# 2 Forests and Climate Change: the Knowledge-base for Action

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## Introduction

Forests make up around 30% of the world's land surface, and forest ecosystems, including their soils, store approximately 1200 gigatonnes of carbon which is considerably more than is present in the atmosphere (around 762 GtC). A major anthropogenically driven climate change is under way (IPCC, 2007) and this is largely being caused by changes to the global carbon cycle through the emission of carbon dioxide and methane. Clearly, the interactions between forest ecosystems and the atmosphere are critically important.

Together with global political and security issues, climate change is now accepted as being of overriding importance to the future of the world's environment and natural systems and of human society. In the international dialogue on the environment and climate the role of forests in influencing earth systems, including climate and carbon (C), nitrogen (N), hydrological and other geochemical cycles, has not emerged to date as an area for major action, although there are real signs that this is changing. This – the role of forests in climate change – is the principal issue addressed here and, in this publication, it is considered as two related questions:

**1.** How do forests interact with the other components of the physical and natural world and with human society?
**2.** How can we manage forests globally to make the most of their contribution to mitigation of climate change along with the established objective of sustainable management to maximize the full range of economic and non-market benefits which forests provide?

The first of these questions is addressed through examination of the science, principally in three sections: Section II: Climate Change, Forestry and the Science–Policy Interface; Section III: Forestry Options for Contributing to

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Climate Change Mitigation; and Section IV: Impacts of Climate Change on Forests: Options for Adaptation. To address the second question it is necessary to consider the international framework which has been established for forestry and the various international conventions which impinge on forest ecosystems. These issues are introduced in Section I and returned to in Section V: National and International Frameworks: Current and Future Policy and Section VI: Implications for Future Forestry and Related Environmental Development Policy. This final section focuses particularly on the way forward.

Woodlands are an integral element of the landscape. They provide natural habitats, enhancing the biodiversity of predominantly managed, agricultural and urban landscapes and are a potential source of both renewable energy and timber. Woodlands also have a role to play in natural resource protection through flood alleviation, improvement of water quality and soil erosion control. Like all natural systems, woodlands are vulnerable to the impacts of climate change, and the forestry sector needs to respond strategically to the threats posed by such change. Woodland establishment and management have long planning horizons, making a coherent strategic response particularly important in forestry. However, strategic planning, with the objective of adapting to climate change, creates tensions, partly because of the multiple objectives of modern forestry, but also because of the uncertainty associated with climate change projections and their likely impacts. The challenge is to develop a strategic response that both maximizes the contribution of woodlands to climate change mitigation and optimizes natural resource protection. The overall objective of the Wilton Park Conference was to identify how the forestry sector (national and international) needs to respond to the current understanding of climate change. Climate change, both through impacts on forests and because of the potential for carbon sequestration, impacts in all areas of forest planning and management from species choice through to timber utilization. Because forests must deliver multiple objectives (ecological, environmental, recreational, social together with economic/commercial), developing a strategic response to climate change mitigation and adaptation must also be multi-sectoral.

In writing this introduction we are particularly struck by the quality of scientific information presented and by the way that this knowledge-base is focused to identify and guide the actions now needed. The Wilton Park Conference, in November 2006, on this subject was timely and inspiring. We hope that this book expresses and represents the interest and excitement that were generated.

## Climate Change, Forestry and the Science–Policy Interface

Comprehensive and critical review of the scientific evidence-base on climate change and related earth systems has been, and continues to be, provided by the Intergovernmental Panel on Climate Change (IPCC). The scientific consensus that there is an ongoing anthropogenic influence on the global climate was first set out as long ago as 1995 in the IPCC's Second Assessment Report in the historic phase '… the balance of evidence suggests a discernible human influence on global climate'. Many of the chapters in our publication draw on data from the

IPCC Third Assessment Report (TAR; IPCC, 2001) which is a detailed, highly credible and authoritative source. During 2007 the IPCC has published its Fourth Assessment Report with the first Working Group releasing its findings on 2 February 2007 (IPCC, 2007). Over 600 scientists from 113 countries have been involved in producing this fourth report, and the scientific evidence can now be regarded as 'unequivocal'. The tone of IPCC reports has shifted to one of very high confidence in the science. This is made clear by just two sentences quoted from the February 2007 report:

> 'Since the TAR, progress in understanding how climate is changing in space and time has been gained through improvements and extensions of numerous datasets and data analysis, broader geographical coverage, better understanding of uncertainties, and a wider variety of measurements.' 'Warming of the climate system is *unequivocal*, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.'

The report warns that average world surface temperature could rise by 3°C by 2100, and possibly even more, if no measures are taken to reduce greenhouse gas (GHG) emissions to the atmosphere. Behind the science the message is clear: time is running out faster than the scientific community initially thought it would; it is now time for action.

The evaluations presented in the various chapters of this book draw on the IPCC's publications. In most cases our contributors have been involved in the IPCC's work but, in this book, their focus moves quickly to the data and conclusions which relate to forest/climate interactions and to the implications for forest science, policy and thus management. Internationally, forest science is drawn together by the International Union of Forest Research Organisations (IUFRO) which is loosely parallel, and certainly complementary, to the IPCC. Again, IUFRO's knowledge-base is drawn on significantly here and most of the forest scientists who have contributed chapters are active IUFRO members.

The science of climate change has made major progress in the past 15 years, providing a new understanding which has been effectively communicated to the public and, arguably, to policy makers. Forest science has progressed steadily, benefiting from the increasing public concern for the environment, and with public attention focused particularly on tropical deforestation. International frameworks focused around the United Nations Conference on Environment and Development (UNCED) programme (1992 onwards) and now the UN Forestry Forum have provided an arena for science–policy interactions. The progress made within these fora and the related processes of establishment and implementation of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) have been considered in the policy-focused chapters in Sections II, V and VI. In Section II, Burley *et al*. (Chapter 5) describe the three flexible mechanisms which are in place to help achieve the targets for GHG emission reductions of the Kyoto Protocol and the way in which these mechanisms have created an international market for Certified Emission Reduction credits.

We are pleased that many of the chapters presented here place major emphasis on the future, particularly on what we should do in the immediate future and mid-term. Some of the science featured here was 'breaking news' at the time the book was compiled. These exciting and inevitably new insights and established, well-supported and clearly stated science, often have a significant influence on recommendations for the way forward. In the discussion which follows we have attempted to highlight some of those critical areas of science – both the new and the well established but highly relevant.

Twenty-five years of research have substantially increased our knowledge of the global carbon cycle. The budget suggests that the terrestrial biosphere is a sink comparable in size to the oceans. Equally important is the observation that coupled carbon cycle–climate models show simulated climate change reducing the strength of the carbon sinks in both the oceans and on land – a critical positive feedback (Heimann, Chapter 3). The past 25 years have also seen major change in the forest industry worldwide. In developed countries the forestry industry has undergone a radical shift of emphasis away from commercial production forestry to better consideration of the wider benefits, and thus to sustainable forest management implemented through national forest plans, forestry standards, commitments under international conventions and certification systems. Because of the costs associated with production of timber (roundwood), a steady shift in the regions of the world used to provide the raw material for production of sawn timber and pulp started in the early 1980s. Commercial forestry has moved its operations, to a significant extent, from boreal and temperate forests to fast-growing tropical and subtropical regions. However, plantations are increasingly used to produce roundwood, and it is estimated that by 2050 as much as 75% of all industrial roundwood might come from plantations. It is also fascinating to consider that if all roundwood was sourced from effectively managed plantations only some 73 million ha of land would be required. That is, only 2% of the world's forest area would be enough to satisfy the current global needs for roundwood (Seppälä, Chapter 4).

## Forestry Options for Contributing to Climate Change Mitigation

The major importance of forests in the world's carbon cycle, along with the substantial and ongoing changes in the global forest sector (economic and non-market), provides a very real potential for forestry to contribute to the mitigation of climate change. Section III focuses on the various mechanisms by which this contribution might be delivered. The UK Government report on the economics of climate change (Stern, 2006) gave a clear message that acting to lessen the impacts of climate change now is a far better economic strategy than management of the social and economic crises that will arise if mitigation measures are not taken. The Stern Report also provided specific authoritative proposals, one of which related directly to global forest management. Land-use change, principally deforestation, accounts for some 18% of $CO_2$ emissions (IPCC, 2001). Stern sees carbon (C) emissions from deforestation (particularly in the tropics), as a significant and tractable component of anthropogenic emissions. Some of the C lost through deforestation is offset by reforestation and afforestation (Schlamadinger, Chapter 10). A number of countries have experienced transitions from deforestation to reforestation and, more controversially, there appears to be a relationship between gross domestic product and the recorded change of forest growing stock. Important variables in considering this relationship are national forest area, growing stock per unit area, biomass per unit growing stock volume and carbon concentration in biomass (Kauppi *et al.*, 2006). There is also good experimental and modelling evidence that the net ecosystem production (NEP) of standing boreal and temperate forests will be maintained or even increase as climate change proceeds (Jarvis and Linder, Chapter 9). The inventory approach supports this general view in showing that forests above a variable age threshold are usually net carbon sinks, although there are interesting spatial and temporal variations of sink and source strength (Nabuurs *et al.*, Chapter 13). The modelling work of the ATEAM project (Eggers *et al.*, Chapter 14) suggests that European forests will remain a strong carbon sink for several decades with the size of this sink influenced by wood demand. Climate change is predicted to have a positive impact on growth but if management does not respond to this there could be major problems of biotic and abiotic damage.

In addition to the sustainable management and protection of forests, and to the prevention of deforestation, detailed consideration is given to product substitution and woodfuel as carbon-lean approaches to the provision of raw materials for construction and energy generation (Matthews *et al.*, Chapter 12). Bioenergy forestry systems and the active removal of carbon from the atmosphere by forestry systems is introduced by Sims in Chapter 11. Woody biomass is currently used to a varying degree geographically for cooking, heat, electricity and in co-generation plants, and in future may be sought after for biofuel processing, in biorefineries and hydrogen production plants. However the role that woodfuel will play in future energy supply will depend on overcoming the current barriers to project development and to commercial investment. Sims provides an authoritative evaluation of these. In Chapter 8, Brown and Kurz make a serious analysis of why the implementation of forest mitigation activities has lagged behind their perceived potential. The inclusion of forestry activities in carbon trading schemes and in the Clean Development Mechanism of the Kyoto Protocol are both discussed. It is hoped that over the coming decades the greenhouse gas mitigation benefits of well-managed forestry schemes and of wood substitution for fossil fuels will become better understood, and that such schemes will gain public acceptance.

In a number of countries there are now schemes which allow individuals and businesses to offset their carbon emissions by tree planting. There is ongoing controversy over the value of such schemes relative to the apparently more obvious benefits of emissions reduction. Carbon offset schemes – depending on how they are managed and on the end use and life cycle of any products – may provide an additional benefit and indeed a new incentive for the creation and protection of multi-purpose woodlands. But this is a very different approach to that of planting trees solely for carbon sequestration. Governments and international organizations need to work with stakeholders to provide and improve the standards and guidance on forestry so that these encompass carbon offset schemes and to ensure that such schemes are robust, providing consumers and customers with assurance of their effectiveness.

## Impacts of Climate Change on Forests: Options for Adaptation

The current role of forests in mitigating the impacts of climate change and their potential in future mitigation are both dependent on the impacts of ongoing climate and environmental change on forest ecosystems. These direct impacts of climate change are examined in Section IV. The model predictions presented in Chapter 18 by Loustau *et al*. illustrate the dramatic changes in the geographical distribution of 'climate space' for tree species in temperate and Mediterranean regions. The possibility of significant forest dieback in tropical regions and from wider environmental problems including air pollution, drought, wildfire, melting of permafrost and insect and pathogen outbreaks in other regions are considered in a number of the chapters of Section IV, particularly Reichstein (Chapter 16) and Solomon and Freer-Smith (Chapter 19). The latter also discusses the interactions between biological and abiotic factors. Widespread forest dieback would represent a strong positive feedback for climate change and this possibility has been considered in a limited number of the climate prediction exercises (Heimann, Chapter 3; Reichstein, Chapter 16). Adaptation measures to increase the resilience of forest ecosystems to climate change are explained in several chapters, including Solomon and Freer-Smith (Chapter 19), Loustau *et al.* (Chapter 18) and Broadmeadow and Carnus (Chapter 26). These measures and the policy barriers to their effective implementation clearly need to be addressed and resolved if the forestry contribution to climate change mitigation is to be maintained and fully realized.

The direct effects of elevated atmospheric carbon dioxide ($CO_2$) concentrations on trees (Karnosky *et al.*, Chapter 17) are likely to be one reason for the current increases in standing biomass of European forests (and potentially in other regions), although there are certainly other factors operating. Changes in tree growth rates, in environmental factors including soil moisture deficit, storm and fire frequency and in the severity of pest and pathogen outbreaks will also have major impacts on soil systems, both physically and biologically. In boreal forest systems there is as much as five times the quantity of carbon stored in the soil as in above-ground biomass, while in tropical systems the ratio is, typically, closer to unity (Schepers and Lynch, Chapter 15; Reichstein, Chapter 16). Soil carbon must therefore be considered along with the wider role of soils in terrestrial and aquatic systems.

## National and International Frameworks: Current and Future Policy

In Section V, and in two of the earlier chapters, the difficult questions of how international actions interact with national sovereignty are discussed and some specific difficulties associated with the operation of the current international conventions are outlined (Jauregui, Chapter 22; Dresner *et al.*, Chapter 6; and Filho, Chapter 7). Perhaps the most optimistic element of this discussion is the decision of the UN Forestry Forum in February 2006 to work towards the adoption of a non-legally binding instrument on forests at UNFF7 (2007). The policy objectives of sustainable forest management and of forest conservation and the need to identify climate change impacts and to monitor forest carbon stocks require effective forest monitoring systems. The effectiveness of the current systems which depend on national monitoring data submitted to regional (e.g. EU and the Secretariat of the Ministerial Convention on the Protection of Forests in Europe) and international (e.g FAO's Global Resource Assessment) data management centres becomes critical (Holmgren and Marklund, Chapter 20). Similarly, the effectiveness of carbon accounting within the Kyoto Protocol as set out in the Land Use, Land-use Change and Forestry (LULUCF) discussions becomes increasingly important as forest carbon is considered part of national compliance with GHG emissions reduction targets. In much of the developing world there are direct links between poverty and land-use policy, including deforestation, and in Chapter 23 Badiozamani discusses rural development and forestry policy with a focus on Latin America, the Caribbean, Asia and Central Africa. Monitoring and reporting need to address the assessment of forest degradation and land-use change, and the political and economic contexts vary considerably among countries. International instruments will need to be supported by financial measures to ensure that the resultant actions, whether national or programme-based, support local social and economic development goals and ensure long-term health and vitality of people and forests. Examples are given of barriers to the implementation of integrated climate change, and Teplyakov (Chapter 21), Solomon and Freer-Smith (Chapter 19) and Eggers *et al*. (Chapter 14) also describe the notional initiatives and processes which support climate change/forestry policy.

## The Way Forward

Section VI (Implications for Future Forestry and Related Environmental and Development Policy) addresses future policy – forestry, environmental and development – with four chapters based on workshops held during the course of the Wilton Park conference and a final chapter which draws these discussions together. The four workshops considered Risks and Uncertainties (Harper and Swift, Chapter 24), Governance (Sangster and Dudley, Chapter 25), Forest Sector Responses (Broadmeadow and Carnus, Chapter 26) and Commercial Projects and Research Initiatives (Hanson and Kurz, Chapter 27). This final section of the publication presents an exciting picture. The forestry sector believes that a change is needed and is imminent and that forestry has an important part to play. There is a continuing and rising global demand for both sawn timber and woodfuel, and, in many regions, data show increased forest growth rates. Furthermore, harvesting is lagging behind increment, and standing volumes (and thus carbon stocks) are increasing. The protection of forests through designations and certification schemes is becoming more commonplace and in some regions forest cover is increasing. Although the net change of global forest area remains a significant and worrying annual loss, the rate of loss of total forest area is decreasing. There is a real expectation that forests will increasingly be able to meet the demands of society for a range of services.

Change is occurring rapidly and is driven largely from outside the sector; for this and other reasons there are some key issues to be resolved if forestry is to make the contribution which it has the potential to fulfil. Much of the evidence-base for these views is presented in this publication. The chapters that follow on from this introduction indicate how forestry may be able to provide not only the multiple and sustainable benefits which can perhaps now be regarded as an established role, but also contribute to the mitigation of climate change. Climate change science, as summarized by the IPCC and here, shows unequivocally that a number of actions are urgent, or indeed overdue, and the evidence presented makes it absolutely clear that forestry is a sector that is ready to take action at a global scale. Undoubtedly there is frustration that, for example, UNFCCC and Kyoto negotiations and the formulation of guidelines on forestry action have been so drawn out that forestry features little in carbon trading, that net global forest cover continues to decline at an alarming rate and that the international framework on forestry appears to have gone over the same ground again and again without finding a way forward. It is increasingly recognized that taking action to protect forests is too important to wait until the next commitment period of the Kyoto Protocol (i.e. after 2012). New institutional, financial and market mechanisms are needed to mobilize new resources and allow implementation of sustainable forest management, as discussed by Rollinson in his conclusions (Chapter 28).

The forestry sector believes that it must and can now make progress, and this publication is effective in presenting the data to support this position. The last Sections (V and VI) identify the overall objectives and point to the next steps. We see forestry as having a crucial role to play and are of the view that forest science and the science–policy interface are now poised to implement a new framework for delivery, but that there is a real need for leadership. We hope that this publication presents a sound knowledge-base, provides a strong steer and will increase the momentum for change.

## References

FAO (2006) *Global Forest Resources Assessment 2005: Progress Towards Sustainable Forest Management*. FAO Forestry Paper 147. Food and Agriculture Organization, Rome. www.fao.org/forestry/fra2005

IPCC (1995) *The Second Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK.

IPCC (2001) *The Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, UK.

IPCC (2007) *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC Secretariat, Geneva, Switzerland. www.ipcc.ch

Kauppi, P.E., Ausubel, J.H., Fang, J., Mather, A.S., Sedjo, R.A. and Waggoner, P.E. (2006) Returning forests analysed with the forest identity. *Proceedings of the National Academy of Sciences, USA* 103(46), 17574–17579.

Stern, N.H. (2006) *The Stern Review: The Economics of Climate Change*. UK Government Cabinet Office and HM Treasury. Cambridge University Press, Cambridge, UK.