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Mohan Munasinghe and Rob Swart
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Climate change: scientific background and introduction

1.1 Objectives and background

Is the climate changing? If so, how does it affect sustainable development opportunities? What are the options to respond to the changes: adapting, mitigating, both? What do these response options cost? How can we maximize synergies between the climate change response and broader sustainable development strategies, and minimize trade-offs between the two? These are the central questions addressed in this book.

Since global climate change was put on the international political agenda in 1992, developments in both climate science and climate policies have been swift, taking into account the complexity of the issues at stake. On the political side, the United Nations Framework Convention on Climate Change (UNFCCC) was agreed upon in 1992, and the subsequent Kyoto Protocol with legally binding commitments was signed in 1997. Progress was stalled after the repudiation of the Protocol by the US government in 2001. In a world divided by a wide variety of stakeholders, the UNFCCC continues, however, to be the main negotiations platform and the only available international regime that has to meet the challenge of achieving global co-ordination of national climate change responses in the direction of a common goal: avoiding dangerous interference with the climate system (see also Box 1.1). During negotiations in The Hague in 2000, in Bonn in the summer of 2001, and finally in Marrakech in autumn 2001, barriers were overcome and a very detailed cookbook was agreed describing the implementation modalities of the Protocol: the Marrakech Accords. In 2002, it is hoped that sufficient countries ratify the Protocol to make it enter into force even without the participation of the USA.[1] The political deliberations were supported by scientific assessments,

[1] In order to enter into force, fifty-five countries should have ratified the Protocol, incorporating Annex-I countries accounting for at least 55 per cent of the total Annex-I emissions in 1990.

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Box 1.1 The United Nations Framework Convention on Climate Change and the Kyoto Protocol

The UNFCCC was signed at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. Its ultimate objective (Article 2) is 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe 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.' The UNFCCC also explicitly acknowledges a number of principles (Article 3), such as the precautionary principle, protection of the climate system on the basis of equity, the need for developed countries to take the lead in combating climate change and its adverse effects, full consideration of the specific needs and special circumstances of developing countries, and the need for pursuance of sustainable development. The UNFCCC also states that 'where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost'. The UNFCCC came into force in 1994, and as of May 2004, 189 parties had ratified it.

After 5 years of negotiations, the Kyoto Protocol was agreed in 1997. This Protocol has legally binding obligations, e.g. 'The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012.' The Protocol also includes three international mechanisms to facilitate its implementation: International Emissions Trading, Joint Implementation and the Clean Development Mechanism. Notwithstanding the fact that these mechanisms specifically had been developed to satisfy concerns from the USA, it announced in early 2001 that they would not ratify the Protocol. Unexpectedly, the other countries managed to reach agreement on the implementation details of the Protocol in November 2001: the Marrakech Accords. Many view these agreements as watered down versions of the

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original Kyoto Protocol commitments. However, by relaxing the original targets and offering countries various escape routes, the Marrakech Accords increase the possibility that the Protocol will be ratified by sufficient countries to keep it alive. This would avoid the renegotiation of a different international climate change response framework, which would be likely to take many more years, if not decades. According to the UNFCCC Secrtariat, 126 countries had ratified the Kyoto Protocol by mid 2004, representing over 44 per cent of total global emissions in 1990. With the subsequent ratification in October 2004, by Russia (representing 17 per cent of emissions), the Kyoto Protocol takes effect in February 2005, despite absence of the USA. This will also give impetus to discussions about the next commitment period for further emissions reductions.

notably those of the Intergovernmental Panel on Climate Change (IPCC). The IPCC was established in 1988 by the World Meteorological Organization and the United Nations Environment Programme (UNEP). It has developed three major comprehensive assessment reports in 1990, in 1995 and in 2001, in addition to a series of technical papers and special reports addressing specific issues (see also Box 1.2). These interdisciplinary reports reflect the rapid progress made in the scientific understanding of the climate system, the impacts of, and vulnerability to, climatic change, and the options to respond to these changes, both through adaptation and mitigation.

A key reason why it is so difficult to achieve a co-ordinated international response to the climate change threat is that countries have more urgent priorities, the foremost being economic development. But also in the area of environmental problems, climate change is not the only, or for many countries the most important environmental problem, nor is it detached from others. The UNFCCC was just one of the multilateral environmental agreements agreed upon during the 1992 UNCED, together with the Convention to Combat Desertification and the Convention on Biological Diversity. At UNCED, the challenge to reconcile the pursuance of an equitable economic development with the preservation of the natural resources of the Earth was addressed in the action programme Agenda 21, which laid out a blueprint for a just and sustainable world in an integrated, holistic manner. Agenda 21 covered the three global environmental problems mentioned above, and others, at global, regional and local levels.

After 1992 however, progress in implementing this agenda was slow, and the debate on the various global environmental problems largely was organized independently. In many areas (e.g. the availability of sufficient safe fresh water resources and fertile land for food production) the situation in many regions in the world actually has deteriorated, not withstanding overall positive

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Box 1.2 IPCC organization and mandate

The IPCC was established in 1988 by the World Meteorological Organization and UNEP to assess periodically the scientific, technical, and economic knowledge pertinent to the problem of global climate change. The IPCC has issued comprehensive Assessment Reports in 1990, 1996, and 2001. It has published a series of technical papers, and special reports on specific issues, since 1999, e.g. regional impacts, aviation and the global atmosphere, emissions scenarios, methodological and technological issues in technology transfer, and land use, land-use change and forestry. Currently, there are three working groups: (a) on the science of the climate system; (b) on impacts, vulnerability and adaptation, and (c) on mitigation, respectively. Each working group has two co-chairs, one from a developed country and one from a developing country. The substance of all IPCC reports is the full responsibility of interdisciplinary writing teams of experts from all parts of the world. The rules of the IPCC ensure a rigorous scientific peer-review process, including an extensive scientific review of drafts of the report by independent experts. But also, the intergovernmental nature of the IPCC is important at three stages of report development: (a) governments approve the terms of reference or main outline of the reports; (b) they participate in the review of the second draft of the report (in addition to scientific expert reviewers), and (c) finally approve the so-called *Summary for Policymakers* line by line. Any changes in the *Summary for Policymakers* at the approval stage should be completely consistent with the underlying document, which is confirmed by the authors who are present at this stage. In this way, governments acquire ownership of the assessment reports, while the scientific integrity is maintained fully. The IPCC reports are important background documents in support of the negotiations in the context of the UNFCCC, notably for the Subsidiary Body on Scientific and Technological Advice. They may, directly or indirectly, have influenced important advances in the negotiations. The 1990 First Assessment Report (IPCC 1990) preceded the agreement of the UNFCCC, the 1996 Second Assessment Report (IPCC 1996a, b) the agreement of the Kyoto Protocol, and the Third Assessment Report (IPCC 2001a, b, c) the Marrakech Accords.

economic development in most regions. Thus, the implementation of the actions proposed in Agenda 21 is as important and urgent now as it was in 1992, if not even more so. However, the debate about the implementation of Agenda 21 basically left the climate change issue to the UNFCCC, while the UNFCCC negotiations –

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notwithstanding the mentioning of sustainable development in the Convention and the associated Kyoto Protocol – did not make significant advances in linking the two issues. Some parties in the UNFCCC see the linking even as a threat, drawing the attention away from their main negotiation issue: climate change. Also, the discourse in science about sustainable development and climate change has progressed largely independently. One reason is that the framing of climate change in the late 1980s by natural scientists with their climate models divorced the issue from its social context and normative aspects have long been ignored (Cohen *et al.* 1998). Although, in the 1990s, social elements increased in climate change research and assessments, these were related mainly to quantitative economic analyses rather than including other social sciences and humanities. Only recently, the importance of looking closer at the linkages with social issues has been acknowledged by the IPCC in its Third Assessment Report (IPCC 2001a, b, c).

The IPCC notes in the Report that both in terms of natural processes and in terms of policy responses, climate change is linked closely to other environmental and socioeconomic problems. Climate change response strategies can be made more effective, if they are integrated with broader sustainable development efforts (Munasinghe 2000; Munasinghe & Swart 2000). This notion is at the core of this book.

The objective of the book is to provide a comprehensive and up-to-date overview of the options to adapt to and mitigate climate change and their economic, social and environmental implications. Also, in Chapter 1, a concise update of the science of climate change, and its possible impacts, is provided. The starting-point is that climate change response should be guided by broader objectives of development, equity and sustainability. As authors, we have both been involved closely in the IPCC process since its inception in 1988 in various roles and therefore the book to a large extent builds upon the authoritative IPCC reports, but is not constrained by those assessments. We recognize that climate change is a very serious problem threatening natural and human systems, but also that humankind has the ingenuity to develop and apply technologies to address it effectively and the ability to adjust lifestyle patterns associated with those technologies in order to remain within the carrying capacity of our globe. It is a matter of choice.

1.2 Chapter outline

The issues discussed in this book are focused on the linkages between climate change and sustainable development. While the volume covers the science of climate change, its potential impacts, and climate change response options comprehensively, the emphasis is on the latter – in particular adaptation and mitigation options, which are related to sustainable development. The framework

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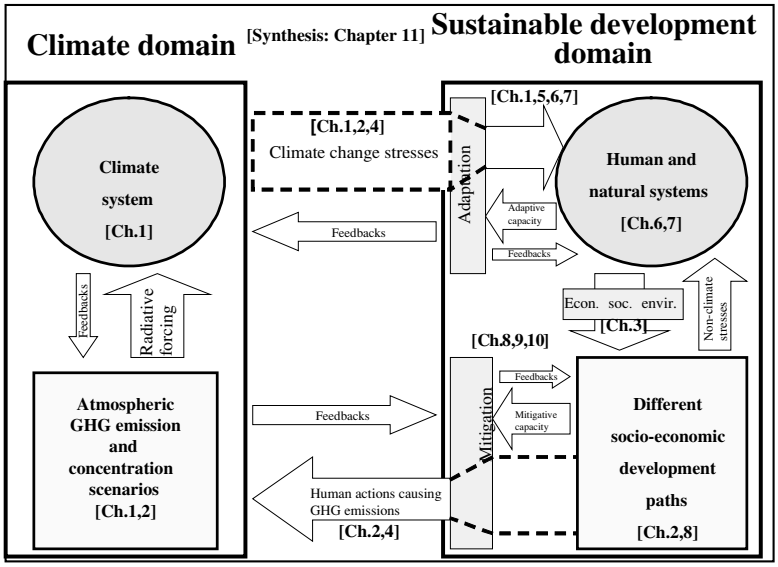

Figure 1.1. Organization of the book. GHG = greenhouse gas.

according to which the book is organized is depicted in Figure 1.1. The state of knowledge of the science of climate change and its potential impacts is summarized in the next section. Climate change is with us today, but its main impacts are expected to occur in the future. Not only the climate system, but also socioeconomic systems, are characterized by important inertia (see Box 1.5). Therefore long-term scenarios are indispensable for the analysis and assessment of climate change, its impacts, and possible response options. Chapter 2 reviews a number of long-term scenarios for the development of the global economy, population, technology, and the use of key resources, e.g. energy and land. It focuses on the greenhouse gas emissions scenarios developed by the IPCC in the *Special Report on Emissions Scenarios* (*SRES*) and broader scenarios, notably those developed by the Global Scenario Group. Both these sets of scenarios combine narratives about alternative development pathways with quantitative information about key indicators of development and forces driving climate change. The chapter also provides an overview of the future climate changes and impacts that can be associated with these emissions scenarios. Chapters 3 and 4 have sustainable development as the main focus. Chapter 3 lays out the sustainomics transdisciplinary framework for making development more sustainable, including some key methodological elements of sustainable development, different conceptual definitions and approaches to sustainable development, and its linkages with climate change. It also addresses different decision-analytical tools used in the area

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of climate change analysis, and discusses their relevance for sustainable development issues. Chapter 4 draws the findings from the results of studies applying the methodologies discussed in Chapter 3 to make development more sustainable while the climate changes. What are the opportunities for synergy, and what are the pitfalls of trade-offs between climate change response and sustainable development policies?

Chapters 5 to 10 focus on climate change adaptation and mitigation, paying as much attention as possible to their linkages with broader issues of sustainable development. Chapters 5, 6, and 7 discuss adaptation, while Chapters 8, 9, and 10 cover mitigation. In Chapter 5, we explain how development choices influence vulnerability to climate change and can enhance adaptive capacity. In particular, it reviews what the future costs and benefits of climate impacts and adaptation might be. While in Chapter 5 we discuss climate change adaptation in a generic sense, in Chapter 6 we evaluate options to adapt to climate change in the areas of: (a) hydrology and water resources; (b) natural and managed ecosystems; (c) coastal zones and marine ecosystems; (d) energy, industry and settlements; (e) financial resources and services, and (f) human health. Adaptation options differ not only across various economic sectors but also across regions. Therefore, in Chapter 7, an overview is given of adaptation options in the various regions of the world, both developed and developing.

After these three Chapters on adaptation, Chapters 8 to 10 deal with options to mitigate climate change. Chapter 8 starts with an overview of basic concepts, methods and approaches. It also discusses possible long-term goals that could be associated with the ultimate objective of the UNFCCC. In Chapter 9, the core of the information about mitigation options for short, medium and long term is presented, e.g. (a) which technologies and practices to abate greenhouse gas emissions or enhance sinks are known; (b) which social, economic or institutional barriers prevent these options from being implemented, and (c) which policies, measures and instruments are available to overcome these barriers? Methodologies for quantifying the costs of mitigation at different levels are described in Chapter 10, and results are discussed. This review includes important ways of reducing costs, including removal of market barriers, taking into account ancillary benefits, and revenue recycling in order to achieve an economic and environmental 'double dividend'. In Chapter 11, we conclude with a synthesis of the information regarding climate change response strategies in the context of sustainable development: how adaptive and mitigative capacity can be enhanced while at the same time accelerating efforts towards development, sustainability and equity. This final chapter would not be complete without our views on the future directions in research and climate policy assessment.

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1.3 Historical record, recent observations, and climate system outlook

1.3.1 Introduction: new and stronger evidence

Observed climatic changes

In 1995, the IPCC concluded that 'the balance of evidence suggests a discernable human influence on climate' (Houghton *et al.* 1996). In 2001, this finding was strengthened, referring to 'new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities' (Houghton *et al.* 2001). Because of climate variability, it is difficult to detect changes in climate, and if such changes can be detected, to attribute them to either natural or anthropogenic influences. This area of research has received much attention and, on the basis of detailed analysis of available datasets, rigorous evaluation of their quality, and comparisons amongst data from different sources, researchers have been able better to understand climatic change. Figure 1.2 shows the variations in the surface temperature of the Earth for the past 140 and 1000 years. In the twentieth century, global average surface temperature has increased by about 0.6 °C. This number is 0.15 °C higher than assessed in Houghton *et al.* (1996), due primarily to the relatively warm years since 1995, and improved data-processing. The global mean surface temperature in 2002 was 0.48 °C above the 1961–90 annual average. This places 2002 as the second warmest year since 1861; 1998 was the warmest year on record, and the 1990s the warmest decade. The warming was not equal over time and space. For example, in the latter half of the twentieth century, minimum night time air temperatures over land increased twice as fast as maximum daytime temperature changes (0.2 versus 0.1 °C/decade), and the increase in sea surface temperature was about half as much as the increase in mean land surface temperature. In contrast with most regions in the Northern Hemisphere, parts of the Southern Hemisphere oceans and Antarctica have not warmed recently. Panel (a) of Figure 1.3 shows schematically how temperature changes are different for land and ocean areas.

But climate change is not limited to changes in temperature. Although less certain, it is also considered to be very likely that precipitation has increased by 0.5–1 per cent per decade in the twentieth century over most of the mid and high latitudes of the Northern Hemisphere, and by 0.2–0.3 per cent in tropical areas, while it has decreased by 0.3 per cent per decade in the subtropical regions of the Northern Hemisphere (see Figure 1.3, panel (b)). These changes in precipitation are particularly important for impacts because of their importance for ecosystems and agriculture (see Section 1.4). Changes in climate variability, extreme weather and other climate events also have been observed, e.g. increased occurrence of heavy precipitation events in the Northern Hemisphere, an increase in cloud cover over mid and high latitudes, a reduction in the frequency of very low temperatures, and

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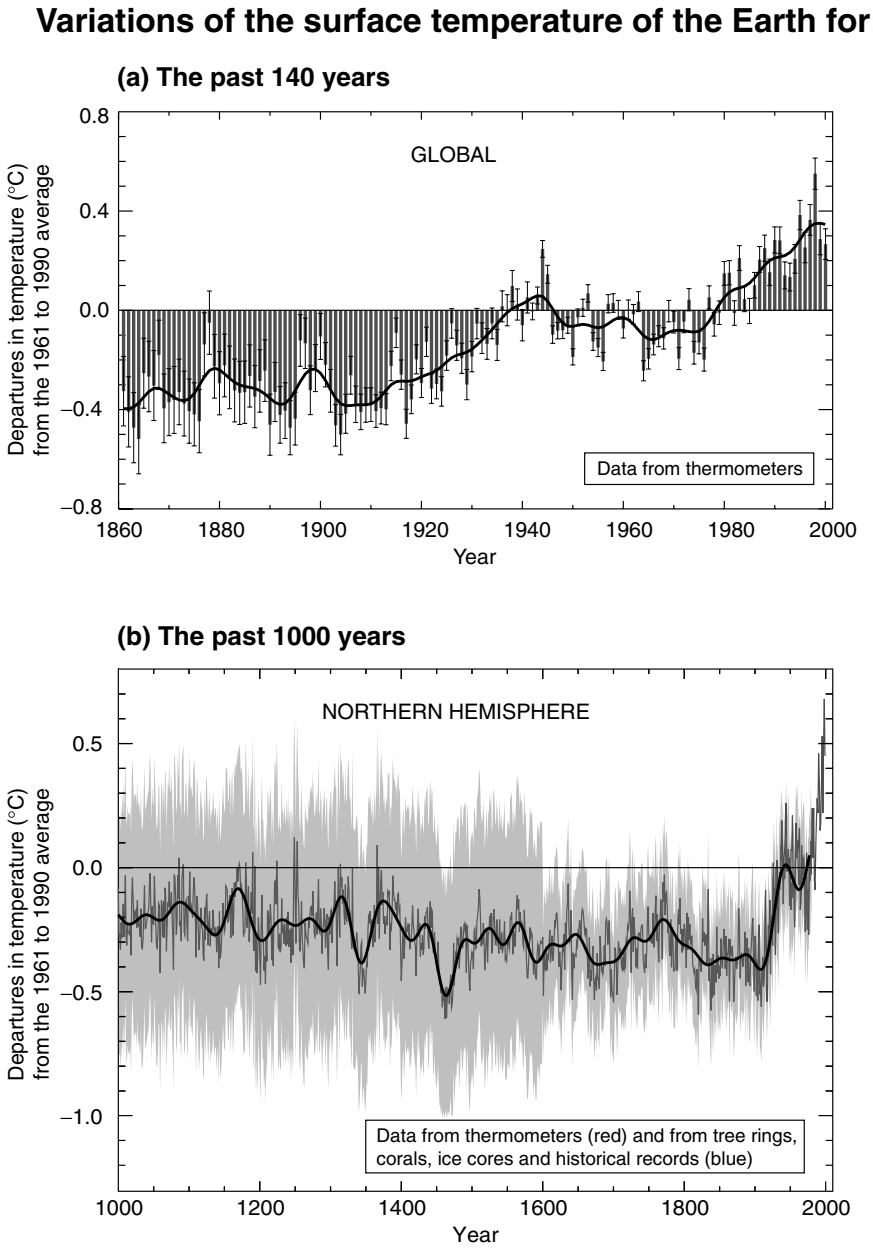

Figure 1.2. Variations of the surface temperature of the Earth over the last 140 years and the last millennium. The black line in (a) represents a decade by decade curve, in (b) the 50 years average variations. The thin whisker bars in (a) and the grey shaded area in (b) represent the 95% confidence range. For the difference between the direct data sources (thermometer, red) and indirect data sources (tree rings, corals, ice cores, historical records, blue), we refer to the original publication or website http://www.grida.no/climate/ipcc_tar/wg1/figspm-1.htm.
Source: Houghton *et al.* (2001).

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Box 1.3 Key conclusions of the IPCC's Third Assessment Report, Working Group I: The scientific basis

Key conclusions

(1) An increasing body of observations gives a collective picture of a warming world and other changes in the climate system as follows.
   (a) *The global average surface temperature has increased over the twentieth century by about 0.6 °C.*
   (b) *Temperatures have risen during the past four decades in the lowest 8 km of the atmosphere.*
   (c) *Snow cover and ice extent have decreased.*
   (d) *Global average sea-level has risen and ocean heat content has increased.*
   (e) *Changes also have occurred in other important aspects of climate, e.g. precipitation, cloud cover, the frequency of extreme low temperatures, warm episodes of the El Niño–Southern Oscillation phenomenon, global land areas experiencing severe drought or severe wetness and frequency and intensity of droughts.*[1]
   (f) *Some important aspects of climate appear not to have changed, e.g. temperatures in some areas of the world, Antarctic sea ice extent, changes globally in tropical and extra-tropical storm intensity and the frequency of tornadoes, thunder days, or hail event.*[1]

(2) Emissions of greenhouse gases and aerosols due to human activity continue to alter the atmosphere in ways that are expected to affect the climate as follows.
   (a) *Concentrations of atmospheric greenhouse gases and their radiative forcing have continued to increase as a result of human activities.*
   (b) *Anthropogenic aerosols are short-lived and produce mostly negative radiative forcing. Natural factors have made small contributions to radiative forcing over the past century.*

(3) Confidence in the ability of models to project future climate has increased.

(4) There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activity.

(5) Human influences will continue to change atmospheric composition throughout the twenty-first century.

(6) Global average temperature and sea-level are projected to rise under all IPCC *SRES* scenarios.[2]

(7) Anthropogenic climate change will persist for many centuries.

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