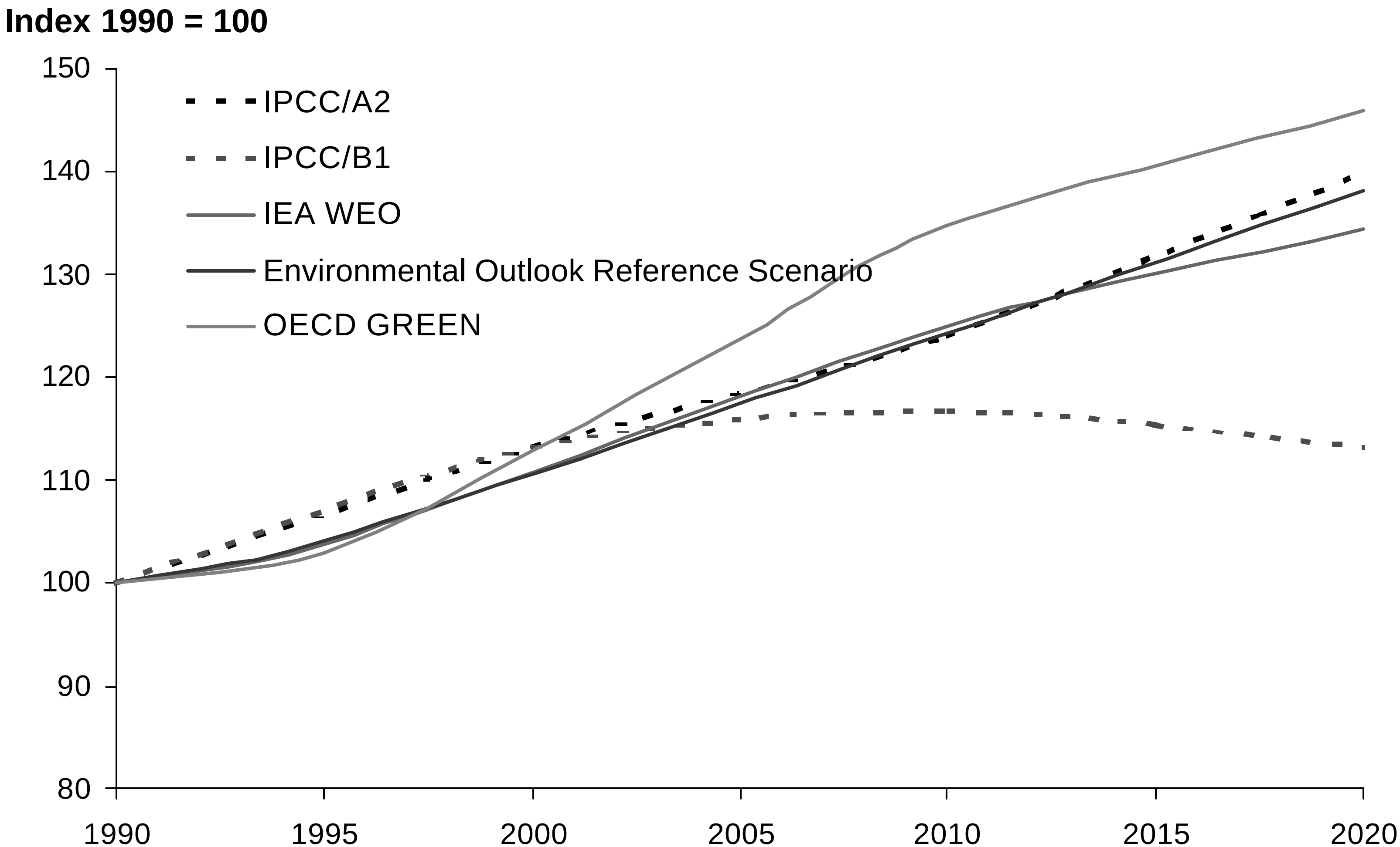
- Some air pollutants (lead, CFCs, NOx, SOx)
- Forest coverage in OECD regions



- Water use
- Surface water quality
- Hazardous waste & toxic emissions from industry
- Energy production & use
- Forest quality in OECD regions

- Agricultural pollution
- Over-fishing
- Greenhouse gas emissions
- Motor vehicle & aviation air pollution
- Biodiversity & Tropical forest coverage
- Chemicals in the Environment

OECD CO_2 emissions



Some recent improvements, but overall . . . . .

- Natural resources are being overused
- Pollutants are accumulating in the environment
- Vital base for economic and social activity in jeopardy
- Life-support function of environment being lost

An OECD Environmental Strategy for the First Decade of the 21st Century

Maintaining the integrity of ecosystems through efficient management of natural resources

- "…respecting the limits of *regeneration* and *substitutability* of natural resources, to the *assimilation capacity* of the environment, and the need to avoid major environmental effects which may be *irreversible.*"

OECD, 2001

An OECD Environmental Strategy for the First Decade of the 21st Century

- **Maintaining the integrity of ecosystems through efficient management of natural resources**
- **De-coupling environmental pressures from economic growth**
- **Improving information for decision-making: measuring progress through indicators**
- **The social and environmental interface: enhancing the quality of life**
- **Global environmental interdependence: improving governance and co-operation**

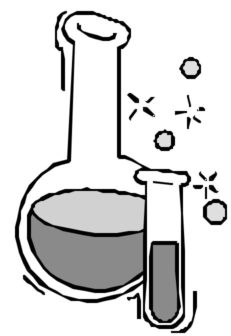
The role of developing countries is increasingly important, but OECD countries must take the lead.

➧ ***challenges, national actions, measurement of progress (indicators), further work in the OECD.***

OECD Policy Framework

Making markets work for sustainable development

Strengthening decision making



Harnessing science and technology

Managing linkages with the global economy

OECD MCM 2001: SD Mandate

- Use of agreed SD indicators in peer review processes
- OECD report to WSSD
- Social aspects of sustainable development
- Overcoming obstacles to policy reforms
- Policy coherence and integration

2. Make Markets Work for SD:

Phase out environmentally harmful subsidies

- **Subsidies in OECD countries are estimated at $ 400 billion in 2000 (1.9 % of GDP).** *Source, OECD*
- **Non-OECD countries: $ 340 billion, 6.3 % of GDP (1994-1999 average).** *Source, van Beers and de Moor (2001)*

Making Markets Work for SD: Phase out environmentally harmful subsidies

- Agriculture: 310 billion $, 1.3% OECD GDP (2001)
  - Induce intensive farming, conversion of forest and wetlands into agricultural land, overuse of fertilisers and pesticides, over production (EU CAP).
- Fisheries: 6 billion $ = 20% value of landing (1999).
  - Over-capacity of fishing fleet, exhaustion of fish stock
- Energy Production: 20-30 billion $ p.a. (of which 1/3 to support coal production)

Wide range of energy subsidies

To consumers:

- low set energy prices
- energy taxes or duties below usual rate
- **Lower price paid by consumers**

To producers:

- market price support
- ***raise the price energy producers can charge***
- input support
- low rate of return financing
- concessional credit, debt write-off
- **lower cost of energy production**

Removing energy subsidies...

- Raises energy prices; reduces energy demand
- Reduces pollution emissions
- Increases economic efficiency

- Effects of removal in 8 non-OECD countries
  - Average subsidisation: 21.12 %
  - Economic efficiency gains (% GDP) 0.76 %
  - Energy consumption (%) -12.80 %
  - CO_2 emissions -15.94 %

Source: IEA 1999

Beyond potential environmental harmfulness, subsidies…

- …hurt poorer countries: OECD country protectionist measures (tariff and non tariff barriers) cost the developing world over $ 43 billion p.a.(total net ODA in 2001 = $ 51.4 billion).
- …hurt poorer segments of the population: e.g. price controls benefit the rich, irrigation subsidies accrue mainly to larger farmers.

2. Improving Policy Coherence: SD in Development Co-operation

- Monitor progress towards UN Millenium Development Goals (with UN, World Bank, IMF)
- DAC Guidelines on National Strategies for Sustainable Development
- DAC Guidelines and statistical reporting of development assistance targeting the Rio Conventions
- *Joint Project on Climate Change & Development*

3. *Improving Policy Coherence:* Joint Project on Climate Change and Development

Context

- Development and climate change have a multi-pronged, two-way relationship.
- Attention to climate change is often limited to environment side of donor agencies and governments
- Development side of donors and governments have typically lacked interest or specific guidance on how to incorporate climate change in decision-making.

Overall Objective

To provide guidance on how to mainstream responses to climate change within economic development planning and assistance,

with natural resource management as an overarching theme.

Key Issues Regarding Project Scope

- Climate variability and climate change
- Adaptation to climate variability is already sensible, and will likely enhance adaptive capacity to climate change.
- Climate change might also require medium to long term responses that go beyond short term coping strategies.
- The emphasis of the project is defined more by the planning horizon of responses, than by whether they cater to climate variability or change.

Framework for Case Studies

1.

Development context and climate change impacts

• Geographic, demographic and economic overview.

• Identification of sectors and regions vulnerable to climate change impacts.

2.

Linkages between climate change and development plans

• Review of relevant economic,environmental and social plans (such as PRSP, NSSD, NEAP) for attention to climate change impacts.

• Assessment of attention to climate change in donor aid portfolios.

3.

In-depth thematic, regional, or project level analysis

• Examination of benefits and trade-offs in incorporating responses to climate change in particular development policies and projects.

• The focus will be on natural resource management issues such as forest policy, coastal zone management, and water infrastructure projects.

Case Study Countries

Country	Population	Area (km^2)	HDI rank	GDP	Illustrative climate impacts
Island States:					
Fiji	844,330	18,270	67	7,300	High percentage of the population affected by sea level rise, significant capital value at risk, loss of wetlands and mangrove fringes.
Asia:					
Bangladesh	131,269,860	144,000	132	1,570	Critical vulnerability to sea level rise due to low elevation and high population density. Impacts on wetlands and crop production.
Nepal	25,284,463	140,800	129	1,360	Significant melting of Himalayan glaciers (including on Mt. Everest), with major impacts such as bursting of glacial lakes, downstream flooding, and loss of tourism revenues.
Vietnam	79,939,014	329,560	101	1,950	Vulnerable to accelerated sea level rise, particularly in the Red River Delta in the north and in the Mekong Delta. Sea level rise threatens about 20,00 km^2 as well as the cities Haiphong, Danang and Vungtau.
Africa:					
Egypt	69,536,644	1,001,450	105	3,600	Sizeable portion of the lower Nile delta threatened from sea level rise with implications on human settlements and agriculture. Economic sectors, especially around Alexandria also critically vulnerable. Irrigated agriculture inland might also suffer due to reduced water use efficiency as a result of significant projected increases in temperatures.
Tanzania	36,232,074	945,087	140	710	Mount Kilimanjaro ecosystem at risk from increase in fire risk and melting of the ice cap with attendant impacts on water resources. Coastal zones at risk of sizeable loss of land and beaches due to sea level rise.
Latin America:					
Uruguay	3,360,105	176,220	37	9,300	Critical sea level rise vulnerabilities in terms of wetlands loss and capital value with implications for tourism. Also offers an interesting case study on how carbon-sequestration is already being integrated with forestry, economic development, and agricultural policies.

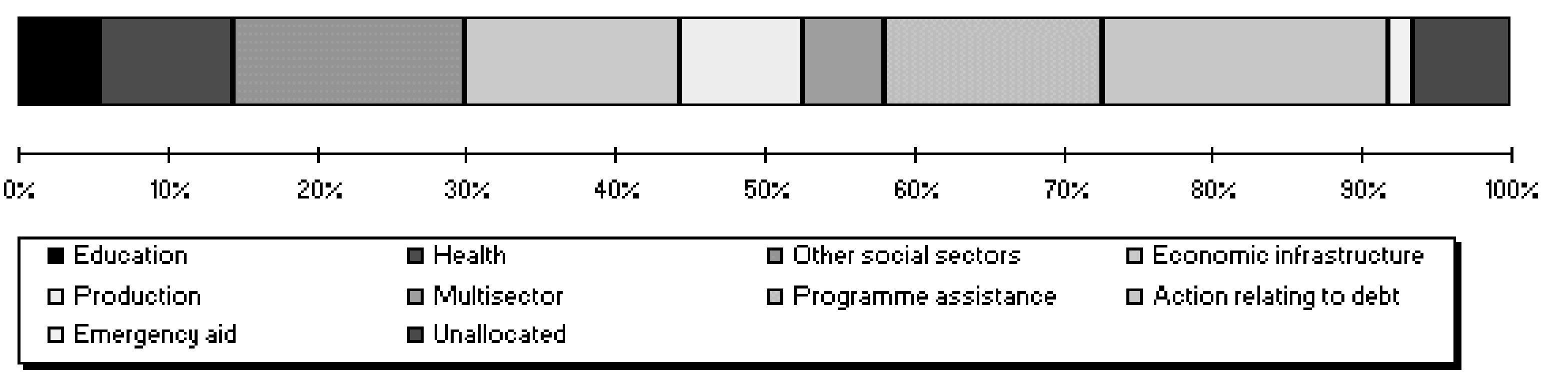
Bangladesh

Receipts	1998	1999	2000
Net ODA (USD million)	1 263	1 215	1 172
Bilateral share (gross ODA)	50%	48%	51%
Net ODA / GNI	2.8%	2.6%	2.4%
Net Private flows (USD million)	150	- 105	53

For reference	1998	1999	2000
Population (million)	125.6	127.7	129.8
GNI per capita (Atlas USD)	360	370	380

Top Ten Donors of gross ODA (1999-2000 average)		(USD m)
1	IDA	385
2	JAPAN	354
3	AS. D B SPECIAL FUNDS	267
4	UNITED STATES	110
5	UNITED KINGDOM	104
6	EC	66
7	GERMANY	42
8	DENMARK	38
9	NETHERLANDS	34
10	CANADA	34

Bilateral ODA by Sector (1999-2000)



Source: OECD-DAC/World Bank

Principles for Case Study Selection

- Scientific criteria
- Socio-political criteria
- Pragmatic criteria

Some Themes for In-depth Analysis

- Coastal wetlands and protected areas
- Forestry and land-use policies
- Mountain systems
- Water Resources

4. Benefits of Climate Policies

Context

TAR focuses on other relevant issues, e.g. costs of mitigation, but not on <u>benefits as a driver for climate policy</u>

- Understanding of benefits is too imprecise to compare to costs (SynR)
- 5 reasons for concern (Ch. 19 - WGII):
  - unique and threatened systems; extreme events; aggregate impacts; distribution of impacts; large scale, singular events (low prob, high risk)
  - these map to a benefits discussion but are not clearly linked to the set of impacts covered in TAR

Why Look at the Benefits of Climate Policies?

Benefits also provide interesting insights about the linkages between adaptation and mitigation policies

- *e.g. adaptation policies can address near term, unavoidable climate change, while mitigation policies can limit longer term (avoidable) impacts.*

Benefits of Climate Policies Project

Overall Objective

advance a conceptual framework to structure benefits information for policy makers and policy analysts

Standardising Categories of Impacts and Metrics for Measurement

How do these relate to different forms of capital?

Commonly used impact categories

Pearce, et al.	Smith and Hitz
Agriculture	Agriculture
Forest	Forestry
Sea level	Coastal (sea level rise)
Energy	Energy
Water	Water
Human life	Health
Migration	Terrestrial ecosystems
Extreme events	
Recreation	Biodiversity
Species loss	Marine ecosystems
Urban	
Air pollution	

Source: Rothman 2003

Natural Capital

Human Capital

Social Capital

Man-made Capital

Is this the right mix of physical and monetary metrics?

How do these relate to different forms of capital?

Metrics from Climate Change Impact Studies

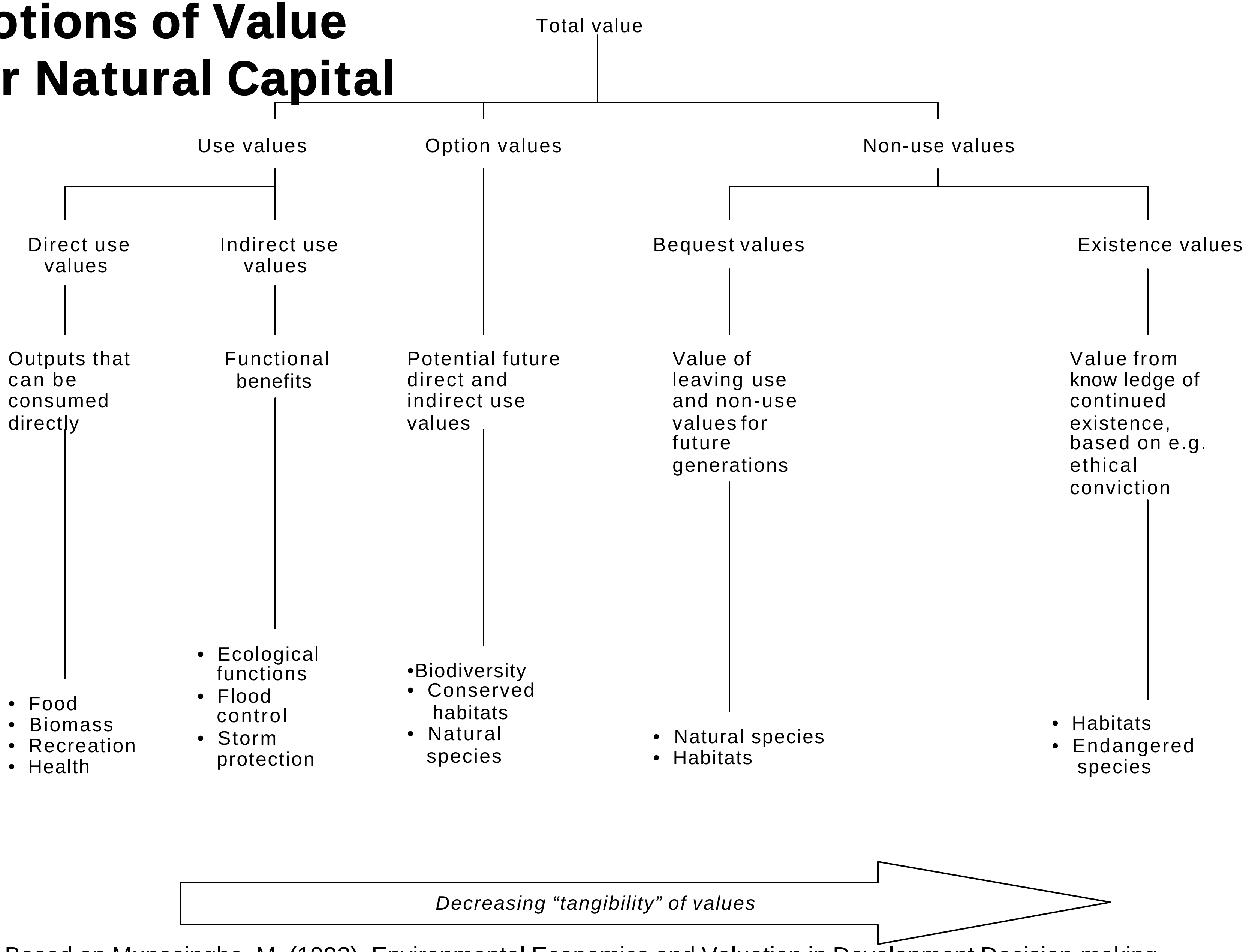
- Mortality: Malaria, Vector-borne diseases
- Area of Potential Transmission (of Infectious Disease)
- Carbon: Vegetation, Soil
- Net Ecosystem Productivity, Net Primary Productivity
- Change in Forest Area, Ecoclimatic Classes in Biosphere Reserves
- People at Risk: Hunger, Coastal Flooding, Malaria
- People Living: under Water Stress Conditions, in Countries Experiencing Water Stress
- Production: Agricultural Commodities, Cereal, Food, Timber, Marine Export
- Stock: Biomass, Softwood and Hardwood
- Loss in $: Dryland, Wetland
- Prices: Food, Forest Products
- Welfare (from Forestry)
- Cost of Protection (against sea level rise)
- Change in GDP, Income, Output

(Source: Smith and Hitz 2003 as summarised in Rothman 2003)

Use Cascading Metrics?

Sector category of impact	**Physical / environmental numeraires**	**Physical / social numeraires** (Parry, Nicholls, Arnell et al. 2002)	**Economic numeraires** (e.g. Hanneman 2003, Tol 2002)
Water resources	• Change in precipitation and run-off	• Millions people under water stress	• Net change in irrigation water demand • Effects on water using industry • Effects on municipal water supply
Coastal Zones	• Sea level rise	• Millions of people at risk of flooding	• Direct cost (protection, dryland and wetland loss)

Valuation and Notions of Value for Natural Capital



Source: Based on Munasinghe, M. (1992), Environmental Economics and Valuation in Development Decision-making, World Bank Environment Working Paper No. 51, Washington DC.

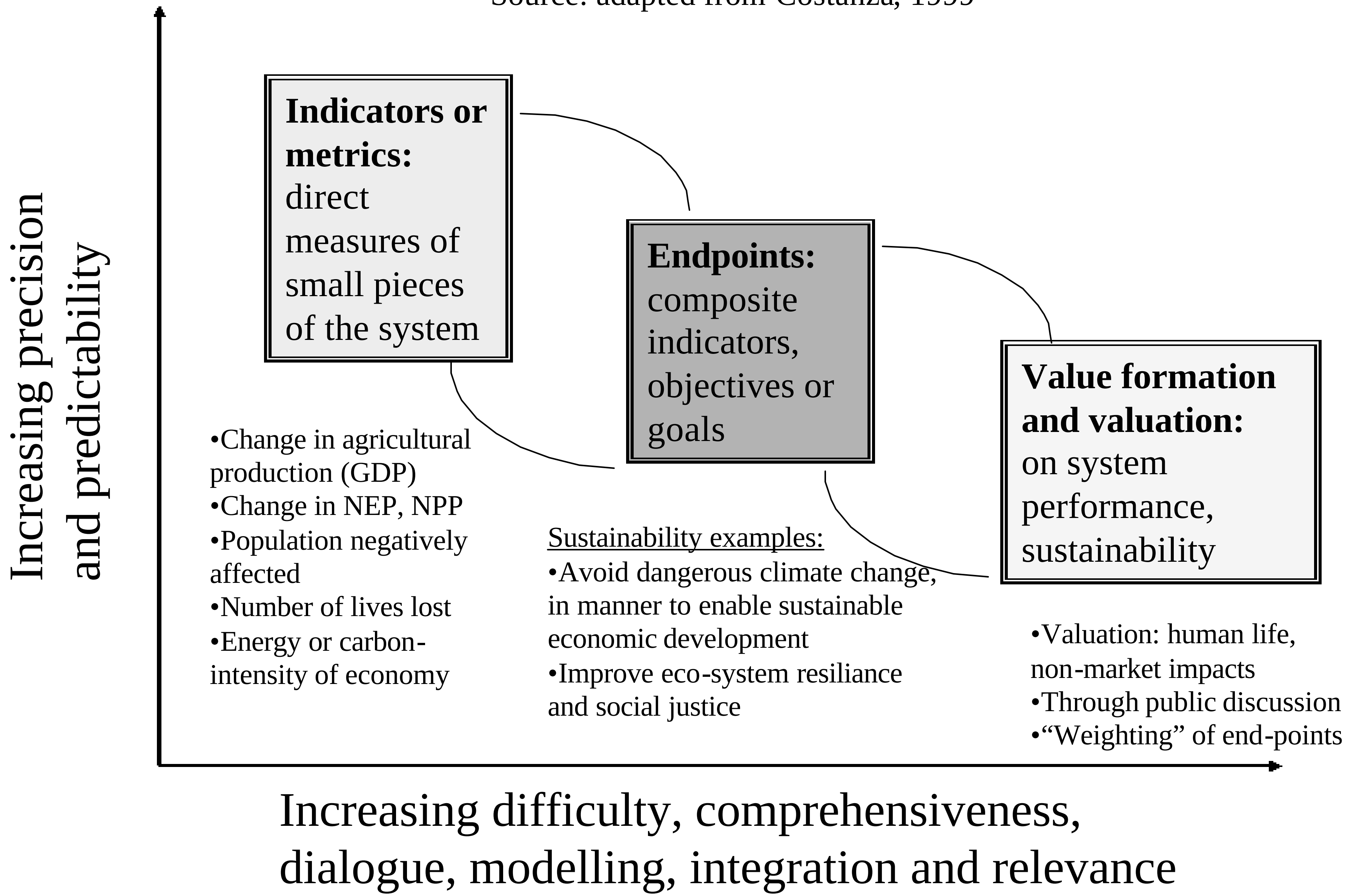
Benefits of Climate Policies Project

Approach to conceptual framework:

- Devise coherent, comprehensive set of impact categories
- Use standard metrics: natural and human systems and monetary metrics
  - *monetary metrics build on physical metrics*
  - *make transparent how go from one to the other*
  - *clarify notions of valuation – what is covered and what is not*
- Relate categories and metrics to 4 forms of SD capital
- Other challenges: *to work across spatial and temporal scales, to make uncertainty explicit*

Relationships between indicators, endpoints and values

Source: adapted from Costanza, 1999



Sustainability Goals & Endpoints: *As Triggers for Climate Change Policy? As Determinants of Impacts?*

- Promote sustainable economic development, material well-being
- Maintain eco-system stability and resilience, sustainable management of natural resource base
- Synergy with solutions for local and regional environmental problems and economic development strategies
- Protect the poor and vulnerable, eradicate poverty, improve education and health for all, improved governance

Climate change impacts

FCCC Policy Framework

Climate Policies

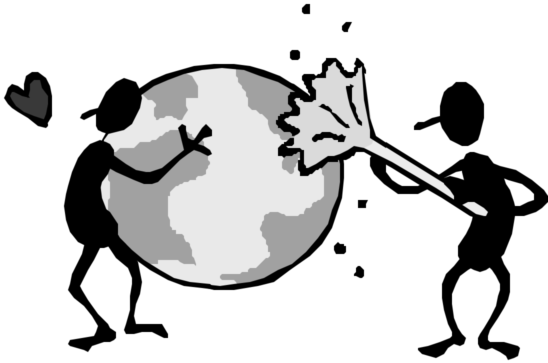
- Mitigation
- Adaptation
- Technology Co-operation
- Financial Assistance, Mainstream Development Co-operation

Climate Policy Goal

Ultimate Goal: *prevent dangerous anthropogenic interference with the climate system…*

Explore the linkages between climate impacts, achievement of sustainable development goals, and climate policies...

Information and updates



Development and Climate

- Concept paper on case studies available now (COM/DAC/WPENV/EPOC/GSP(2002)1),
- Background paper on climate and SD by M.Munasinghe (COM/DAC/WPENV/EPOC/GSP(2002)2)
- Selected case studies due late 2003

Benefits

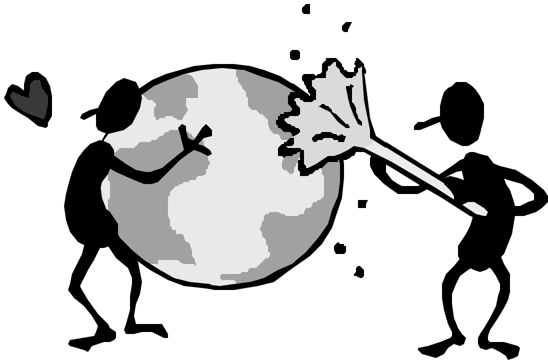
- Workshop report and working papers: mid 2003
- Ancillary benefits (2000 onwards) available now

Global Forums on SD - 2003 and 2004

- March 2003: emission trading: market creation for climate and environmental protection (March 2003)
- 2004: climate, environment and development linkages

www.oecd.org/env/cc

Information and updates: OECD on SD



Social Aspects of SD in the OECD

Making Markets Work: Subsidy Reform

Governance for Sustainable Development

www.oecd.org/sustainabledevelopment

www.oecd.org/env/cc

Food Security, Climate Change and Sustainable Development

Gustavo Best
FAO

* Agriculture is the meeting point of people and nature

* Agriculture is normally an activity of the poor in DC and is largely unsustainable

Poverty MEANS vulnerability

i.e. low inputs and low level technological agriculture coupled with poor and unprepared farmers leads to potentially disastrous CC impact and decreased sustainability

Impact on agriculture in different countries:

*in developed countries it is largely accepted that they will adapt and in some cases actually benefit (farmers – few and prepared)

* In countries with economies in transition the situation varies widely with trends moving (hopefully) towards growing adaptability capacities

* In developing countries the level of impact of CC follows quite directly the situation and level of sustainability of the agriculture, forestry and fisheries sectors;

Most vulnerable d.c countries:

* LDC

* Sub-Saharan

* SIDS

* Food insecure (FIVIMS)

Key reasons for vulnerability follow also reasons of poverty and of low levels of sustainability:

* many and unprepared farmers
* high population increase rates
* low rural infrastructure
* poor natural resource base (soils, water, energy)

ADAPTATION is necessary from the points of view of :

* species
* agronomics
* agro technologies
* agro practices
* genetics and biotechnology
  - soil toxicity
  - draughts
  - pests
  - diseases

Adaptation also of socio-economic factors:

* change of livelihoods
* knowledge/training
* new markets/trading
* traditions/cultures
* info technology
* precision agriculture
* redirecting investment

TAR already refers to many of these issues and elements

The SD/CC Chapter of the Fourth Assessment Report should therefore:

* record present knowledge of the SD/CC equation
* polish methodologies and projections of impact
* establish indicators for SD with CC impact in mind
* identify main areas for action for the Ag/Fo/Fi sectors

Some ideas for renewed action

* review of rural development policies
* training of farmers and extension services
* promote agro meteorological support to farmers
* review different roles of agriculture as means for future adaptation strategies

Key Functions of Agriculture

- Food production function
- Environmental function (+/-)
- Energy function
- Social function (livelihoods)

ISSN 0081 - 4539

2002

THE STATE OF FOOD AND AGRICULTURE

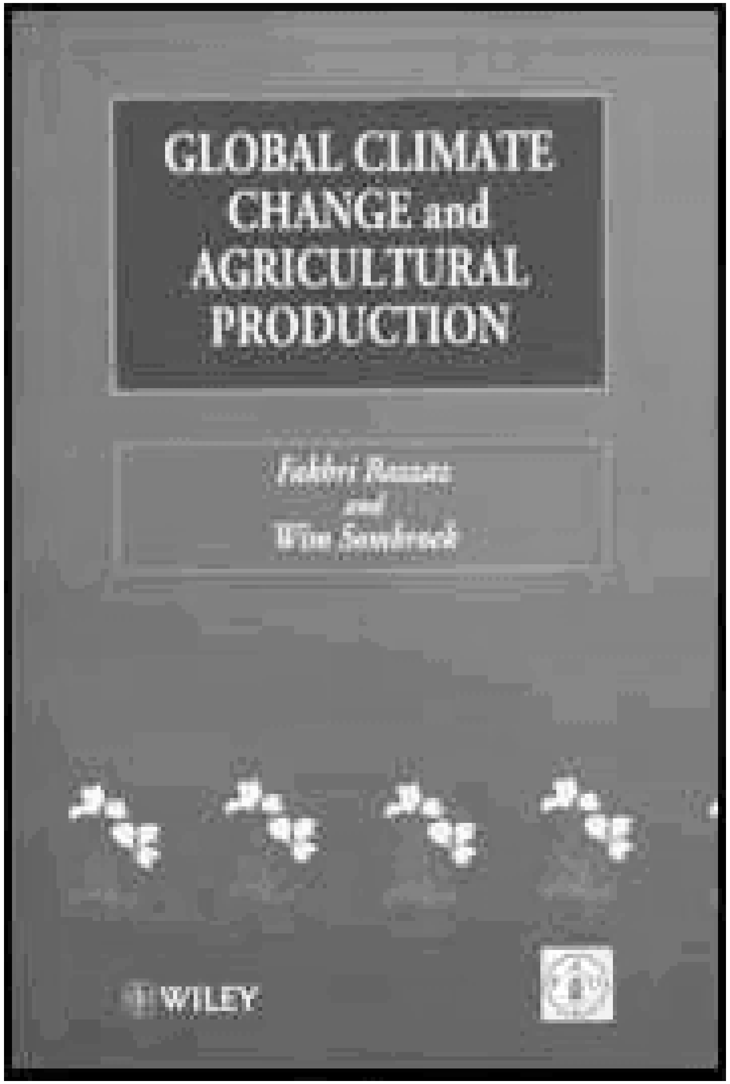
INSIDE

AGRICULTURE AND GLOBAL PUBLIC GOODS TEN YEARS AFTER THE EARTH SUMMIT

PART III

AGRICULTURE AND GLOBAL PUBLIC GOODS TEN YEARS AFTER THE EARTH SUMMIT

I. The role of agriculture and land in the provision of global public goods



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Published 1996 by
John Wiley & Sons Ltd,
Baffins Lane, Chichester,
West Sussex PO19 1UD, Engla

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Agriculture is the basis for sustainable development of rural populations;

Agriculture is impacted and IMPACTS Climate Change

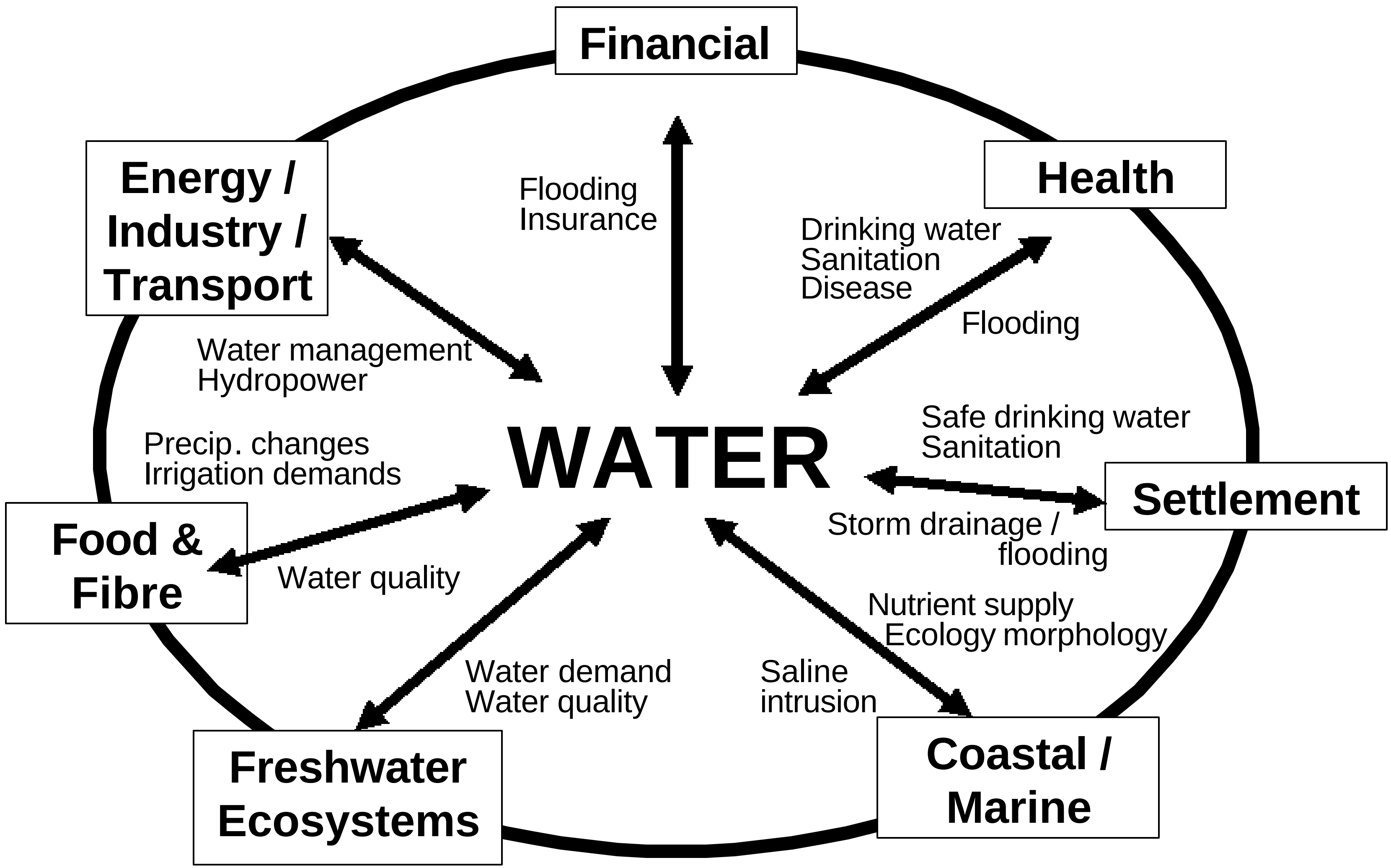
Agriculture must also be an active stakeholder on climate change issues

The most important challenge for 4AR in sustainable agriculture and food security terms is provide paths to URGENTLY Strengthen the social and environmental resilience of the poorest against CC

Water, Climate Change and Sustainable Development

Paul van der Linden
WGII TSU, IPCC

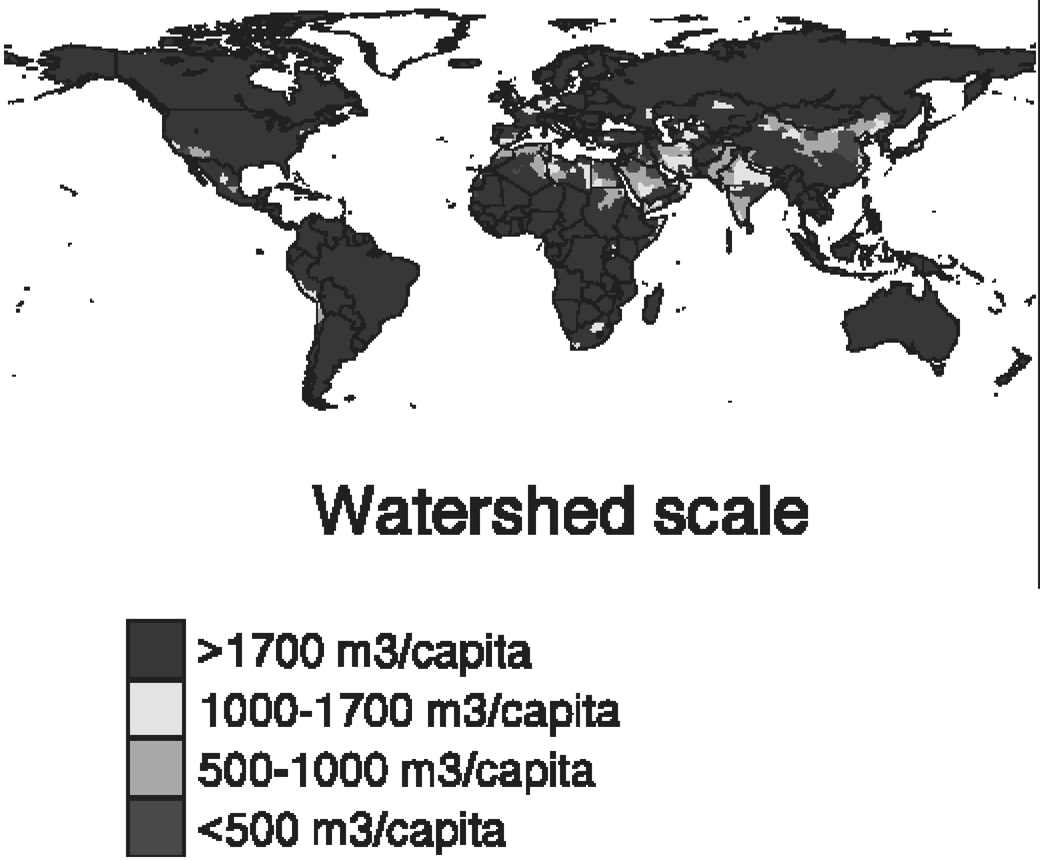
Water - interactions with other sectors



Water - the picture today

- Water is in crisis
  - 1/5 of world has no safe drinking water
  - 1/2 of the world has inadequate sanitation.
- Our use of water TODAY is unsustainable : water quality; groundwater; ecosystem damage; water management fragmented
- How will climate change affect situation?
- How might any adaptation/mitigation to cc fit into wider SD framework?

Water resources stress with no climate change: 1995



142 of 1339 watersheds with < 1000 m^3/capita/year

1368 million people

24% of world population

Source: Nigel Arnell (pers. comm)

The future - without climate change

- Population growth --> more people living in water stressed conditions
- Changes in demand - human and environmental
- Water quality - continuing industrial/agricultural development
- Big challenge for goal of sustainable development

No climate change

People living in water-stressed conditions

1995 1368 million (24%)

	A1/B1	A2	B2
2025	2882	3320	2883
2055	3400	5596	3988
2085	2860	8065	4530

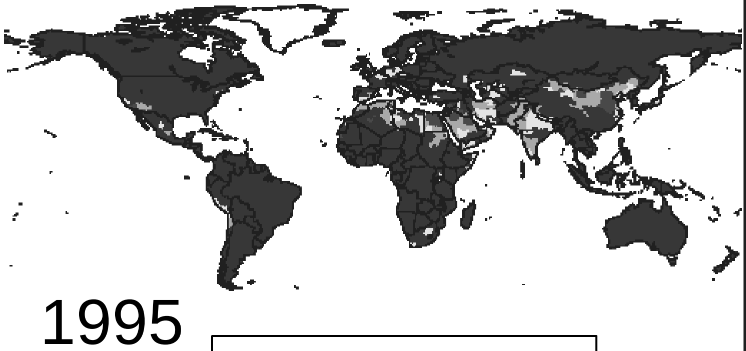
37% 39 36 49% 59 49

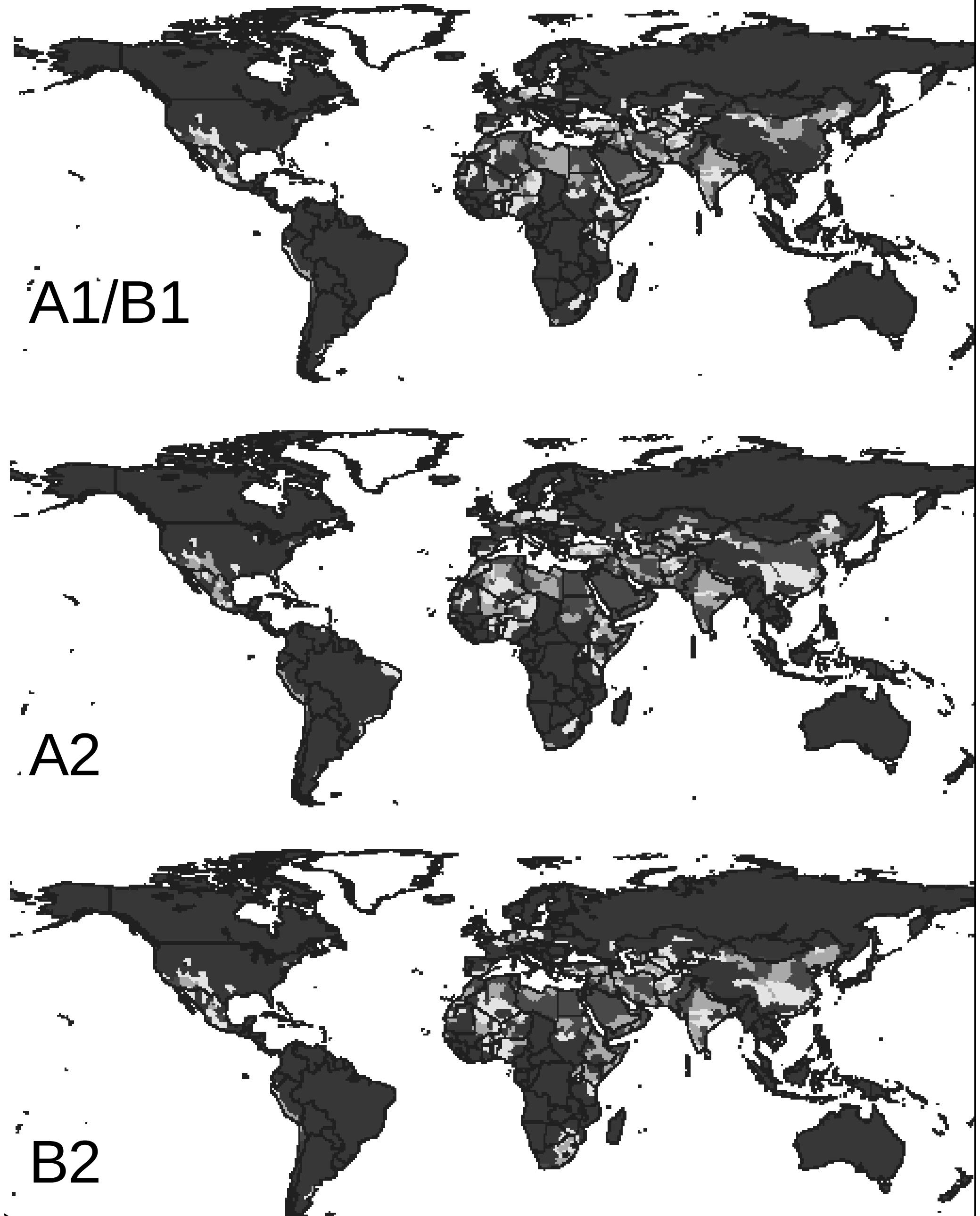
39 48 42 68 106 86

37 57 45 58 132 89

% increase in stressed watersheds

Source: Nigel Arnell (pers. comm)





No climate change: 2055

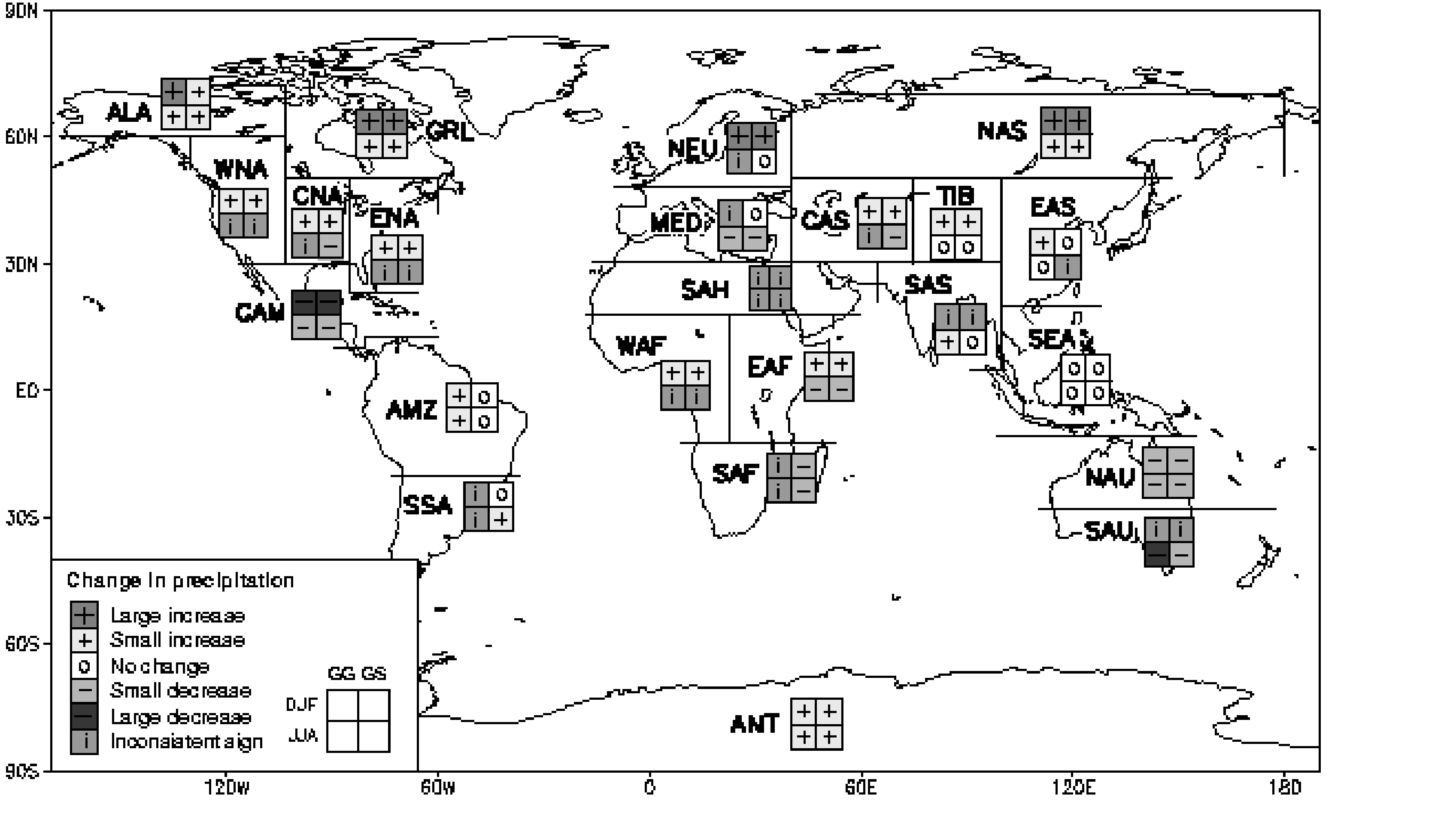
- >1700 m3/capita
- 1000-1700 m3/capita
- 500-1000 m3/capita
- <500 m3/capita

Source: Nigel Arnell (pers. comm)

Climate change and its impacts

- Impacts on supply
    - Rainfall/soil moisture/evaporation
    - Streamflow
    - Climate variability/extremes
- Impacts on demand
- Water quality/groundwater/lakes/cryosphere
- CC impacts depend on water resource management system

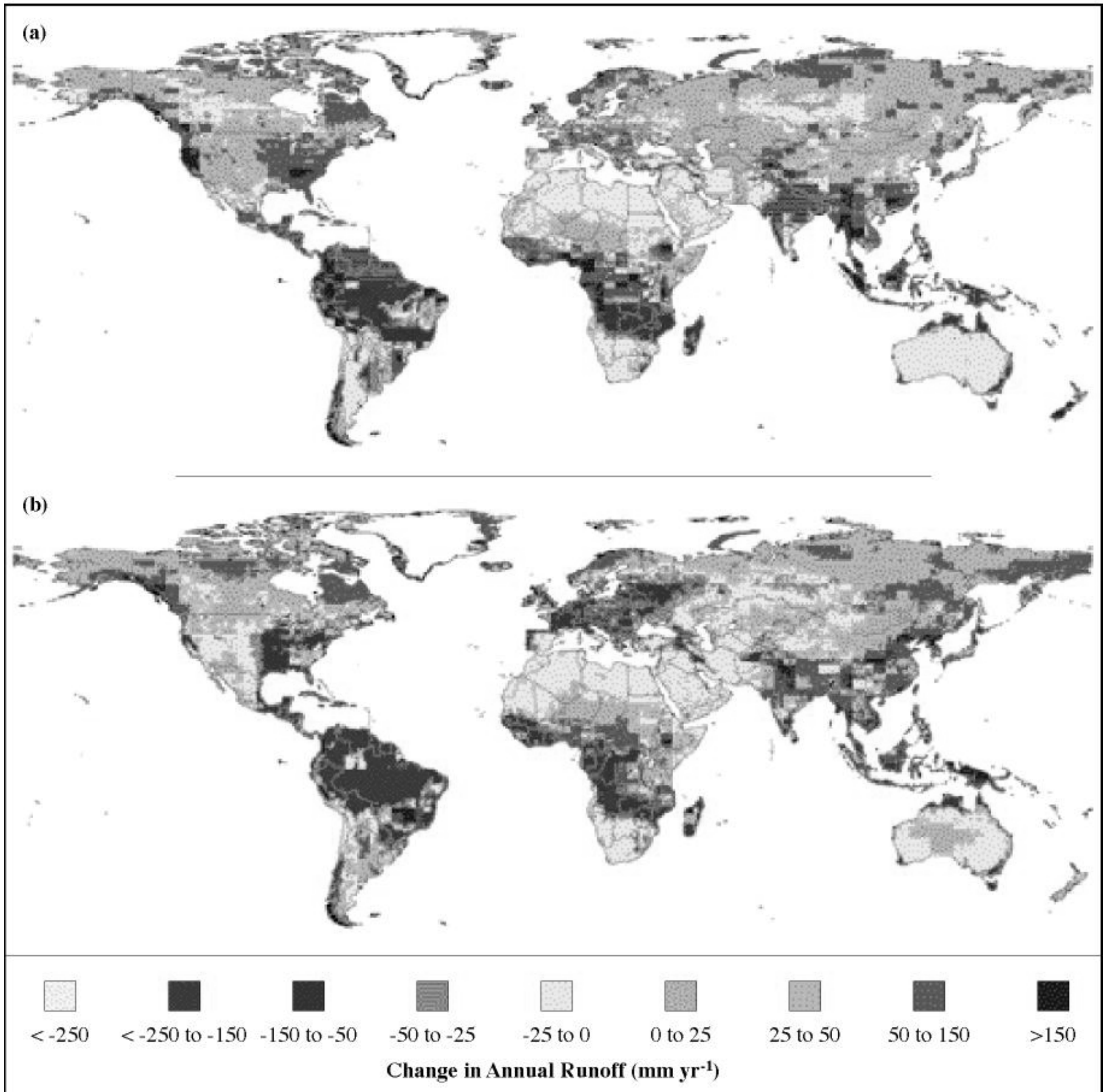
Regional precipitation changes



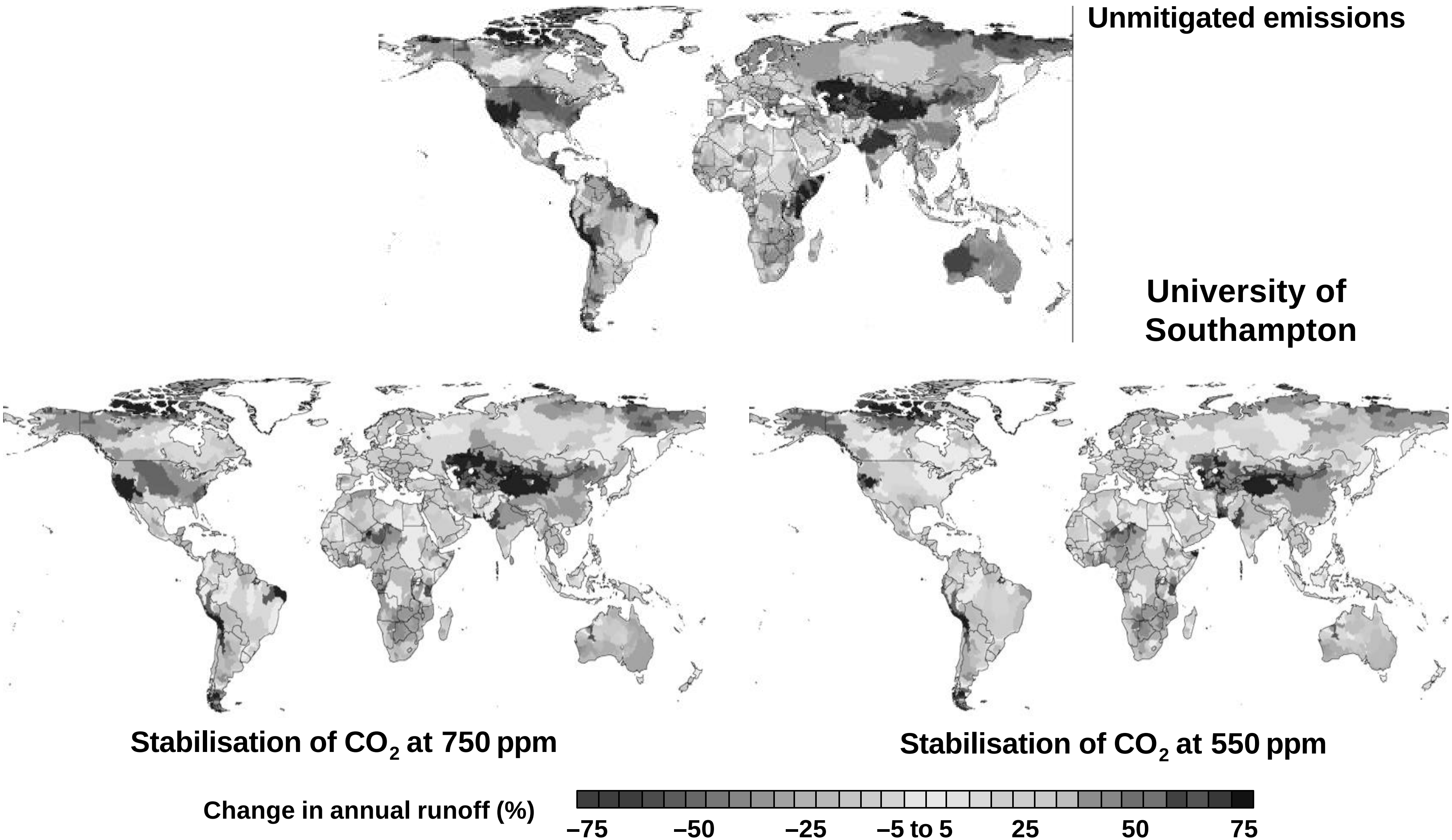
Changes in annual run-off in 2050s

FIGURE 3.5

(SYR, SPM-Fig 4)



Changes in river runoff
from the present day to the 2080s



Indicators of impact

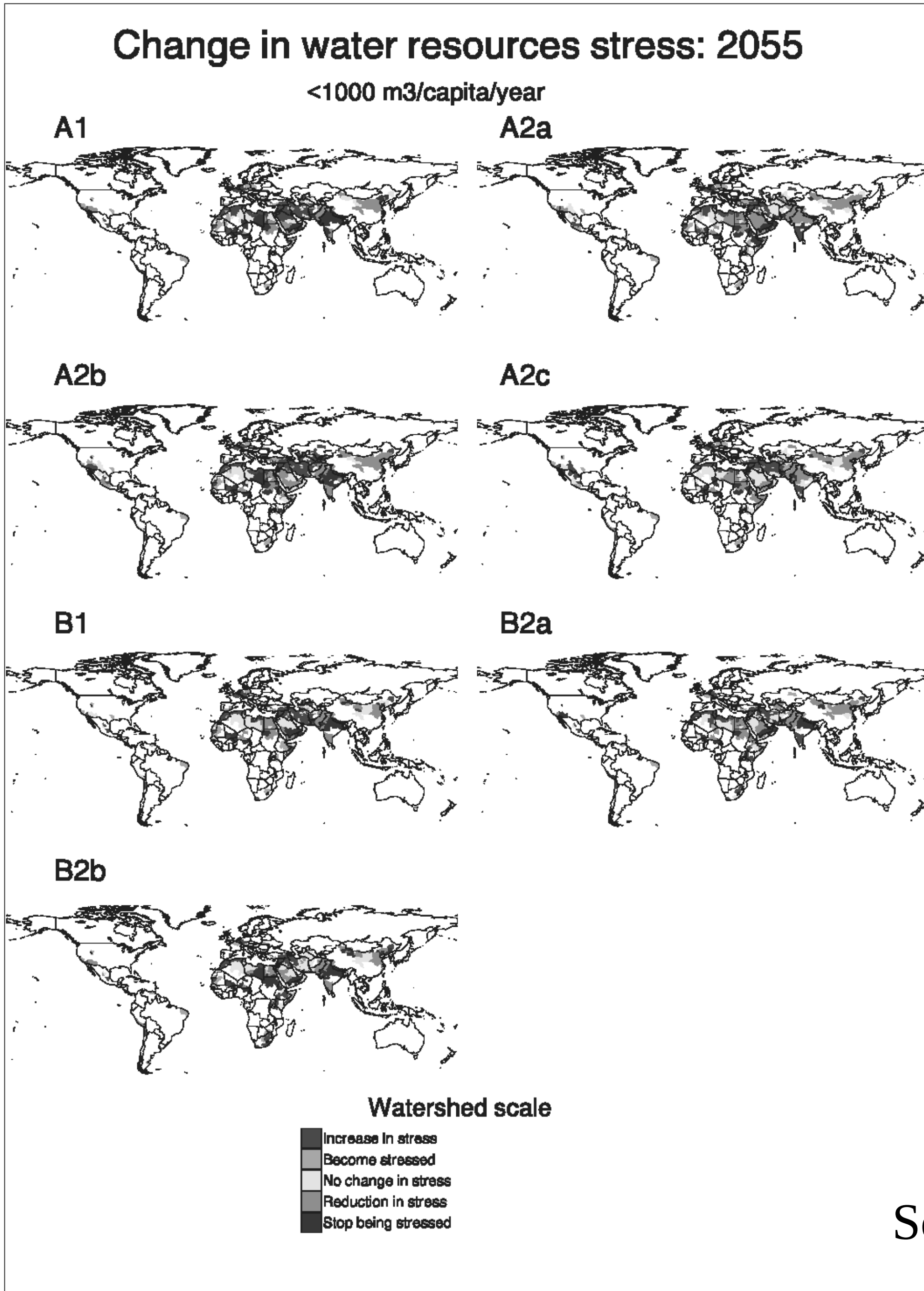
People living in watersheds which become stressed due to climate change (< 1000 m^3/capita/year)

+

People living in watersheds that are already stressed and have a "significant" decrease in runoff

"significant": runoff changes by > s.d. of natural variability

Source: Nigel Arnell (pers. comm)



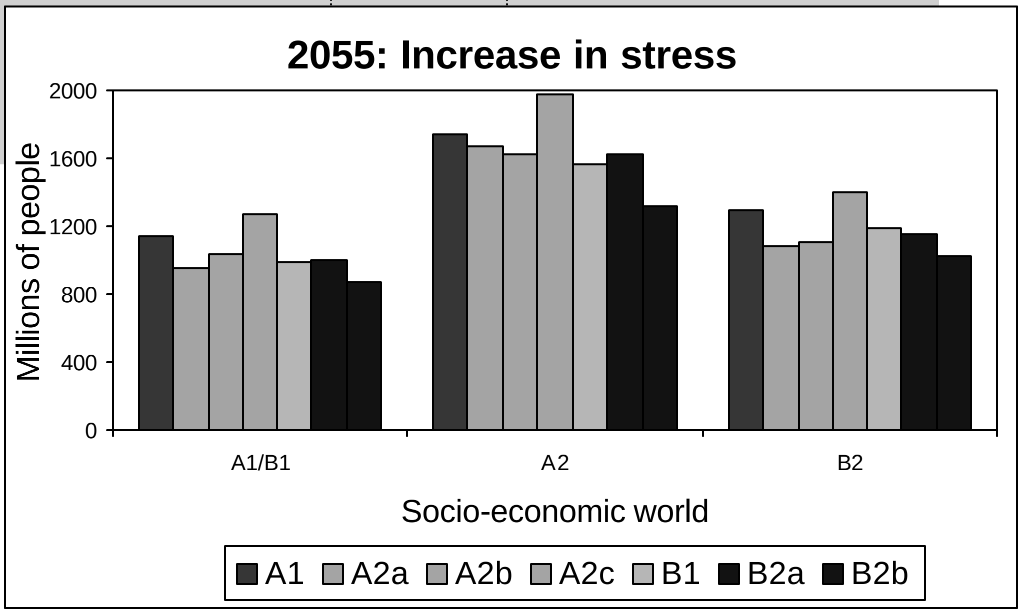
Effect of climate change: 2055

Source: Nigel Arnell (pers. comm)

Global totals

	A1	A2a	A2b	A2c	B1	B2a	B2b
			increase in stress				
2025	829	715	615	1661	395	592	508
2055	1136	1669	1620	1973	987	1157	1020
2085	1256	2664	2583	3210	1135	1535	1196
			decrease in stress				
2025	649	1616	1893	1385	1819	1651	1937
2055	2364	3424	3813	2803	2359	2407	2623
2085	1818	5137	5375	4688	1732	2791	3099

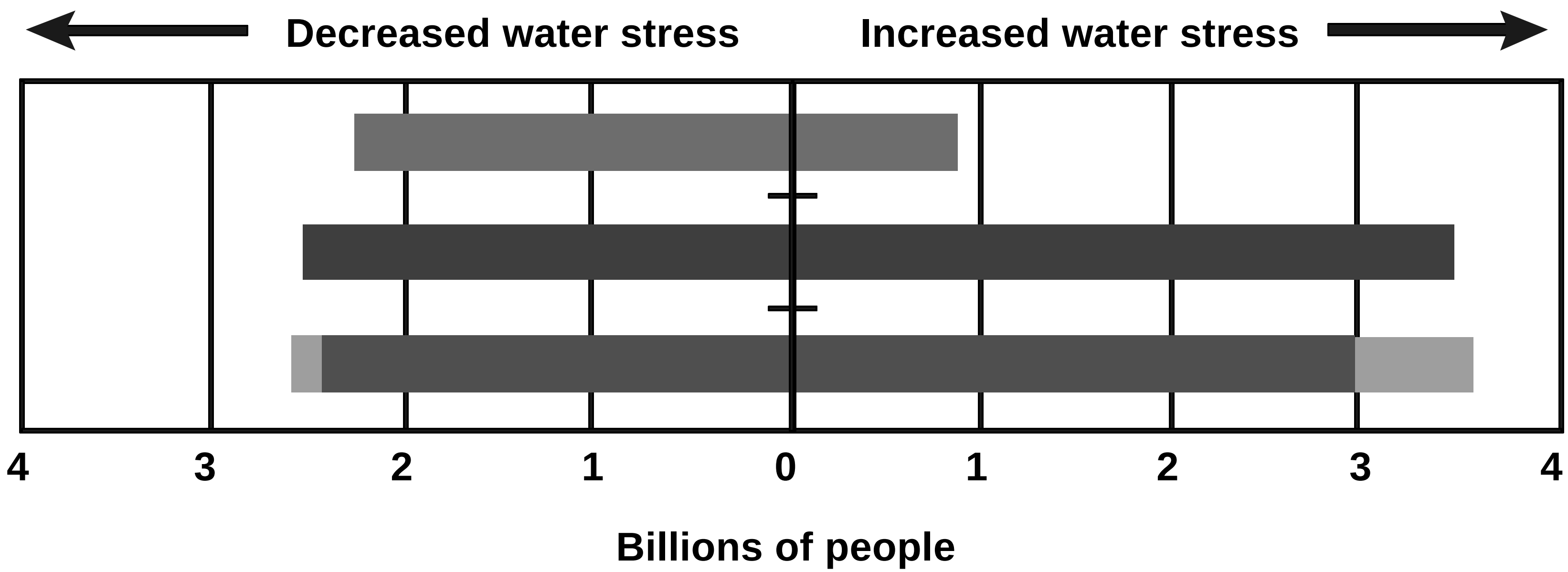
Millions of people



Source: Nigel Arnell (pers. comm)

Changes in water stress

from the present day to the 2080s



University of Southampton

Changes in climate variability /extremes

- Results from WGI TAR:
    - more extreme rainfall events over NH mid to high latitude land areas.
    - Increased risk of drought in mid-latitude continental areas in summer
    - increased Asian summer monsoon variability.
    - increased risk of floods/droughts associated with ENSO.
- But little work on hydrological extremes

Other hydrological factors to consider

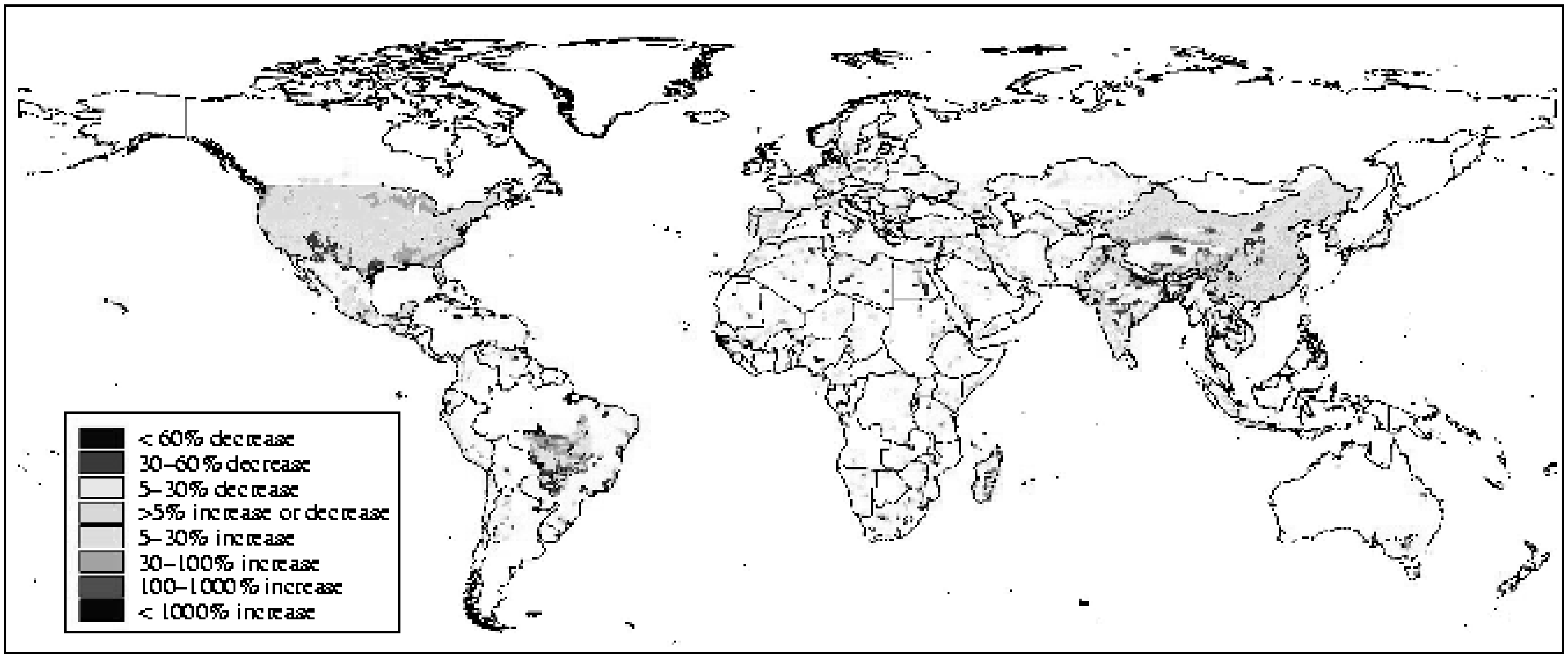
- Water quality
- Groundwater
- Lakes
- Cryosphere

Impact of climate change on demand

- Agricultural demand most sensitive to climate
    - temperature/rainfall (quantity and timing)
    - CO_2 concentration and stomatal conductance.
    - Global estimates: 3.5-5% increase in demand by 2025 due to cc ALONE. Regional details depend on climate scenario.
- Many non-climate related influences on demand

Irrigation demand

relative change (1961-90) to 2025



Impacts of cc and sustainable development (SD)

- CC impacts depend on water resource management system (WRMS) - not fixed in time.
- Water management systems (and other sectors affecting water) will develop in response to goal of SD.
- CC impacts in water area pose additional threat to SD in many sectors: economic, social, environmental.

…….. continued

- There are likely to be beneficial as well as adverse effects of cc.
- Few studies on real-world systems, but some general points:
  - over a time horizon of less than 20 years, cc likely to be small compared with other pressures.
  - cc implications likely to be greatest in those areas already highly stress.
  - unmanged systems are more at risk.
  - impact of climate variability/extremes

Adaptation to climate change

- Water managers accustomed to adapting to change – e.g., extreme events/variability, increased demand, more focus on environmental needs.
- Wide range of adaptive techniques/options available (supply/demand side), but barriers to uptake.
- Uncertainty element of cc is a challenge.
- Consider adaptation in SD framework - little done in TAR.

Water in a sustainable development context

- Does the affect of cc on water threaten SD?
  - Use of water already unsustainable, cc could exacerbate, knock-on effect to other sectors
- Does the goal of SD affect cc?
  - Changes to water resource management influences impacts and adaptation to cc.

………. continued

- Adaptation to/mitigation of cc
  - Integrated water resource management (IWRM) - consider all sectors, all stakeholders - this should be compatible with SD.
  - climate change needs to fit within this IWRM matrix

IPCC 4th Assessment Report (AR4)

- Both sustainable development **and** water are themes in AR4 - HOW?
- IPCC focus is of course cc and not sustainable development.
- What information on cc and water is needed to inform international debate on SD, what's needed down on the ground??

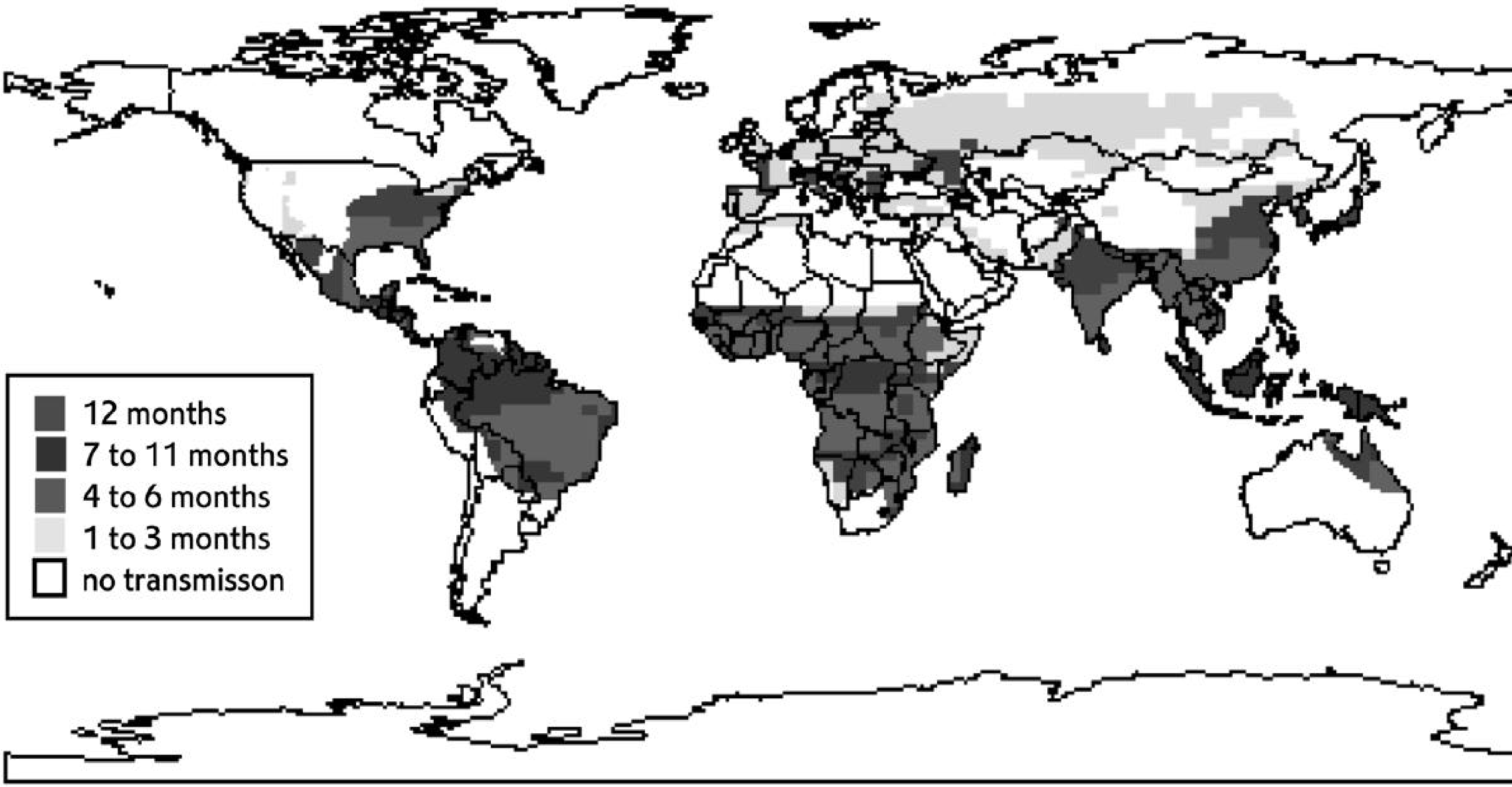
Human Health, Climate Change and Sustainable Development

Martin Parry

WGII, IPCC

Malaria transmission season

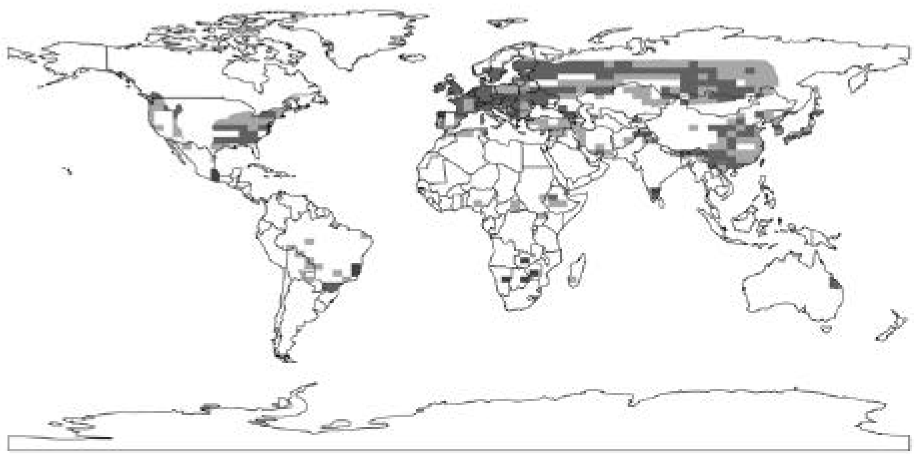
Estimated for the present day (*falciparum*)



London School of Hygiene and Tropical Medicine

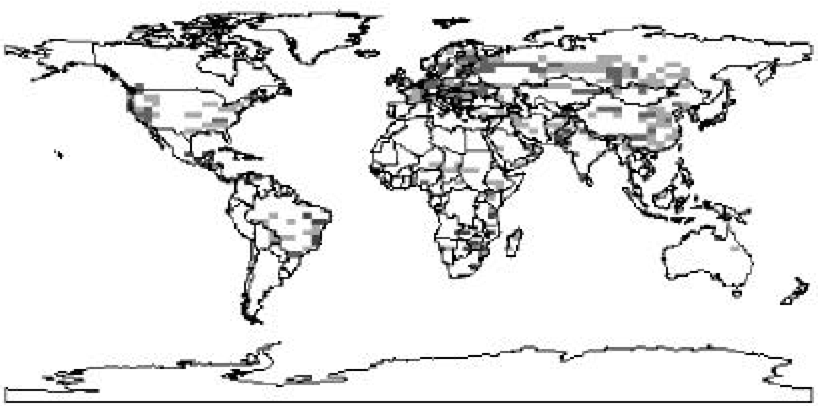
Malaria transmission

Change in duration of season, 2080s

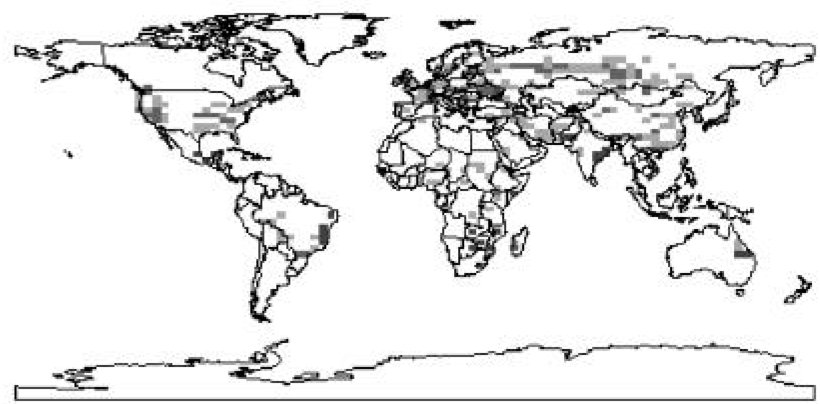


Unmitigated emissions

London School of Hygiene and Tropical Medicine



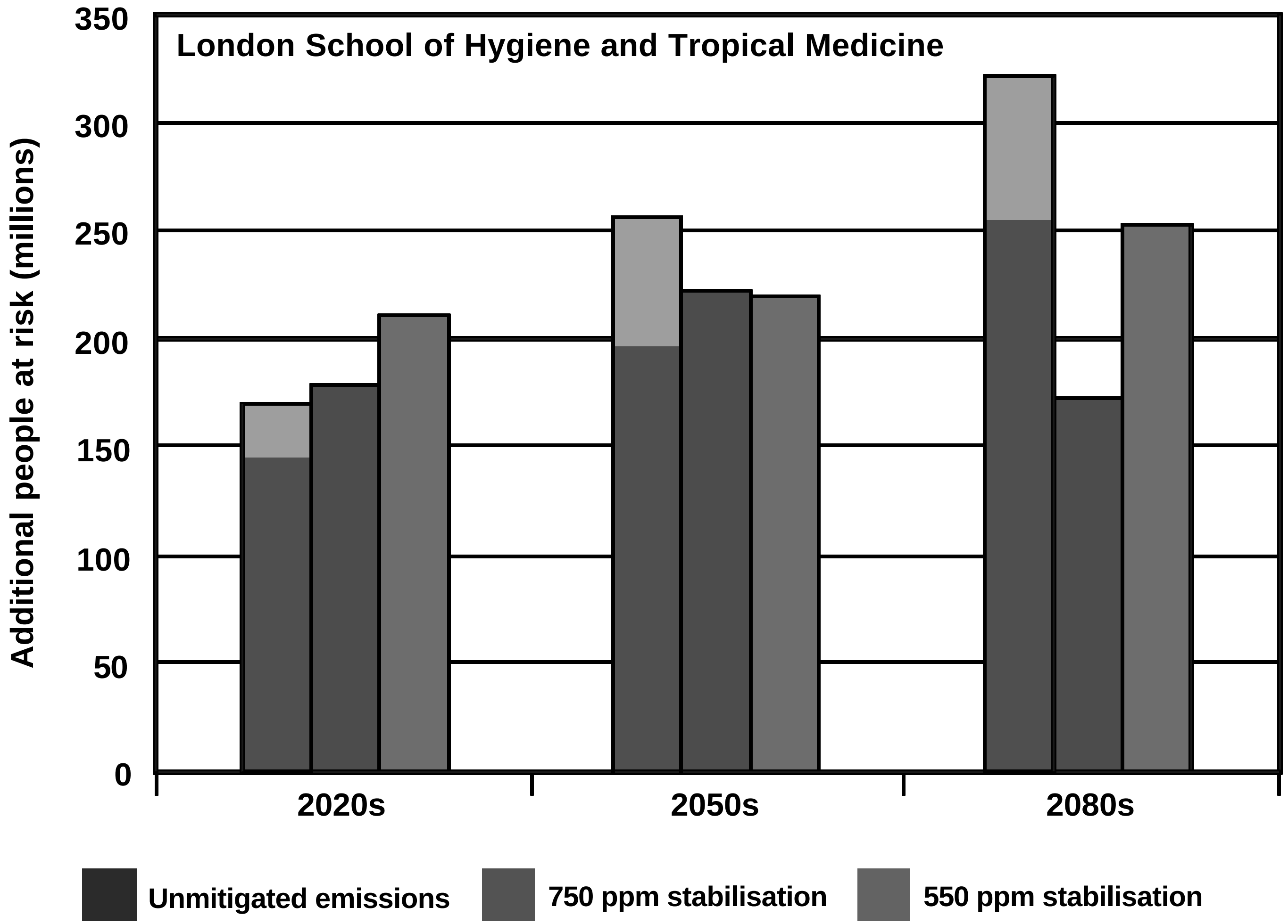
Stabilisation at 750 ppm



Stabilisation at 550 ppm

2 to 5 months | 1 to 2 months | –2 to –1 months | –5 to –2 months

People at risk of malaria additionally from climate change



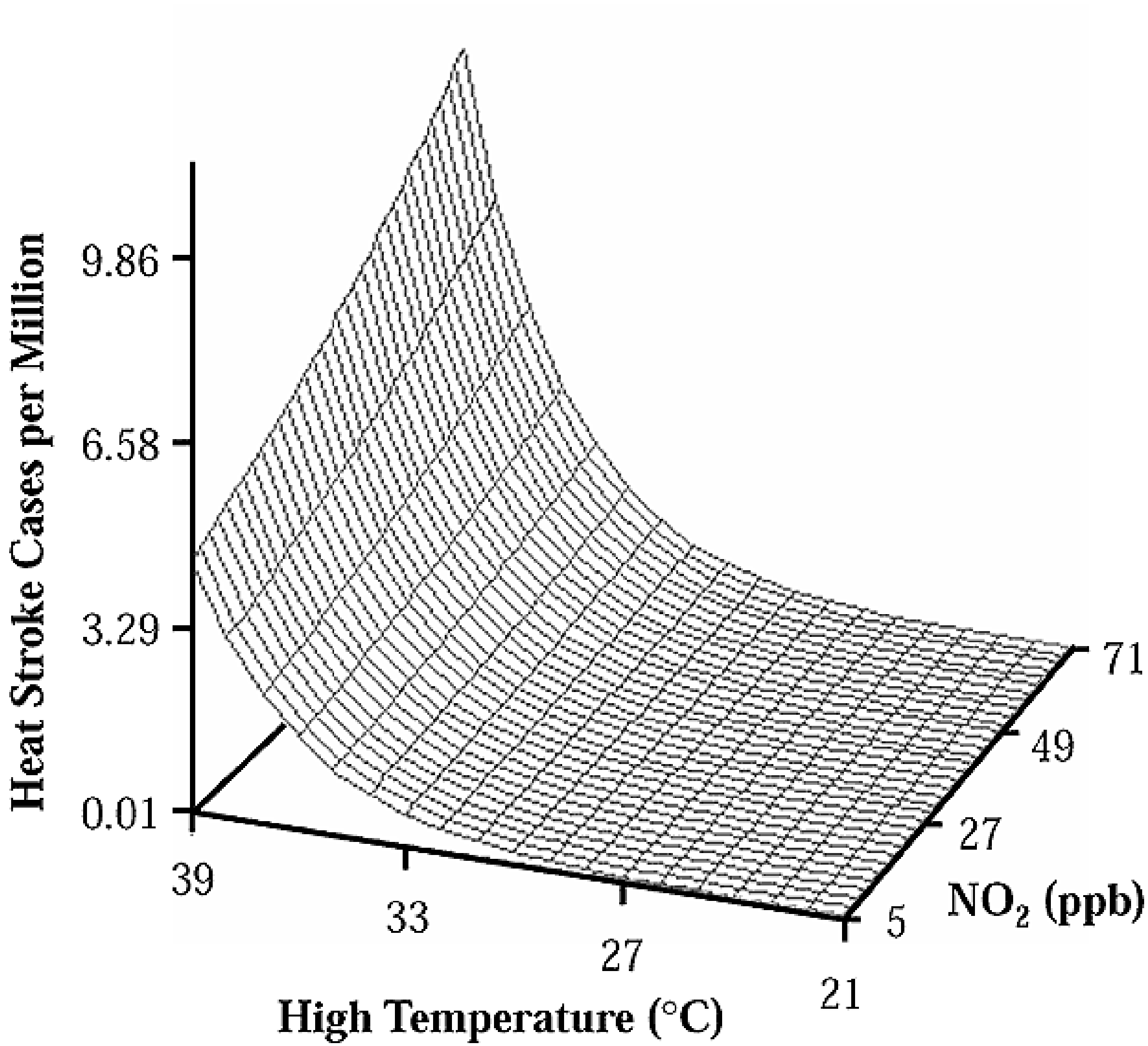
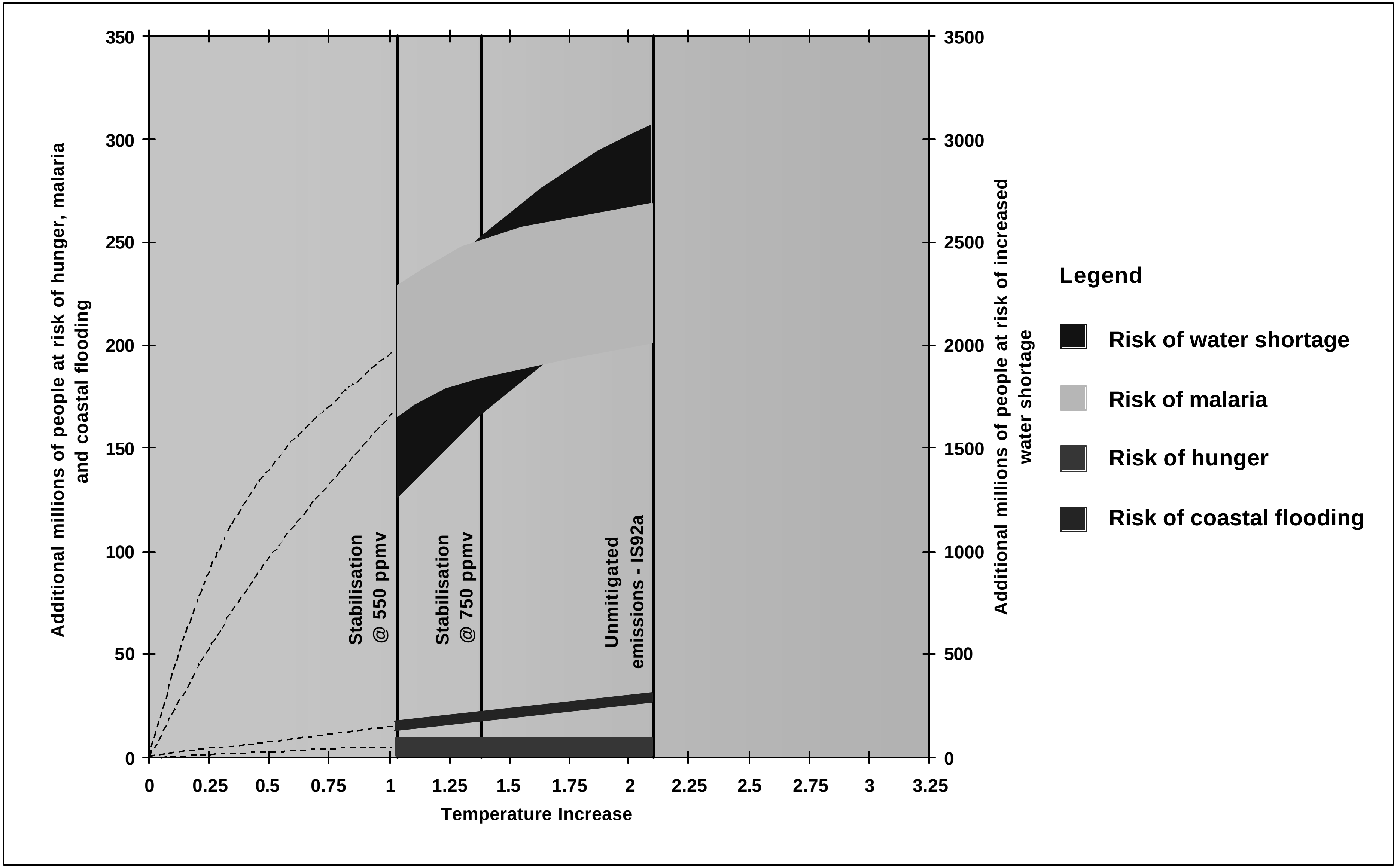
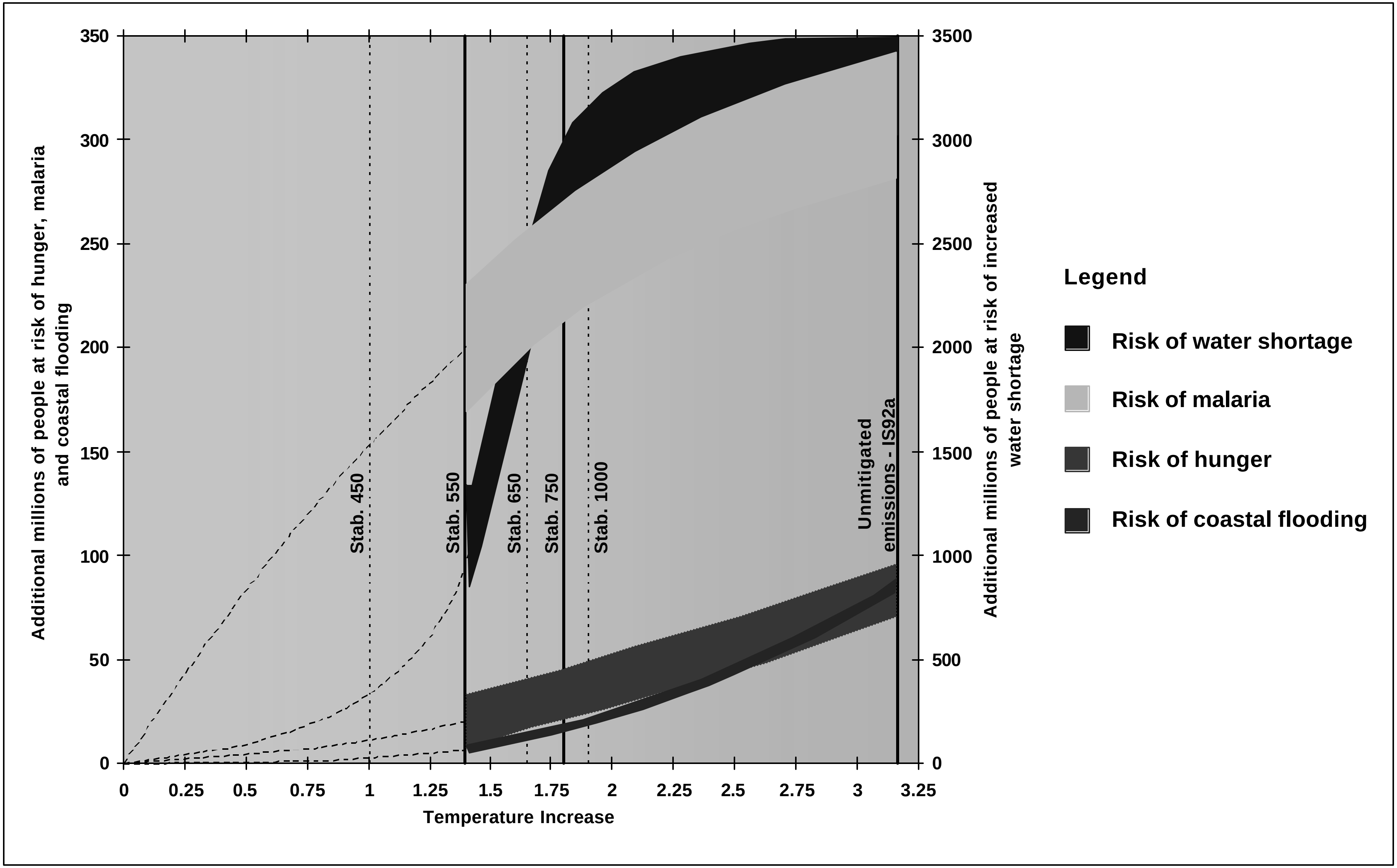


Figure 11-12: Heat stroke morbidity cases per million; Tokyo, July-August, 1890-1995, males >65 years) (*Piver et al., 1999*)

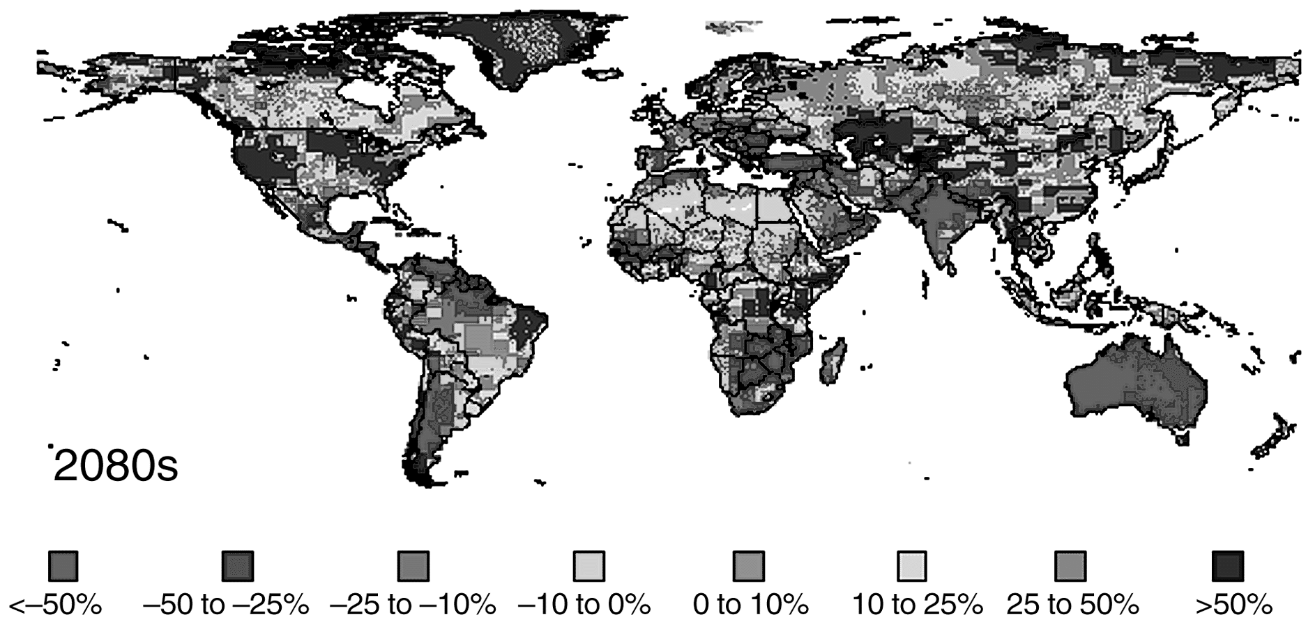
Millions at Risk in the 2050s



Millions at Risk in the 2080s

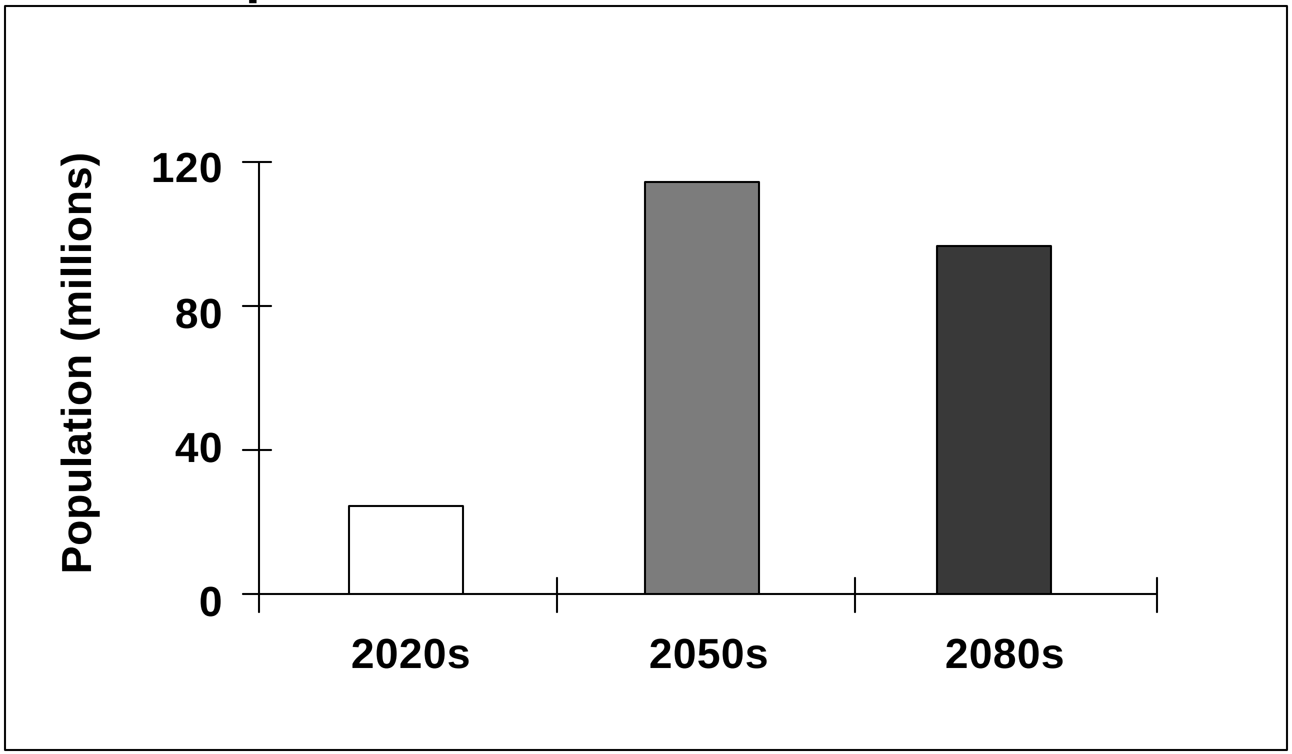


Annual runoff



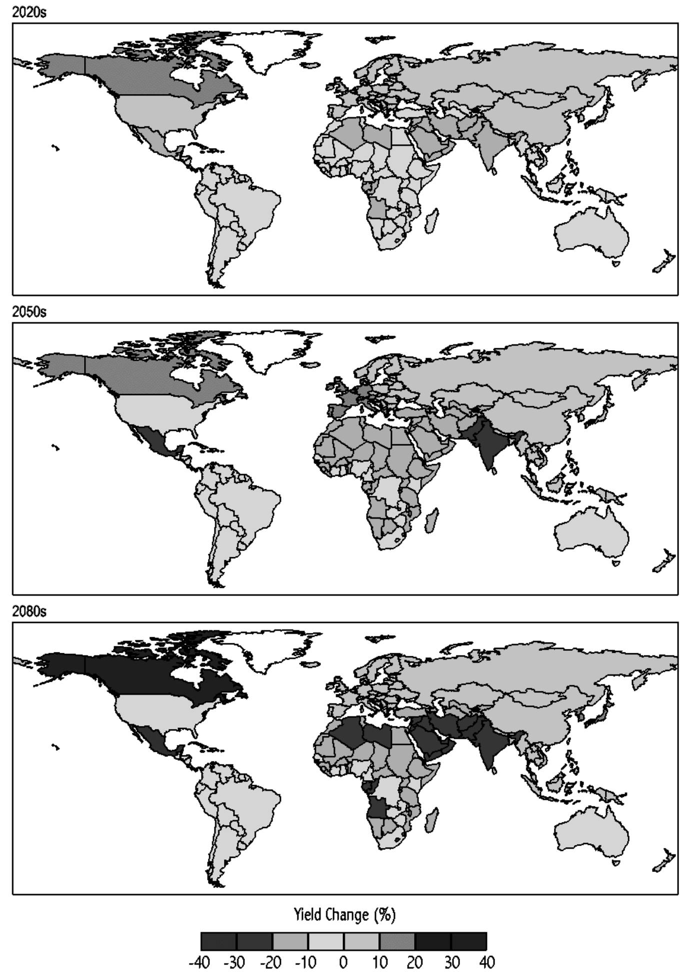
Percentage change in 30-year average annual runoff by the 2080s.

Population under extreme stress



Change, due to climate change, in the number of people living in countries with extreme water stress.

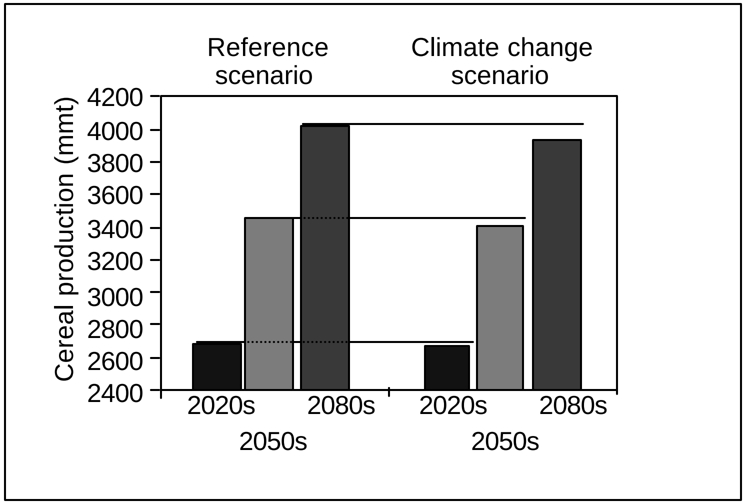
Crop yield change (Hadley model)

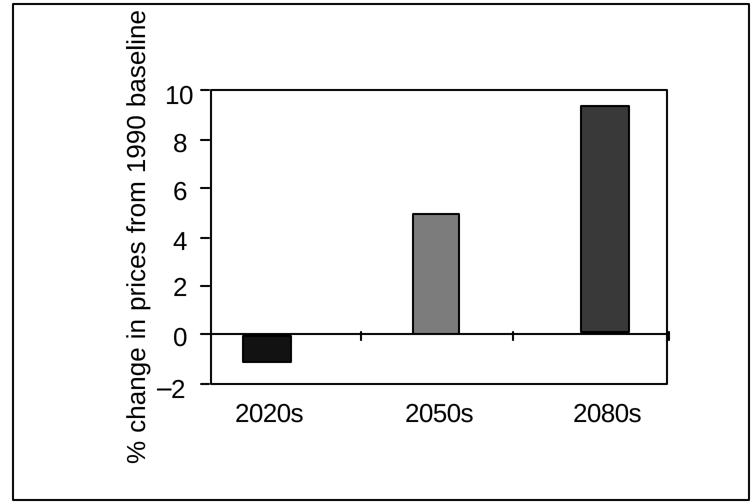


Percentage change in average crop yields for the climate change scenario. Effects of CO_2 are taken into account. Crops modelled are: wheat, maize and rice. Changes shown are averaged for national or regional levels based on the economic components of the Basic Linked System.

Jackson Environment Institute

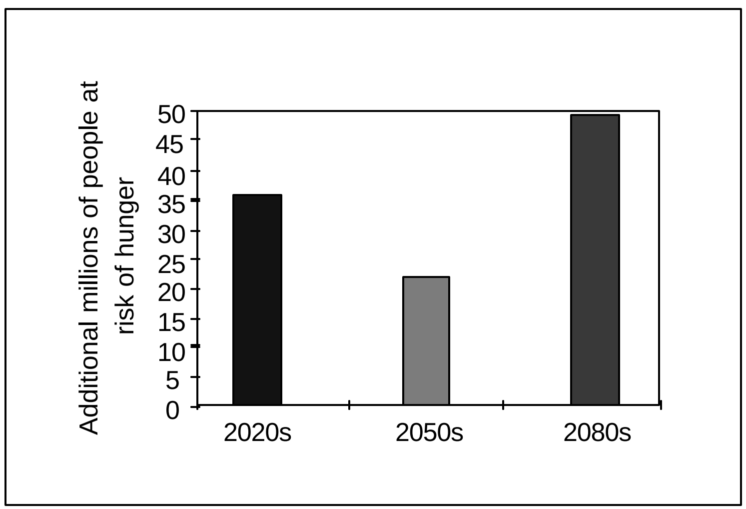
Jackson Environment Institute, University College London /
Goddard Institute for Space Studies /
International Institute for Applied Systems Analysis





Projected global cereal production for reference case and the climate change scenario.

Percentage change in global cereal prices under the climate change scenario (0 = Projected reference case).

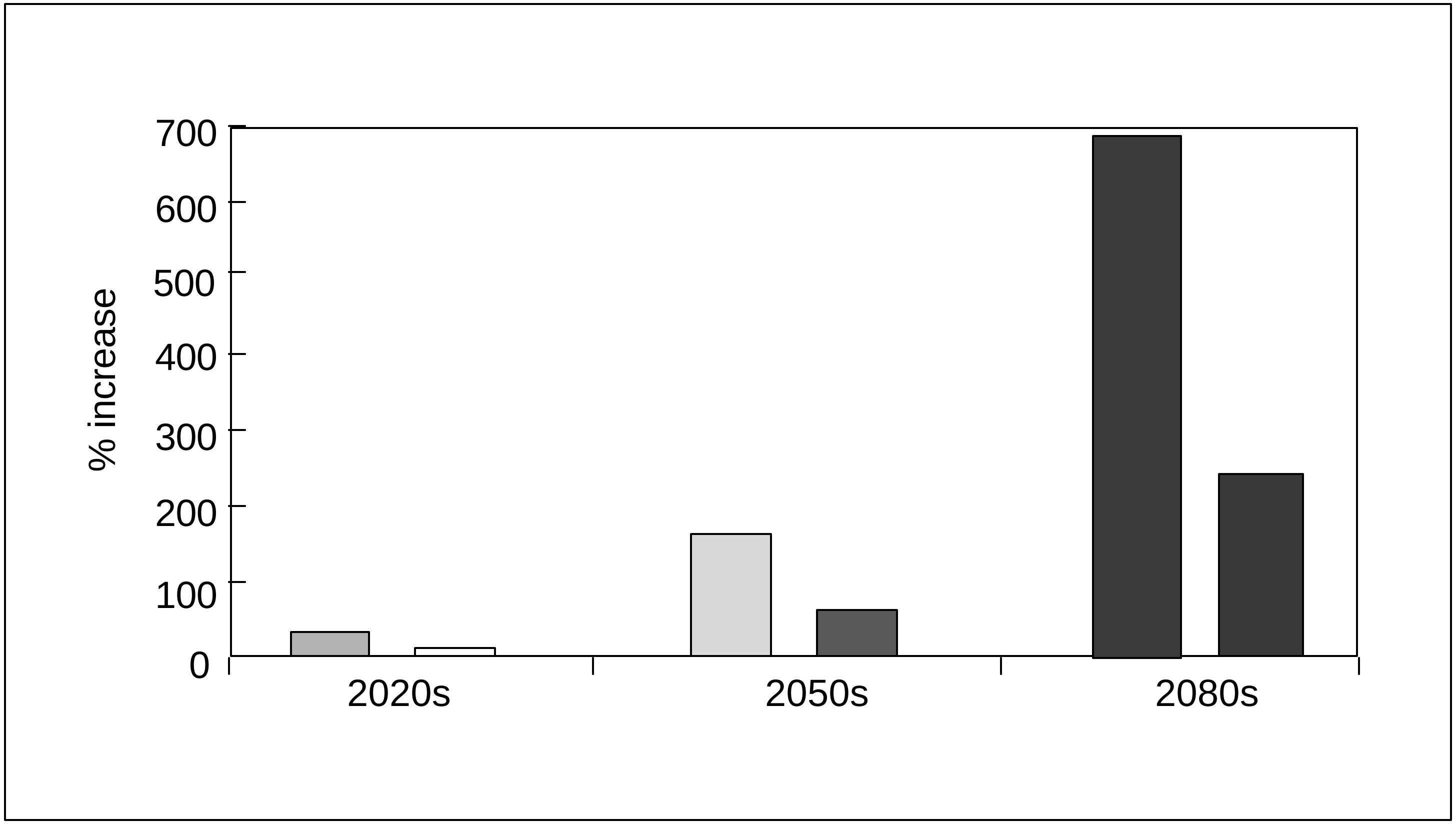


Additional people at risk of hunger under the climate change scenario (0 = Projected reference case).

Jackson Environment Institute

Jackson Environment Institute, University College London /
Goddard Institute for Space Studies /
International Institute for Applied Systems Analysis

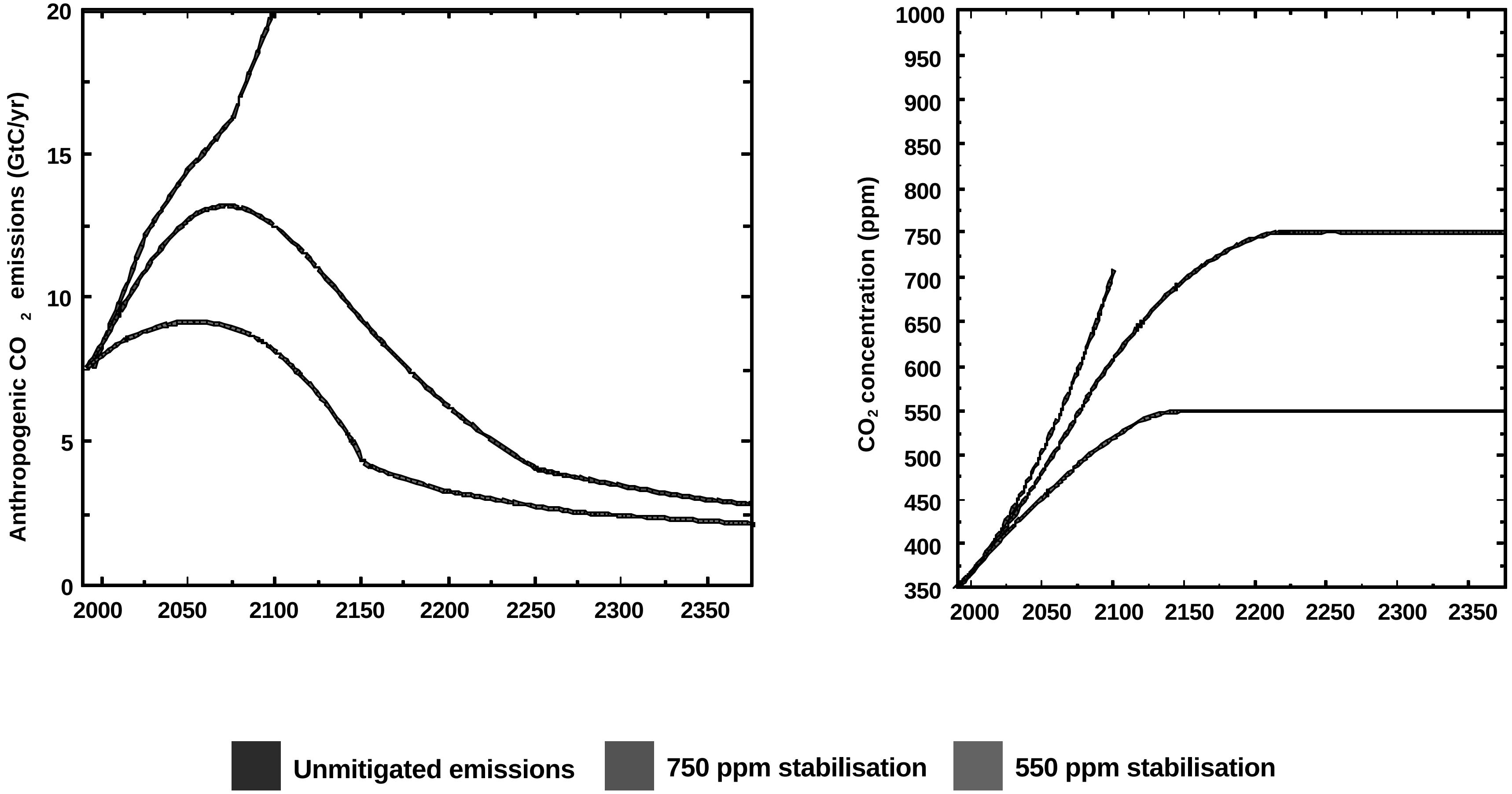
People at risk from sea-level rise



Percentage change in the number of people at risk under the sea-level rise scenario and constant (1990s) protection (left bar) and the sea-level rise scenario and evolving protection (right bar).

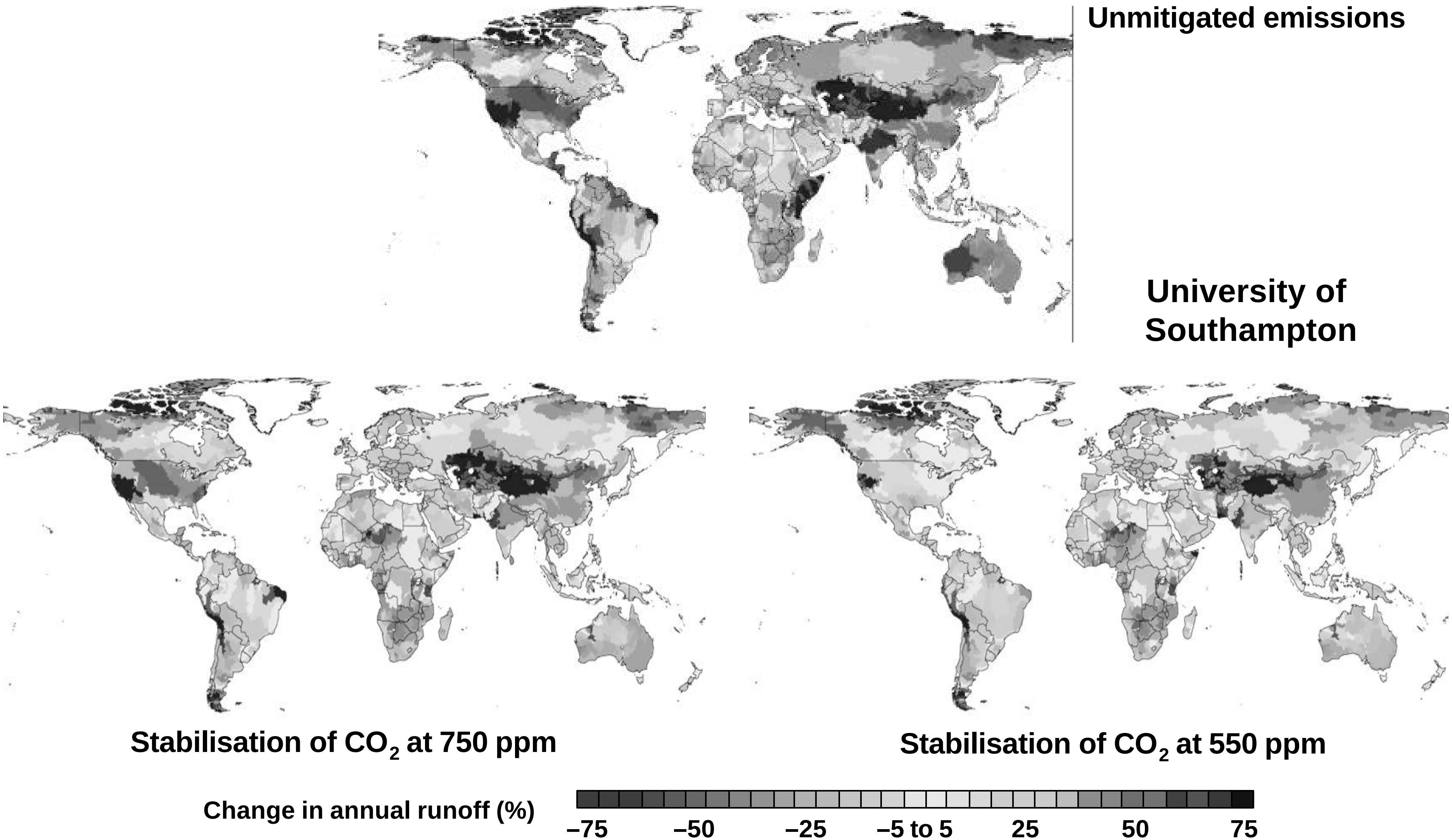
Middlesex University / Delft Hydraulics

Emissions and concentrations of CO_2 from unmitigated and stabilising emission scenarios

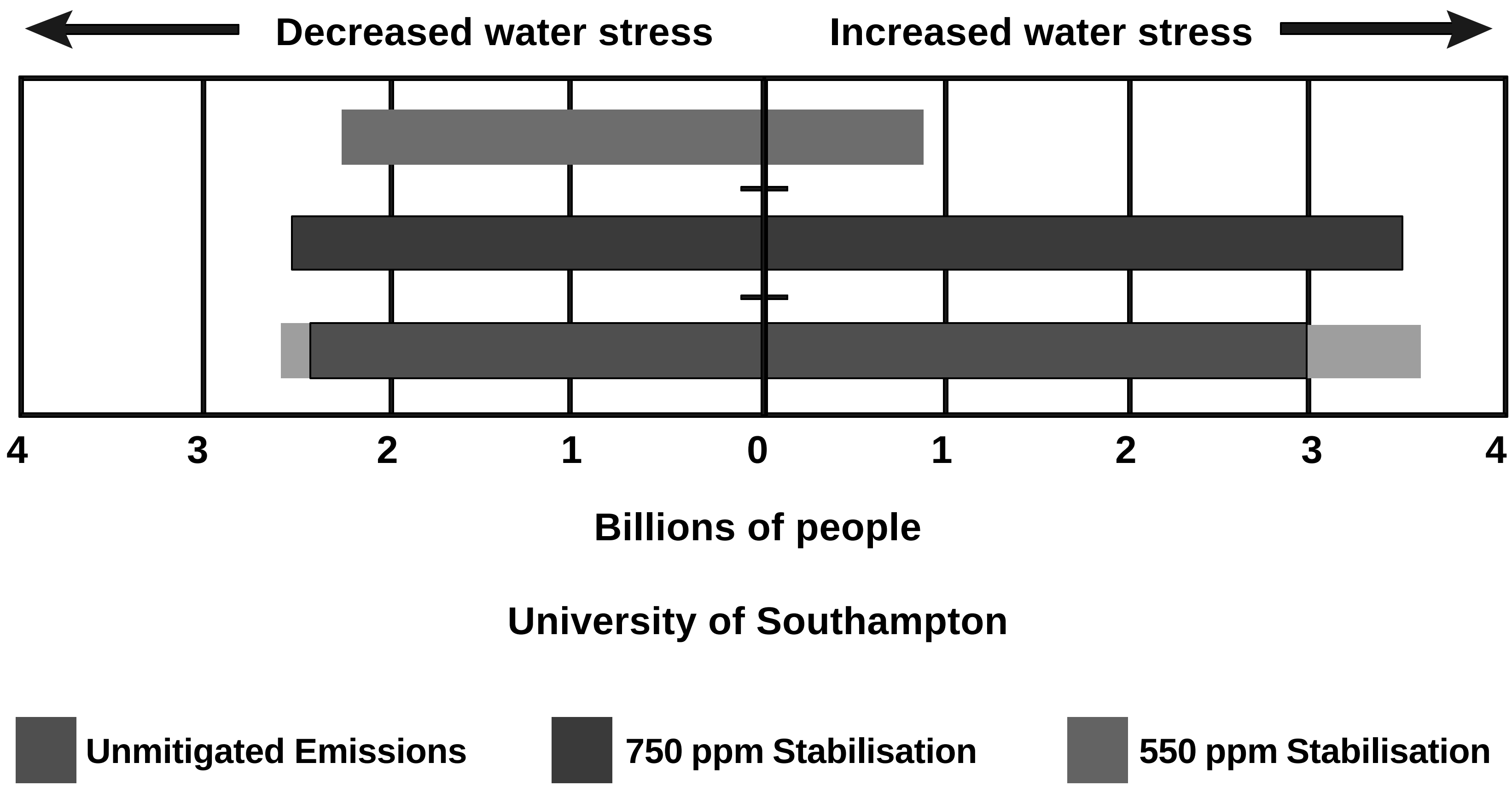


Hadley Centre for Climate Prediction and Research

Changes in river runoff
from the present day to the 2080s



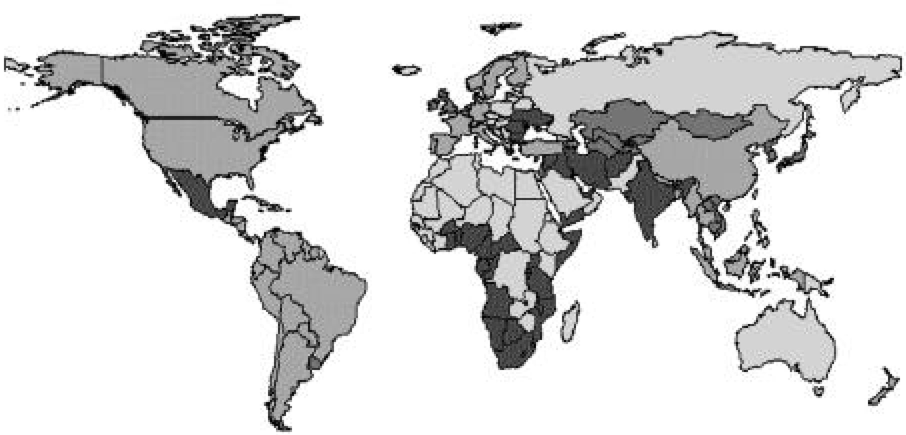
Changes in water stress
from the present day to the 2080s



Changes in crop yield
from the present day to the 2080s

University of East Anglia

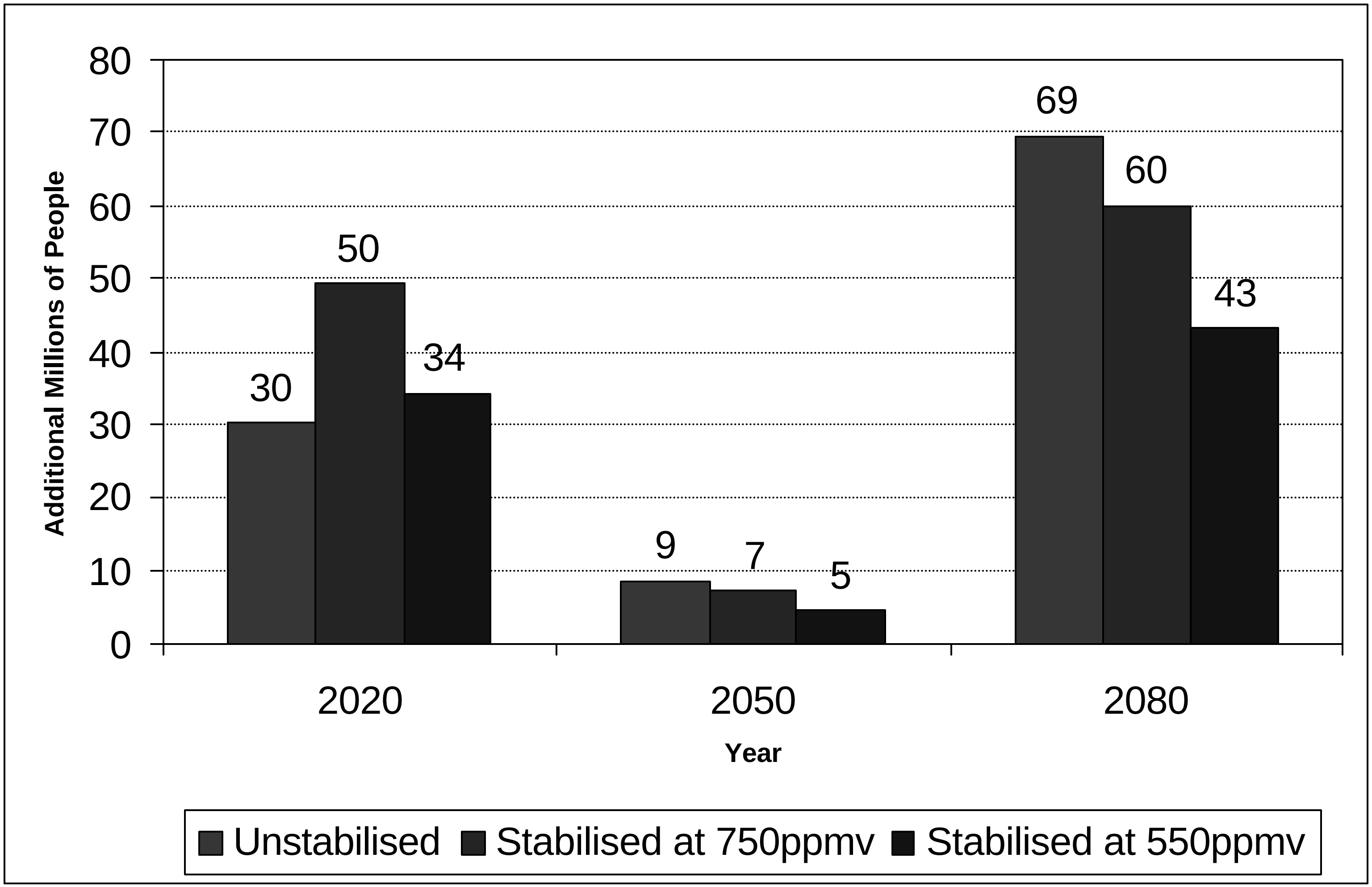
Unmitigated emissions



Stabilisation of CO_2 at 750 ppm

Stabilisation of CO_2 at 550 ppm

Global Estimate of Additional People at Risk of Hunger due to Climate Change



Conclusions

- Most serious effects are at the margins.
- Stab’n at 750 does not avoid most effects. Stab’n at 550 does, but cost (= c.20 times Kyoto reductions).
- Adaptation AND stabilisation are necessary.
- Sustainable development (cf SRES B2 marker scenario) a potential ‘solution’.

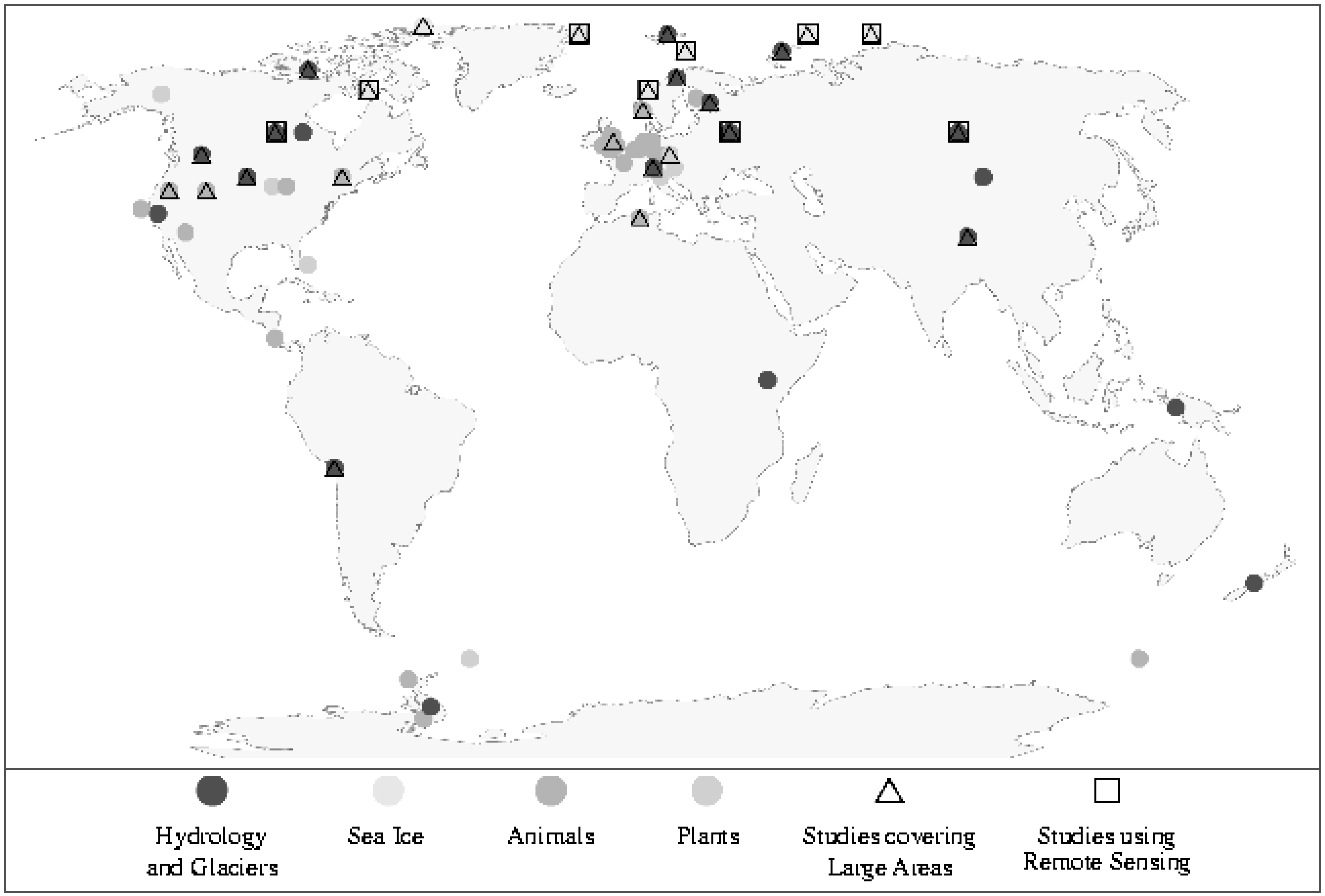
Biodiversity, Ecosystem Protection, Climate Change and Sustainable Development

Mike Harrison
WGII TSU, IPCC

BIODIVERSITY AND SUSTAINABLE DEVELOPMENT

- Ecosystem support for human activities
- Environmental maintenance
- Quality of life – aesthetic, recreational
- Future opportunities – materials, chemicals, biota
- Support of ecosystem dynamics

LOCATIONS WITH WELL-DOCUMENTED TEMPERATURE-RELATED REGIONAL TRENDS



EXAMPLES OF ECOSYSTEM GOODS AND SERVICES - Table 5-2

Value	Examples of Goods and Services
Direct Use	Food, fibre, fuel, fodder, water supply, recreation, non-wood forest products
Indirect Use	Biodiversity, biochemical cycles, tourism, flood and storm control, clean water supply, pollution control
Option	Future discoveries (i.e. pharmacological and biotechnological), future recreation
Bequest	Intergenerational and sustainable development
Existence	Mostly conservation, aesthetic, spritual

Biodiversity links to Sustainable Development referred to in the TAR Chapter 5 - Wildlife

- Pollination/seed dispersal
- Nutrient cycling
- Natural pest control
- Ecosystem stability, health and productivity
- Recreation: revenue, aesthetics, cultural
- Adaptation: replacement of lost ecological services possible, at least in some cases, but may be costly; in other cases not at all. Lowest income groups may suffer most.

Biodiversity links to Sustainable Development referred to in the TAR Chapter 5 - Rangelands

- Desertification/land degradation
- Plant productivity (links to sequestration)
- Species distribution
- Disturbance regimes (fires, pest outbreaks)
- Salinisation
- Adaptation: possible but might be restricted by lack of infrastructure and investment

Biodiversity links to Sustainable Development referred to in the TAR Chapter 5 - Forests/Woods

- Unsustainable logging
- Degradation of forests/infrastructure change
- --> loss of biomass
- Non-wood forest products (resins, fruits, etc.) making important contributions to economies and biodiversity
- Adaptation: costs uncertain and choices may be affected by detailed changes in forest productivity

Biodiversity links to Sustainable Development referred to in the TAR Chapter 5 - Lakes/Rivers

- Capture/Culture/Recreation fisheries
- Affected by other pressures
- Impacts vary locally
- Adaptation: Management of water flows may exacerbate impacts; results of attempts to manage poleward movement of flora and fauna uncertain; aquaculture opportunities

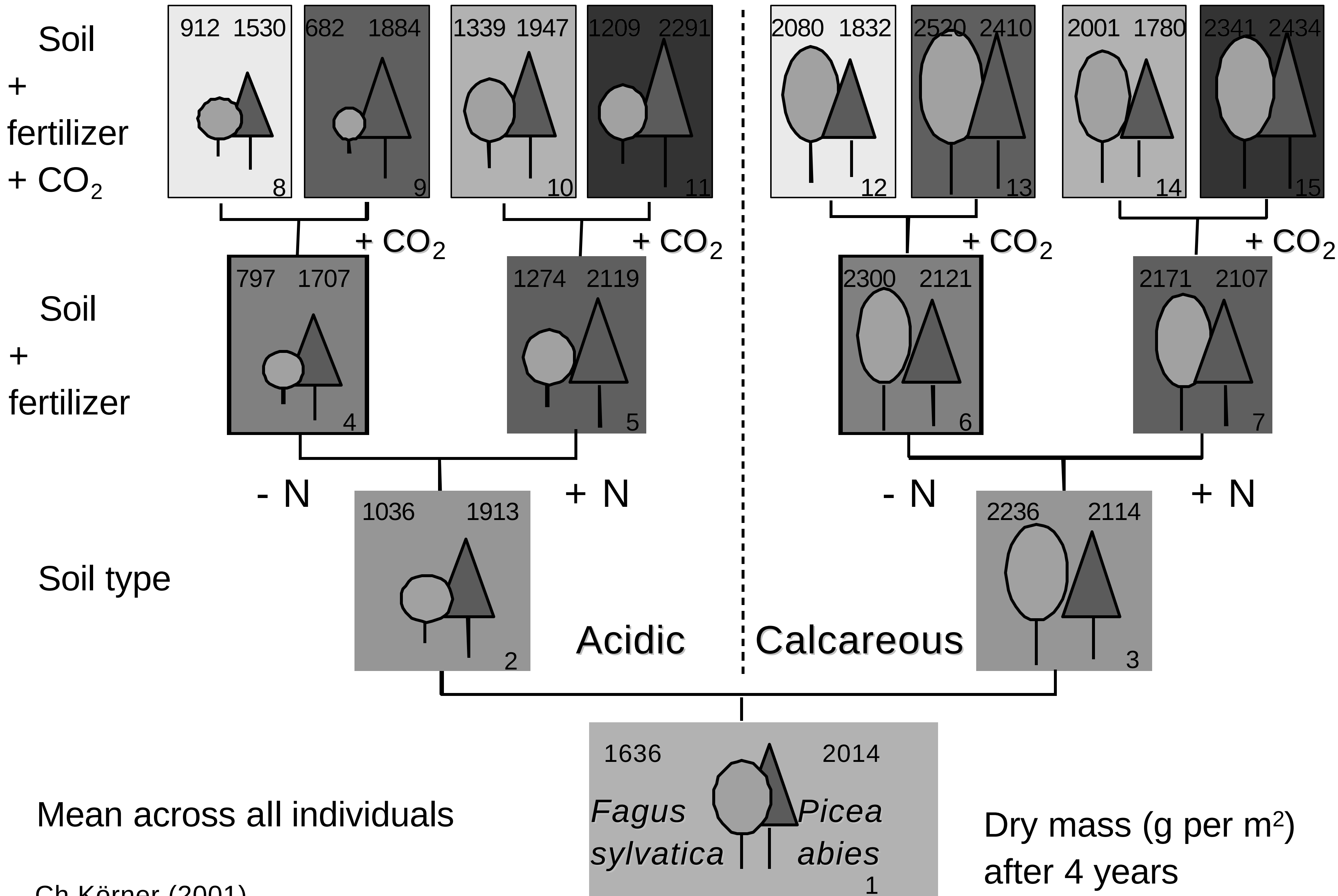
Biodiversity links to Sustainable Development referred to in the TAR Chapter 5 - Inland Wetlands

- Important role in maintaining biodiversity
- Scientific value beyond plants and animals
- Carbon sinks/methane sources
- Adaptation: may be impossible - depends on catchment-level hydrology

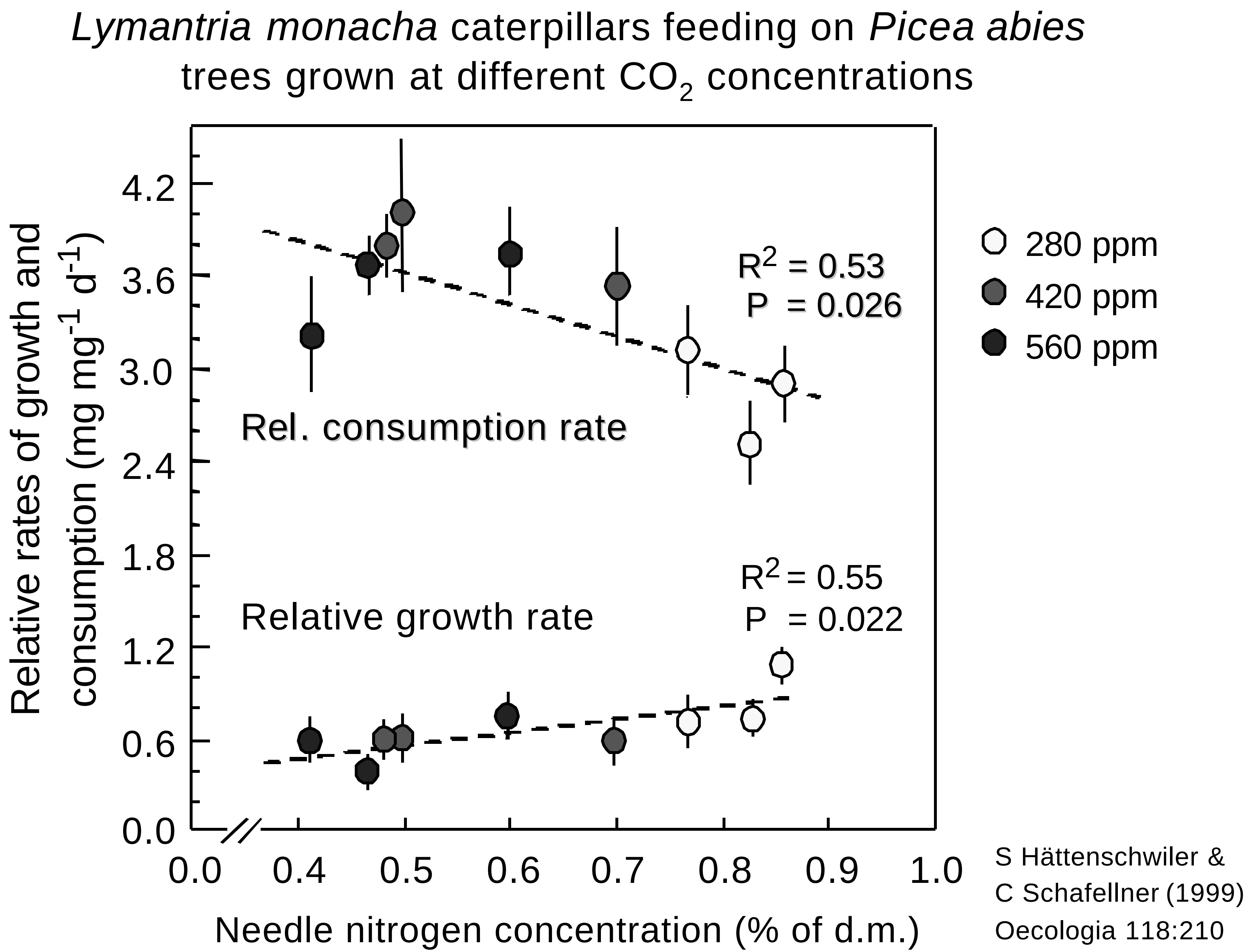
Biodiversity links to Sustainable Development referred to in the TAR Chapter 5 - Arctic/Alpine

- None mentioned, but indicates that human impacts much stronger than climate impacts
- Adaptation: limited but could include economic diversification

CO_2- response as a function of soil type, species and N-addition

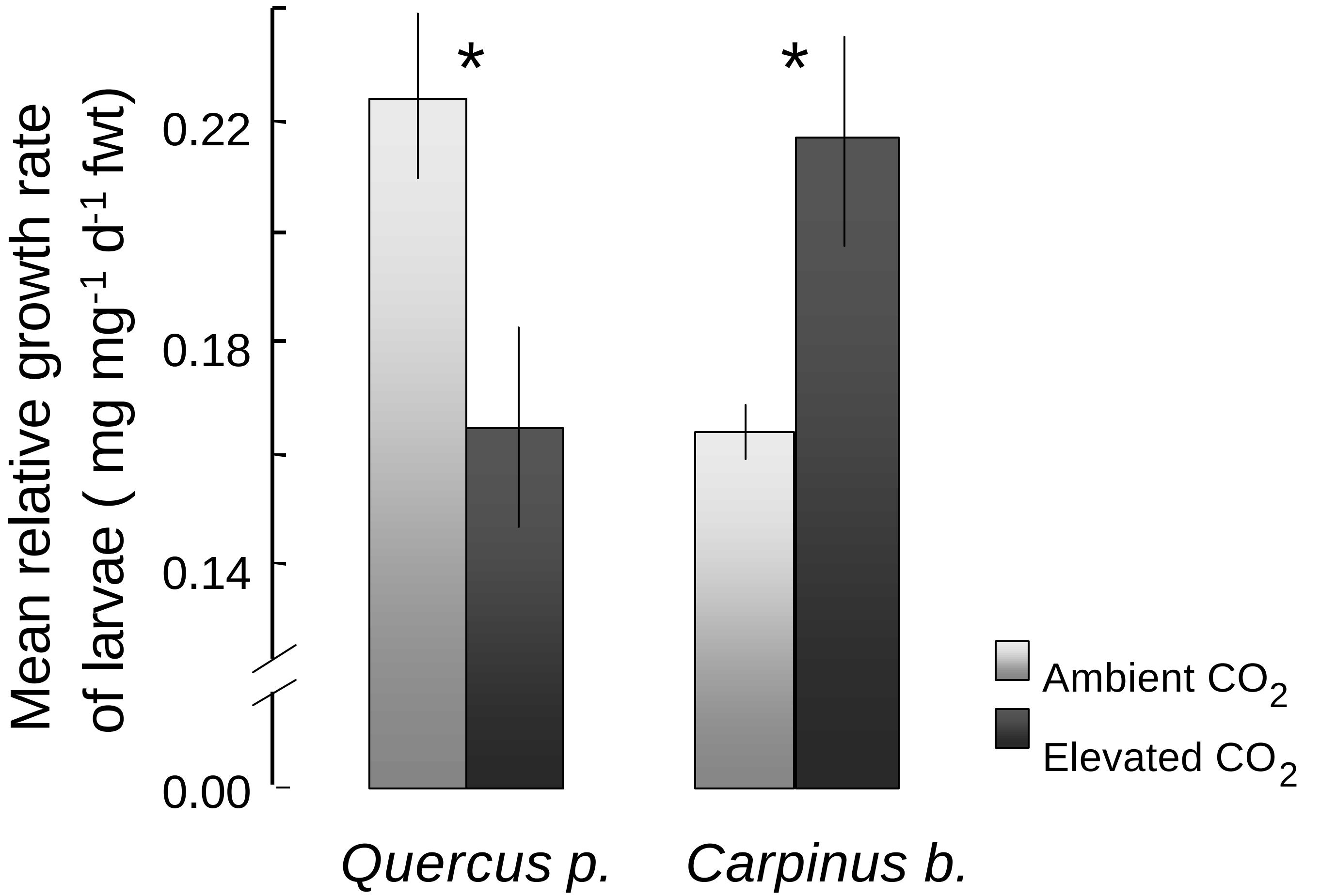


Ch Körner (2001)


Lymantria monacha caterpillars feeding on Picea abies
trees grown at different CO2 concentrations
Relative rates of growth and consumption (mg mg-1 d-1)
4.2
3.6
3.0
2.4
1.8
1.2
0.6
0.0
R2 = 0.53
P = 0.026
Rel. consumption rate
R2 = 0.55
P = 0.022
Relative growth rate
280 ppm
420 ppm
560 ppm
0.0
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Needle nitrogen concentration (% of d.m.)
S Hättenschwiler &
C Schafellner (1999)
Oecologia 118:210

Growth of *Lymantria dispar* larvae feeding on adult forest trees exposed to elevated CO_2

n = 8 branches ± SE (each branch with 5 larvae)



Hättenschwiler S & Schafellner C (June 2002) unpubl. data

Biomass responds in a complex manner to:

- Species
- Nitrogen availability
- Sunlight
- Competition
- CO_2 levels

System dynamics are so complex and chaotic that ecosystem prediction is, at best, challenging and impacts on Sustainable Development hence are difficult to assess

Energy, Climate Change and Sustainable Development

Anand Patwardhan
Indian Institute of Technology Mumbai

Situating energy within the context of CC and SD

- The key proximate driver for CO_2 emissions and climate change
- A key development indicator and target (per capita consumption of commercial energy)
- An important enabler & catalyst for economic growth and development
- A sector that will be impacted as a result of climate change, and responses to climate change
- As an economic good provided to consumers, can quite legitimately look at a range of issues associated with sustainability: distributional equity (availability and affordability), intergenerational equity and efficiency

Cross-sectoral linkages

- Energy is an input for the production and delivery of the basic goods and services that define well-being (food, water, health etc.)
- Therefore climate change impacts on energy are not only direct, but also channeled through the range of services based on energy availability and use

The criticality of the energy sector

- The next two decades will witness a build-out of the energy infrastructure in much of the developing world (India plans to add as much generating capacity in the next 15 years as it did in the last 50)
- At the same time, much of the post-World War II capital stock in energy infrastructure has reached or will reach end of economic life soon. What will be its replacement?
- Whatever we do today will lock us in for another 50 years
- Non-marginal change / discontinuous transitions are most likely to happen in dis-equilibrium conditions

Framing the issue

- Rapid growth in well-being with an emissions constraint is feasible only in the presence of rapid (perhaps unprecedented) improvement in energy intensity and carbon intensity
- This can be viewed as a technology challenge
- But it is unlikely to happen autonomously
- In which case it is also a policy challenge and a business challenge (if we expect a private sector response)
- What can the research and assessment community offer in terms of models and / or historical analogues?

Viewing the energy sector

- Components
  - Commercial energy (electricity as the common carrier)
  - Transport (petrol/diesel as the common carriers)
- Delivering value
  - Producing the common carrier
    - Joint mitigative and adaptive capacity – distributed (local) production – consumption cycles?
  - End-use efficiency
    - Joint mitigative and adaptive capacity - decoupling energy from end service delivery?
    - Implications of energy companies migrating from sellers of energy products to sellers of services

Drivers for energy

- Consumption of all other goods and services
- Direct consumption of energy
- Form and nature of human settlements
  - Patterns of urbanization
- Rapid changes in economic structure and composition are possible

Transport

- Modal mix and evolution
- Urbanization and settlements
- End-use technological change
- Institutional and systemic change

Is sustainable development a characteristic of the outcome, or of the process?

- If the former, then the problem may be framed either in terms of access to & distribution of assets (capital) or the distribution of outcomes (such as well-being)
- If the latter, then the question is whether we are capable of, and are actually able to achieve a balance between multiple and conflicting goals
- Perhaps it is both, and this is important in the energy sector – what structure of the energy industry will enhance sustainability?
  - For example, will distributed generation lead to local production – consumption cycles that may lead to positive environmental and economic outcomes?

Looking at energy in a holistic sense

- Efficiency
  - Technologies
  - Markets
- Equity
  - Procedural
    - Institutions and structural issues of the energy industry
  - Outcome
    - Availability and access
- Emissions pathways

The interface of energy with different domains

- Policy
  - What are the windows of opportunity and points of intervention?
- Technology
  - What should be the direction of technological change?
  - Moving down the price-performance curve is an appropriate strategy for addressing the digital divide in ICT, Is there a similar strategy with regard to commercial energy and transport?
- Institutions and governance
  - How is the energy industry organized, regulated?

What should we do in AR4? (SD – CC)

- SRES was a good start, but perhaps we need to focus on building scenarios that emphasize transitions, and the potential for non-marginal, regime change
- More critical assessment and evaluation of alternative development pathways, and on the elucidation of processes & mechanisms, particularly those associated with technological change
- Joint consideration of adaptation and mitigation will require significant interaction and integration across WG 2 & 3 (and perhaps WG 1)

Example: sequestration

- Techno-economic problem (WG 3)
- Risks to the natural carbon cycle (WG 1)
- Equity, institutions, implementability (WG 3)?
- Linkage with adaptation, and other sectoral issues – water, land use (WG 2)?

What should we do in AR4? (CC – SD)

- What are the end-points or final outcomes that we assess?
- Important to document the changes in final outcome variables (health, yields, water availability)
- Perhaps equally important to document, describe and characterize the mechanisms and pathways – gives us an entry point into adaptation design
- For example, in the case of vector-borne disease, we may have different end-points: vector prevalence, disease prevalence, observed mortality / morbidity
- Each end-point requires the consideration of more complex and often non-climate related processes
- However, if we want to inform adaptation policy we may have to do this

Governance, Climate Change and Sustainable Development

Leena Srivastava

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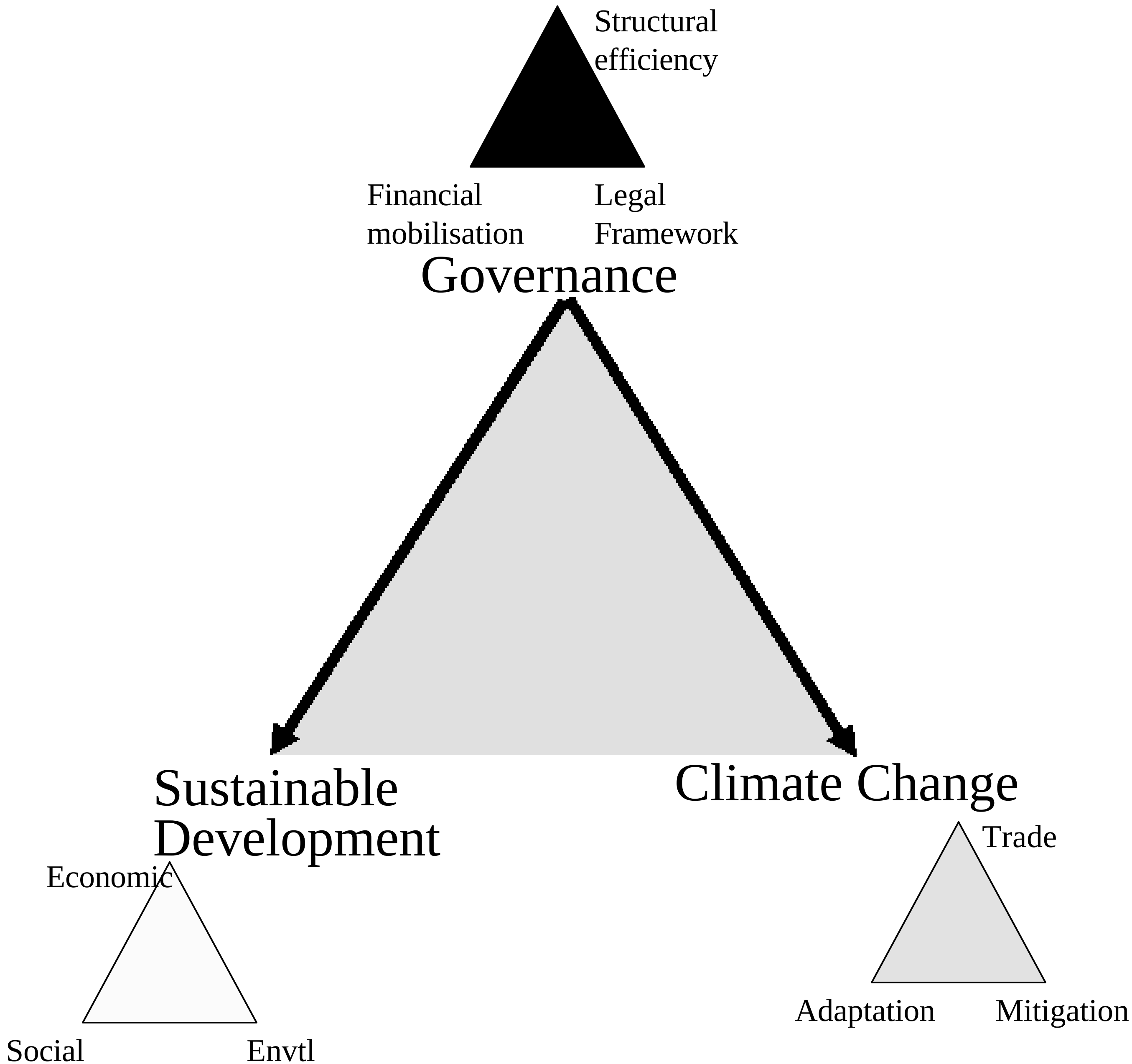
Structural
efficiency
Financial
mobilisation
Legal
Framework
Governance
Sustainable
Development
Climate Change
Economic
Social
Envtl
Trade
Adaptation
Mitigation

Governance Definitions

- Structural efficiency
  - Organisations, participation, transparency, accountability
- Financial mobilisation
  - Financial commitment, technology access
- Legal frameworks
  - Empowerment, enforcement, compliance

Governance: Developing Countries

	Structural Efficiency	Legal Framework	Financial Mobilisation
WEHAB			
Economic			
Social			
Environmental			
Climate Change			
Mitigation			
Adaptation			
Trade			

Developing country view

Governance: Developed Countries

	Structural Efficiency	Legal Framework	Financial Mobilisation
WEHAB			
Economic			
Social			
Environmental			
Climate Change			
Mitigation			
Adaptation			
Trade			

Developing country view

International Governance

	Structural Efficiency	Legal Framework	Financial Mobilisation
WEHAB			
Economic			
Social			
Environmental			
Climate Change			
Mitigation			
Adaptation			
Trade			

Developing country view

Key governance issues

- Need to recognise the interdependence of WEHAB and climate issues
- Coordinated policies and strategies
- Mutually re-inforcing vulnerability
- Challenge of providing access while minimising environmental externalities

Solutions

Ensure access to

- Income, credit, subsidies
- Technology
  - Affordable
  - Suitable
  - Competitive
- Markets

Governance: Developing Countries

- Current focus: Reforms (WEH AB-CC)
  - encourage investments
  - competition/efficiency
  - rationalise tariffs
- Current focus: challenges
  - Universal service
  - Affordability
  - Participation
  - Coordination

Governance: Developed Countries

- Promote technology development and adaptation designed to developing country needs
- Meet financial obligations
- Adopt policies consistent with global development objectives

Governance: International

- Coordination across SD & CC issues
- Protection of Principles of Conventions
- Fair and equitable institutional mechanisms
- Independent and transparent regulatory institutions

ANNEX A

BACKGROUND DOCUMENT ON THE NEED FOR TWO EXPERT MEETINGS ON CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT - PRESENTED TO THE IPCC PLENARY, PARIS, FEBRUARY 2003

Mohan Munasinghe, IPCC Vice-Chair

Background

The linkages between climate change (CC) and sustainable development (SD) were highlighted in the TAR, *inter alia*, based on a crosscutting "guidance paper" and two expert meetings on the subject, organised by WGII and WGIII, in 1999 and 2000 respectively. Nevertheless, there was general agreement that the potential synergies and trade-offs between climate change response options and wider development objectives were still incompletely covered in the TAR.

At the April 2001 IPCC Plenary, the importance of the issue was reconfirmed and a scoping meeting initiated to develop a proposal for a Special Report. This meeting was held in June 2001 in Washington DC, bringing together 35 leading experts from both the climate change and development communities, to produce a scoping paper. The IPCC Plenary of September 2001 reviewed this paper, and requested the sponsors to modify the proposal to cover the preparation of a Technical Paper on the same subject. Following the election of the new Bureau, the April 2002 IPCC Plenary requested a more comprehensive programme to pursue the issue of climate change and sustainable development in the context of the 4th Assessment Report (AR4), including the organisation of one or more Expert Meetings.

This background note seeks to outline the objectives, scope, and other relevant details of the two expert meetings on climate change and sustainable development.

Objectives

The overall objective of the sequence of the two expert meetings would be to systematically develop a plan on how to fully integrate the linkages between climate change and development (including poverty and equity issues) into the structure and contents of the AR4. The plan will take into account the earlier proposals for an IPCC Special Report and Technical Paper, and build on the material in the TAR – using as a starting point, the framework presented in the Synthesis Report (e.g., Figures 1.1 and 8.3). The plan would specify, especially:

- Which key (two-way) linkages between Climate Change (CC) and Sustainable Development (SD) should be covered in the AR4;
- Which report structure would best allow for an adequate assessment of these linkages, within and across the Working Groups;
- What kinds of expertise would be needed for optimal coverage of the linkages, and which specific Lead Authors could potentially provide this expertise.

The first expert meeting will seek to determine the key CC-SD linkages in detail, while broadly identifying both a potential AR4 report structure and the lead author skills necessary to best capture such linkages in the report. The AR4 scoping meetings (April and September 2003) should take the recommendations of the first CC-SD expert meeting into account. Correspondingly, it is suggested that the draft outline of the AR4 resulting from these scoping meetings be circulated to the participants of the first expert meeting for comments, before it is submitted to the IPCC Plenary.

Key objectives of the second expert meeting will be the identification of the relevant CC-SD literature that would need to be covered, and details of how the SD theme might be fully incorporated in the AR4. This meeting could be held by mid-2004, after the outline of the AR4 would have been approved (foreseen at the November 2003 Plenary) and the author teams assembled. This second expert meeting will bring together both external experts and the Lead Authors identified to assure that SD issues are appropriately addressed in the relevant AR4 chapters, to further work out details of the coverage of CC-SD linkages in the draft AR4. It is recommended that this meeting be held in conjunction with a LA meeting (in mid-2004), designed to develop the first order drafts of the WGII and WGIII components of AR4. This could be facilitated by holding the WGII and WGIII meetings in one location back to back. Such an arrangement would also facilitate crosscutting contacts in other important areas, such as the integration of adaptation and mitigation.

Meeting Details

Arrangements are well advanced for the first meeting to be held Colombo, Sri Lanka on 5-7 March 2003. Highlights of the proposed 2-day programme include:

- Introduction and points of departure based on lessons learned from TAR
- Regional viewpoints: climate change and sustainable development viewed from both the developing and developed world -- including coverage of poverty and equity issues, with focus on which SD paths and policies might worsen (improve) CC prospects, and vice versa.
- Sectoral viewpoints: climate change and sustainable development in relation to food security, water, human health, biodiversity and ecosystem protection, governance, etc.
- Discussion Groups on identifying key CC-SD linkages and issues
- Discussion Groups on recommendations for the AR4 structure and content
- Discussion Groups on recommendations for the AR4 regarding author expertise and selection
- Plenary review of results and final recommendations

A major outreach event would also be organised to sensitise senior decision makers from the host country government, private sector and civil society, on key CC-SD issues -- thus taking advantage of this gathering of world experts on the subject.

About 35 participants are expected, including

- 8-9 IPCC Bureau members: Chair, one vice Chair, the co-chairs and selected Bureau members from the Working Groups;
- IPCC Deputy Secretary, heads of Technical Support Units (TSUs) of WGII and WGIII

- 12-14 scientific technical experts from relevant areas, with greater preference for those from the development community
- 8-10 other representatives from the stakeholder community (bi - and multi-lateral agencies, development banks, development NGOs, private sector, etc.)

This would ensure the appropriate balance between scientific experts (20-23, including the Bureau members) and other stakeholders (8-10). The presenters will include some world-renowned experts on SD. The scientific technical experts from the climate change community would be encouraged to make their contributions within the wider context of development.

The second expert meeting will involve LAs dealing with SD issues in the relevant chapters of the WG2 and WG3 reports, selected external experts, and a limited number of Bureau members.

Expected outputs

The expected output of the first expert meeting would be a draft document, including the key recommendations and collated presentations made at the meeting -- for consideration by the two AR4 scoping meetings to be held later in 2003. The IPCC Secretariat in collaboration with the local host organisation and the WGII and WGIII TSUs would be responsible for preparing this document, to be reviewed by the WGII and WGIII co-chairs before the first AR4 scoping meeting.

The expected output of the second expert meeting would be a detailed review of the adequacy of the proposed AR4 chapter structure, Lead Authors, and writing process, in order to fully capture the linkages between climate change and sustainable development. Relevant literature to be assessed in AR4 would also be identified.

ANNEX B

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ANNEX C

EXPERT MEETING AGENDA

Wednesday 5th March, 2003

17.30-18.00	Registration
18.00-19.30	**INAUGURATION** *Speeches by Hon. Karu Jayasuriya, Minister of Power and Energy, IPCC Chair, Bureau and other dignitaries*
19.30	**RECEPTION**

Thursday 6th March, 2003

08.00 - 08.30	Registration
Session 1:	***Introduction***
08.30 – 08.40	Welcome and Objectives of the Workshop *(Chairman IPCC, Local Hosts)*
08.40 - 09.00	Climate Change and Sustainable Development – Points of Departure from the TAR: Mohan Munasinghe
Session 2:	***Climate change and sustainable development – main presentations***
09.00 - 09.20	**Regional viewpoints** Climate Change and Sustainable Development - View from the Developing World: Kirit Parikh
09.20 - 09.40	Climate Change and Sustainable Development - View from the Developed World: J. Corfee-Morlot
09.40 - 10.00	Panel of 4 Discussants (5 minutes each): Ajay Mathur, Neville Nicholls, Adil Najam, S. Huq
10.00 - 10.20	General Discussion
10.20 - 10.50	**TEA BREAK**
10.50 - 11.10	**Sectoral viewpoints** Food Security, Climate Change and Sustainable Development: Gustavo Best
11.10 - 11.30	Water Security, Climate Change and Sustainable Development: Neil Adger Water, Climate Change and Sustainable Development: Paul van der Linden
11.30 – 11.50	Human Health, Climate Change and Sustainable Development: Bettina Menne (presented by Martin Parry)
11.50 - 12.10	Biodiversity, Ecosystem Protection, Climate Change and Sustainable Development: Mike Harrison
12.10 - 12.30	Energy, Climate Change and Sustainable Development: Anand Patwardhan

12.30 - 12.50	Governance, Climate Change and Sustainable Development: Leena Srivastava (comment by Tom Heller)
12.50 - 14.30	**LUNCH BREAK**
Session 3:	***Discussion Groups on identifying key CC-SD linkages and Issues***
14.30 – 15.00	Introduction and Preparation by Working Group Co-Chairs **(**Formation of discussion groups -- DGs)
15.00 - 16.00	Discussion Groups
16.00 - 16.30	**TEA BREAK**
16.30 - 17.30	Discussion Groups
17.30 - 18.30	Report Back from Discussion Groups and Plenary Discussion
19.30 - 20.30	**TRADITIONAL DANCE PERFORMANCE**
20.30 onwards	**BANQUET** *Keynote speech by Hon. K. Rambukwella, Minister of Science and Technology*

<u>Friday, 7th March, 2003</u>

Session 4:	***Discussion Groups on recommendations for the AR4 structure***
09.00 - 09.30	Introduction and Preparation by Working Group Co-Chairs
09.30 - 10.30	Discussion Groups
10.30 - 11.00	**TEA BREAK**
11.00 - 12.00	Discussion Groups
12.00 - 13.00	Report Back from Discussion Groups and Plenary Discussion
13.00 - 14.30	**LUNCH**
Session 5:	***Discussion Groups on recommendations for the AR4 structure***
14.30 - 16.00	Discussion Groups
16.00 - 17.00	Report Back from Discussion Groups and Plenary Discussion
17.00 - 17.30	**WRAP-UP AND CLOSURE OF MEETING**
17.30 -19.00	**SYMPOSIUM FOR SENIOR SRI LANKAN DECISIONMAKERS IN GOVERNMENT, BUSINESS AND CIVIL SOCIETY** *Welcome speech by Hon. Rukman Senanayake, Minister of Natural Resources and Environment* *Presentations by experts on TAR and post-TAR developments relevant to CC and SD*
19.00 - 20.30	**RECEPTION**

ANNEX D

RAPPORTEURS' REPORTS FROM THE THREE DISCUSSION GROUPS
Identification of the underlying issues in climate change and sustainable development

1. Break Out Group I

Why is it important to look at SD and CC?
Leveraging SD concepts towards climate change and vice versa to allow a much wider community to get involved.

- Requires packaging ideas differently rather than being an advocate on SD per se.
- Most useful information is in the form of sectoral or specific themes. Structure in WG II is sectoral, WGIII varies.
- WEHAB is also useful.
- What information is needed will depend upon the decision context.

Common development and climate themes

Food; Energy; Health; Water; Ecosystems (e.g. biodiversity and forestry); Human settlements

Cross-sector issues:

- ability to change, transition management, capacity to address linkages
- poverty reduction and distribution of income; equity (outcomes and process)
- resources allocation - financing for investment
- technology change and technology transfer; innovation systems
- air quality
- national security

Cross-cutting issues *(separate treatment):*

- governance and institutional mechanisms
- trade and globalisation?

Organisation of SD - CC in Mitigation

1) Context Mitigation and SD
   » trends relevant to sd and cc; sd goals, money flows, markets: ODA flows, FDI and commercial strategies, business incentives, innovation, security and market influences, governance, changes in development theory

2) LT stabilisation and necessary transitions
   » development trajectories and interactions with mitigation;
   » cc literature from development view, incl. technology and institutions to manage change
   » synergies and trade-offs, costs, benefits

3) ST/MT Mitigation Options

Overview:

- » Macro-economic/national/regional perspectives; development literature on political economy aspects. **(common)**
- » Dealing with different issues in different regions/countries. By main SD sector: Ag, Water, Eco-system, Health, Human settlements, Energy - opportunities and challenges. **(common)**

Detailed mitigation sectors (transport, buildings, agriculture and forests etc):

- » within each sectoral chapter, impact of SD on particular options and climate on SD;
- » costs, implementation issues and policy capacities and options: start global and move into major regional and national

4) Options for international climate regimes (common mitigation and adaptation)

- » connections to MEAs from SD perspective [also drawing on previous IPCC assessments]

Expertise (in addition to the normal engineers, natural scientists and economists)

- International relations
- Development economists
- Political economists
- Historians of technology
- Trade, investment and finance experts

Compare SD and CC objectives/endpoints

Overall SD objectives e.g. energy: Accessible energy, adequate supply, affordable prices, acceptable impact on environment, adequate returns

Possible to reconcile from two directions?

Energy example

	C-intensity	En-intensity	Supply	Reach
CC	x	x		
SD		x	x	x

National versus International

- Local, national contexts drive decisions and investments that influence SD outcomes/linkages themes
- Are there international contexts for decisions?
- Development assistance initiatives are multilateral
- Some of the sector issues have international activities – eg. international disaster. We could argue that managing risks of extreme hazards requires co-operation. Flood and storm and protection services from the MEA.
- Millenium ecosystem assessment; water – some international momentum;
- On the climate side, mitigation brings out the global dimension

2. Break Out Group 2

Why is it important to look at SD and CC?

Reaching to a broader audience requires packaging ideas differently rather than being an advocate on SD per se. The structure of WG II is sectoral, while in WGIII it varies. Most useful information is in the form of sectoral discussions. A sectoral organisation of the report will resonate with a broader audience than other options. Governance, institutions etc all have sectoral aspects. Most of the relevant information on these issues can be brought out through discussion of sectors.

SD concepts should be levered towards climate change to allow a much wider community to get involved. What information is needed will depend upon the decision context.

Overall objectives

e.g. energy: accessible energy, adequate supply, affordable prices, acceptable impact on environment, adequate returns

	C-intensity	En-intensity	Supply	Reach
CC	x	x		
SD		x	x	x

E.g.: Water

	Price	Supply	Availability	Access
CC				
SD				

Two-way relationships

- synergy between water development and climate risk management goal.
- end use efficiency – development and energy

How do different sectors change as per capita incomes change? A broad framework is needed for understanding and studying different sectors.

Introducing normative concepts into the TAR? Broadening the analysis beyond climate change will require getting further into the normative, value laden issues. It may be better to bring these up under the sectors.

Within each sector, think about the normative issues more easily.

How to organise CC and SD discussion?

» Climate impacts: measures to be taken to address impacts, results of measures taken

» Two directional assessment – FCCC and Economic development are two different spheres of action, actions under each will have impacts on the other sphere. Might be win-win strategies e.g. where mitigation and adaptation interact

Climate sensitive sectors, for example:.

Energy (drivers)

Water (sensitive sectors)

Eg: Water – climate change vulnerability is one of several stresses on water/hydrological systems; other stresses may be just as compelling and climate can add to this.

WEHAB – but go beyond? For example should poverty and equity be dealt with explicitly or not?

Ecosystems

Human settlements

Go beyond economic or technological scope to enlarge the debate for AR4 – Institutional, organisational, political economy

National versus International

Local, national contexts drive decisions and investments that influence SD outcomes

Development assistance initiatives are multilateral

Some of the sector issues have international activities – eg. International disaster

Could argue that managing risks of extreme hazards requires co-operation. Flood and storm and protection services from the MEA.

Millenium ecosystem assessment

Other issues, e.g. energy, largely in the domestic domain.

Water – some international momentum

On the climate side, mitigation brings out the global dimension

How can AR4 address these new issues?

3. Break Out Group 3

Sustainable Development and Climate Change Linkages

- Conceptual framework for SD and CC:
  - » Impacts of and on CC/SD should be linked to accepted and official goals and indicators
- Millenium development goals versus sectors. Sectoral focus can narrow the discussions.
- Millenium development goals are preferred as a starting point but need to be supplemented with policy goals for IC's. Agenda 21 can be used as a supplement.
- Provide overview of official SD plans/guidance provided by OECD and others.
- National development plans can also be relevant sources including IC plans.
  - » SD and CC analysis should be related to "development goals", and vice versa.
  - » Longer term perspectives are needed to link development policies to CC.
  - » What difference does it make for the analysis
    - Look at experience in approaches, instruments and tools (comparable assessment)

- Provide an overview of the literature and compare how CC has been addressed related to SD.
- Issues like physical impacts, technologies, social, economic, governance, equity, and decision making framework should be assessed for all sectors.
- Policies are conducted at sectoral level so SD should still be linked to this context.
- A broader range of literature should be assessed (development focussed literature). The variability literature is an example.

- New sectors and issues to be covered in AR4:
  - » Detection of current cc impacts and vulnerability issues.
  - » Changes in the water area that have been observed.
  - » Linkages to other conventions including synergies between MEA (avoid going beyond the IPCC mandate).
  - » Development terms should be included in the IPCC terminology to facilitate communication with "other" communities.

- How can CC be a barrier to SD:
  - » Vulnerability and adaptive capacity. Enhance the capacity to adapt.
  - » The achievement of SD is affected by CC policies. CC makes it more difficult to achieve development goals (additional stress).
  - » Efficiency gains thorugh SD intgration in CC policies can be exemplified (e.g. water).
- Mitigative capacity has similarites with adaptive capacity, but opportunities are different (policies and technologies).
- Development first approach creates opportunities (shows what is needed, and identifies barrier removal policies). Assessment of co-benefits both ways is important.
- Climate risk assessment in project finance should be covered.
- Specific IPCC assessment issues:
  - » Be as dis-agggregated as possible.
  - » Cross-cutting national comparisons.
  - » Some regional aspects should be included: infrastructure, water etc.
  - » How to link regional impact assessment with SD aspects. There is a need to link economic and social aspects with the physical impact assessment.
  - » Interactions between sectors (e.g. water and health). A special effort is needed to capture the linkages, which can be complicated. Case studies from the sector can be used to illustrate SD.
  - » WEHAB can be addressed (linkages) in one chapter, eventually supplemented with individual sector chapters.
  - » Assessment of social impacts e.g. related to millenium goals. New literature should be integrated in the vulnerability and adaptation issues. We need LA's with a broad perspective. Conclusions need to be supported by case studies.

Preferred AR4 Structure

- a. Linkages between climate change and MDG's and OECD development goals
- b. Importance of WEHAB sectors to MDG and OECD SD goals.

- Assessment of physical impacts, and of risks and opportunities, social, economic technology transfer, and governance issues within the WEHAB sectors.

- Assessment of instruments arising out of the WEHAB chapters:
  a) Methodologies for risk/opportunity – benefit assessment.
  b) International governance.
  c) Aggregation of policy/experience assessment.

ANNEX E

RAPPORTEURS' REPORTS FROM THE DISCUSSION GROUPS
The structure of cross cutting themes on climate change and sustainable development from the perspectives of Working Groups II and III

WORKING GROUP I

General discussion

- Discussions were initially framed around the following general issues:
  - To whom should the IPCC Report on CC and SD be useful and why; (issues identified were: cost effectiveness of early action and external financial support)
  - What are the value-added elements to be contained in the AR4; (make a further advance on linkages between CC and SD in both conceptual and operational terms)

Recommendations for the CC/SD chapter

- It was agreed that linkages between SD and CC should include both the impact of CC on SD and the effect of SD on CC; it was clear that the goal was SD and not development only;
- A good framework for establishing these linkages was the WEHAB (water; energy; health; agriculture and biodiversity) concept arising from WSSD;
- The WEHAB concept did not explicitly refer to some critical issues such as security, innovation, risk management, governance and transport and that these should be included as complementary issues;
- The assessment of these linkages should follow the pillars of SD, i.e. economic, environment and social;
- Four levels of analysis were recommended:
  - Policy processes (macro level), to include strategic elements; it is important to stress that all countries should be included, i.e., industrialized countries; developing countries and countries with economies in transition;
  - Sectoral level analysis, where CC could be considered as one of the key stress factors; sectors to be considered include health, agriculture, finance, coastal areas; projects and programmes within specific time frames;
  - International context; linkages should be established with other international negotiations and processes relevant to CC; this could include N-S, S-S cooperation;
  - Integration/coordination should be pursued with other IPCC crossectoral studies, particularly those of high relevance to SD such as those on key vulnerability; water; and integration of adaptation and mitigation.
  - Information and literature are overarching issues applicable to all above items.

WORKING GROUP 2

3 questions

- Nature / extent of info (coverage and scope)
- Ways of assessing and presenting
- Connections

WG 2 structure?

- Opening chapters
  - Observed change in climate and responses, modeled futures
- WEHAB++ chapters
  - WEHAB was directly related to sustenance of life
  - The ++ chapters, which refer to Goods and Services, should be selected on the basis of climate sensitivity, importance and relevance to policy
- Closing chapters
  - critical rates and thresholds
  - Cross-cutting themes, SD?

WEHAB++ (goods and services)

- Water
- Energy
- Health
- Agriculture (includes forests & fisheries)
- Biodiversity
- Others:
  - Habitat & settlements
  - Tourism
  - Air quality
  - Transport
  - Finance, insurance and industry
  - Disasters

Chapter structure

- Need a common template for the WEHAB++ chapters. What should that template be?
- In the TAR: Sensitivity, Scenarios, Anticipated / projected impacts (), Anticipated adaptation, Conclusions
- Now?
  - Articulating patterns of climate-society interaction
  - Consumption patterns
  - Income generation and poverty alleviation
  - Cross-sectoral issues
  - Mitigation, impacts, detection signals, adaptation policies

Closing chapters

- Sustainable development
  - Income generation & poverty alleviation
- Institutions / governance
- Technology
- Equity
- Adaptation synthesis

What are the connections?

- WG 1 & 2:
  - long-term climate change, instabilities, low probability high consequence events
  - Interannual to decadal predictability (moving from scenarios to predictions)
- WG 2 & 3:
  - Common threads – institutions / governance, equity, technology?

How to present the connections

- Common chapters
- Regional pullouts
- Synthesis
  - Structure before the fact?
  - Structure after the fact?

Expertise areas

- Domain expertise
- Cross-cutting expertise
  - SD, institutions / governance,
- Climate expertise
- Methodological expertise
  - Decision-making, economics, risk management, political science

New sources / areas of information

- Current climate impacts and responses
- Adaptation related information
  - Adaptation "baseline" (how are climate risks being managed today)
  - New literature being developed on V&A
- Technology / technological change issues

Implications for AR4 as a whole

- Assumptions?
- Scenarios
- Timescales (two, three?)
  - Short-term (decision-makers in business and government)
  - Medium-term (infrastructure assets)

  - Long-term (magnitude and scope of the problem)
  - Implication for WG 1
- Indicators
- Overall presentation of report
  - Layered presentation (how to unpack regionally and sectorally)?
  - How to ensure that the information is available to the different audiences for different purposes

How can the CC – SD linkage be developed in AR4?

The first step would be the identification of linkages with climate. This can be done sectorally (agriculture, industry etc.) or in terms of development goals (national macroeconomic objectives, millennium development goals, or any other). A sectoral identification may be more specific and useful.

For some sectors, the CC – SD linkage might be more in terms of the fact that the sector is sensitive to climate risk (example health, water). For other sectors, the linkage might be that the sector is a key driver of climate change (example energy). There may also be some sectors where there are linkages in both directions (example food, habitat). We can think of both adaptation and mitigation in terms of the windows of opportunity and points of intervention for modifying the strength and nature of the linkage.

The charge for WG 2 therefore might be to:

- situate climate change and climate risk within the context of other factors that affect the sectors (for instance other determinants of vulnerability)
- examine the relative importance of climate change for that sector
- elucidate the processes and mechanisms by which climate risk is manifested (extreme events come in here)
- identify windows of opportunity and points of intervention by which these processes and mechanisms could be altered to reduce climate risk, and examine the extent to which the are synergistic with developmental activities

Modifications: think of “capacity” more broadly, no separation between adaptive and mitigative.