The importance of climate change in considering the role of forests in the alleviation of poverty

A paper by

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Forests could play a major role in the alleviation of poverty in many different parts of the world. However, forests are dynamic, and their rate of change is accelerating as a result of anthropogenic activities. Climate change, for example, will alter the nature of many protection forests in mountainous areas, exposing the inhabitants to increased risk from natural hazards. It will also affect the viability of plantation forests established in drier areas as a source of fuelwood or to combat desertification. Sea-level change will destabilize coastal forests, particularly mangroves, reducing their effectiveness in coastal protection. Air pollution has already destabilized many forests, and is likely to be an increasing problem in the forests surrounding urban areas in developing countries. Many impacts remain uncertain, and there remains a great need to integrate the biophysical knowledge that currently exists with socio-economic information associated with the impact on forest-dependent communities.

Key words: Environmental change; Air pollution; Forest benefits; Poverty alleviation

Introduction

The agenda of the global forest policy community is focused on the use of forests to alleviate poverty. This reflects the very substantial changes that have occurred in the nature of forestry over the past 20 years. Instead of concentrating on the bio-physical aspects of forests, traditionally covered through subject areas such as silviculture, pathology, engineering, and tree breeding, the emphasis has shifted to the roles that forests play in the maintenance of communities, particularly the livelihoods of those that depend on them. This is requiring a whole new skill set, one that many foresters trained in traditional aspects of forestry do not have. As a result, the roles that have until recently been taken by those trained in forestry are increasingly being taken by those trained in other disciplines.

The importance of forests as a means of alleviating poverty in rural areas cannot be over-emphasized. However, in some cases, forest management practices themselves have actually created or deepened that poverty, such as when local people are excluded from the benefits accruing from the forests that surround their homes. In other cases, it has been a failure to recognize the true value of the goods and services that forests provide that has led to the destruction of forests that were playing an important in the maintenance of the livelihoods of local people.

These problems are being increasingly recognized, and a number of new forms of forestry have emerged that place much greater emphasis on the involvement of local people and the contributions that forests make to their livelihood. In some areas, such benefits have been widely recognized, as with the use of protection forests in alpine areas. In others, we are still learning of the potential benefits and the optimal ways to harness these so that local people at least receive some of the benefits. However, as we learn about the ways in which forests could benefit local people, a major uncertainty is looming that could alter

many of the relationships between people and forests. This uncertainty is climate change.

Climate change

Climate change has always occurred and will continue to occur, regardless of anything that humans do. The last Ice Age ended about 12,000 years ago and, since then, there have been many smaller variations in climate. During the last 500 years, we have experienced the “Little Ice Age”, which appears to have reached its maximum extent about 200-300 years ago, although this date varies geographically. As a result, for the last 150 years, temperatures have become progressively warmer. Superimposed upon this natural trend, the effects of increasing concentrations of greenhouse gases in the atmosphere have resulted in an increased rate of warming. The changes, averaged globally, amount to 0.6°C over the past 100 years (Houghton *et al*. 2001). These increases are already having noticeable impacts on forests, particularly in northern regions and at higher altitudes, where the changes in temperature have been most marked.

Various effects are apparent. Forest productivity is known to be responding to climate change. In temperate and boreal zones, the increased temperatures are leading to the increased growth of trees in many areas. However, in some tropical forests, there is evidence that the reverse effect occurs: productivity decreases with increasing temperature (Clark *et al*. 2004). The differences are related to the interactions between temperature and soil moisture: these play an important part in determining the nature of the impacts on forest trees.

The seasonal development of some insect pests is changing. For example, the current massive outbreak of the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) in central British Columbia can be directly related to the absence of extreme cold periods during the winters of the last five years. Most is known about the effects of temperature on insects, since temperature has a direct effect on insect development. Changes may be induced in life-cycle duration, voltinism, population density, genetic composition, size, extent of host plant exploitation and distribution (Bale *et al*. 2002). There is much less information on the effects of precipitation on insects.

Many animal species are beginning to show behavioural responses to climate change, such as caribou (*Rangifer tarandus*) in Alaska (Haskell and Ballard 2004). There are also direct responses to changing climate being observed in many other species. For example, the pied flycatcher (*Ficedula hypoleuca*) is responding to variations in the North Atlantic Oscillation through changes in the timing of the breeding season and the size of clutches. The long-term increase in spring temperatures is leading to earlier breeding and smaller clutch sizes, with the changes being most obvious in northerly populations (Sanz 2003). There are many other documented cases of climate change impacts on birds (e.g., Järvinen 1994; Crick and Sparks 1999; Winkel and Hudde 1997).

Political responses to climate change

Concerns about climate change, particularly increasing global temperatures, triggered the United Nations Environment Program and the World Meteorological Organization to establish the Intergovernmental Panel on Climate Change (IPCC). This body of scientists has now produced three major scientific assessments, and has contributed to the UN Framework Convention on Climate Change and, more recently, to the Kyoto Protocol.

The UN Framework Convention on Climate Change commits parties to actions that are likely to help offset the impacts of climate change in some of the more vulnerable developing countries. Specifically, Article 4.4 of the UNFCCC states:

"*The developed country Parties and other developed Parties included in Annex II shall also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects*".

The Global Environment Facility was made responsible for the operation of the financial mechanisms to enable this to take place. The negotiations over the Kyoto Protocol established three new funds related to climate change adaptation in developing countries. A Special Climate Change Fund and a Least Developed Countries Fund were set up under the GIS, whereas an Adaptation Fund was created which would be funded through the proceeds of the Clean Development Mechanism. Two per cent of CDM transactions go into the Adaptation Fund, with the exception of projects hosted by Least Developed Countries.

According to Klein (2002), Decision 5/CP.7 of the Conference of the Parties, the Special Climate Change Fund and the Adaptation Fund can be used for, amongst other things,

- Starting to implement adaptation activities promptly where sufficient information is available to warrant such activities, *inter alia*, in the areas of water resources management, land management, agriculture, health, infrastructure development, fragile ecosystems, including mountain ecosystems, and integrated coastal management;
- Improving the monitoring of diseases and vectors affected by climate change, and related forecasting and early-warning systems, and in this context improving disease control and prevention;
- Supporting capacity-building, including institutional capacity, for preventative measure, planning, preparedness and management of disasters relating to climate change, including contingency planning, in particular for droughts and floods in areas prone to extreme weather events;
- Stengthening existing and, where needed, establishing national and regional centres and information networks for rapid response to extreme weather events, utilizing information technology as much as possible.

The attempts to link climate change adaptation, poverty and development have been grouped by Eriksen and Næss (2003) into four categories:

- Climate change assessments have changed from scenario-based approaches to including analyses of factors affecting vulnerability. Links to development and poverty are now possible through the Clean Development Mechanism and National Adaptation Programs of Action (NAPAs). The NAPAs (which are funded by the Least Developed Countries Fund) were intended to address the needs of the Least Developed Countries and are therefore particularly relevant to poverty reduction. They made countries recognize local communities and the need to help them adapt to climate change.
- Poverty reduction is now being directly addressed as multi- and bi-lateral agencies increasingly involve climate change in the Millennium Development Goals, Poverty Reduction Strategy Papers and other development mechanisms.
- Disaster and mitigation risk management is increasingly recognizing the need to address disaster mitigation in relation to climate change and long-term social development.
- Natural resource management is an increasing focus for many agencies. The importance of biodiversity as a buffer to climate change has been recognized by many, as has the need to incorporate climate change into resource management strategies. For example, the Caribbean Project on Planning for Adaptation to Climate Change, funded by the Global Environment Facility, is looking at how climate change can be incorporated into the sustainable development agendas of the Caribbean countries, including Small Island and Low-lying Developing States.

Impacts of climate change

The IPCC is generally seen as representing the broad consensus of scientists working in the field of climate change. Although some of their conclusions are disputed, the IPCC has added reliability estimates to some of its estimates of likely trends in global climate. Some of the most important trends are (Houghton *et al*. 2001):

(i) Higher maximum temperatures (90-99% certainty);
(ii) Higher minimum temperatures (90-99%);
(iii) More intense precipitation events (90-99%);
(iv) Increased summer drying over most mid-latitude continental interiors and associated drought risk (60-90%);
(v) Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities (60-90%); and
(vi) Increased Asian summer monsoon precipitation variability (60-90%).

The IPCC bases its conclusions on the output of sophisticated Global Circulation Models. The models are developed according to a number of different scenarios about the way that human development may occur over the

next 100 years. The nature of the scenarios is very different, as the results that are produced. However, they provide important information on the range of possible outcomes given different developmental scenarios.

Some of the likely effects of these climatic trends have been evaluated by the IPCC. They include (Houghton *et al*., 2001):

a) Higher maximum temperatures, which could lead to increased incidence of death and serious illness in older age groups and amongst urban poor, increased heat stress in livestock and wildlife, shifts in tourist destinations, increased risk of damage to trees and crops, and increased energy demands and reduced energy supply reliability.

b) Higher minimum temperatures, which could lead to decreased cold-related human morbidity and mortality, decreased risk of damage to some trees and crops, greater risk to others, extended range of activity of some pests and disease vectors, reduced heating energy demand, and reduced operating seasons (in the far north).

c) More intense precipitation events, which could lead to increased flood, landslide, avalanche and mudslide damage, increased soil erosion, increased flood runoff perhaps leading to increased recharge of some floodplain aquifers, and increased pressure on government and private flood insurance systems and disaster relief.

d) Increased summer drying over most mid-latitude continental interiors and associated drought risk, which could decreased crop and tree yields, increased damage to building foundations caused by ground shrinkage, decreased water resource quantity and quality, increased risk of forest fire, and changes in insect population dynamics.

e) Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities (Hulme and Viner 1998; Walsh and Pittock 1998), potentially leading to increased risks to human life, risk of infectious disease epidemics, and other risks, increased coastal erosion and damage to coastal infrastructure, and increased damage to coastal ecosystems, including coral reefs and mangroves.

f) Increased Asian summer monsoon precipitation variability, possibly leading to increased flood and drought magnitude and damage in temperate and tropical Asia

Within forestry, the risks can be stated more specifically, as described below.

<u>Plantation failures due to poor adaptation, extreme climatic events</u>
Many plantations have been established using stock that is relatively genetically uniform. This has several advantages, including preferential growth rates and increased quality of the stems. However, the lower the level of the genetic diversity in a stand, the higher will be its chances of being adversely affected by

climate change – there will no variation, with, for example, some trees being more resistant to drought or particular insects, as would occur in natural stands (even monospecific ones).

Increased insect or disease problems

As indicated above, the spread of diseases and insect pests is likely to continue under most scenarios of climate change. There have already been examples of insects attacking stands outside their known ranges, and this will likely continue. The problem will be exacerbated by the ease with which insects and disease can be transferred from one part of the world to another.

Increased frequency and severity of fires

Fires remain a huge issue in virtually every forest of the world. Traditionally, the response of foresters to fire has been immediate suppression. This has the benefit that, in the short-term, it minimizes loss of timber. However, in the long-term, fire suppression can lead to the development of undesirable stand characteristics, and can ultimately lead to even more severe fires, due to the buildup of fuels in forests undisturbed by fire.

The fires in Indonesia in the 1990s emphasized just how vulnerable even moist tropical forests are to climate change, especially when that change is combined with social pressures to convert forests to other forms of land use. In tropical forests, fires lead to the degradation of the forest towards xerophytic and pyrophytic plant communities dominated by grasses and fire-tolerant trees and shrubs (Goldammer and Price 1998).

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Unacceptable levels of tree mortality

There is evidence for interactions between fragmentation, fires, climate change and tree mortality in tropical forests (Sizer and Tanner, 1999; Laurance, 2004). The mortality is induced by increased desiccation and disturbance near fragment edges, and the edges are also probe to damage by fires. Increasing frequencies and intensities of drought in some areas is also likely to induce excessive tree mortality. Mortality may also result from changed water regimes: Ahmed *et al*. (1999) propose that flooding could result in heavy mortality of *Arctocarpus* species in Bangladesh

Changes in forest composition

There are suggestions that even in the Tropics, climate change may lead to substantial changes in the composition of forests (Dixon *et al*., 2003). Some of these changes could be adverse, others might result in increased productivity. For example, in Sri Lanka, models suggest that there may be a northward shift of the tropical wet forest into areas currently dominated by tropical dry forest (Somaratne and Dhanapala 1996). Conversely, in Thailand, models suggest that the tropical dry forest may replace some of the subtropical moist forest (Boonpragob and Santisirisomboon 1996). Similarly complex changes in the composition of forests are expected in mountain areas (Priya-Deshingkar 1998). Loope and Giambelluca 91998) argue that tropical montane forests on islands are particularly vulnerable to change, mainly in the form loss of native species and replacement by non-native invasive species.

Loss of productivity (wood volume)
While tree growth in some areas may increase as a result of climate change, in other areas it will decrease. The nature of the change will depend on the situation. For example, in areas where lower altitudinal treelines are determined by water availability, the growth of trees close to this ecological boundary will decrease. There will not be compensatory growth increase at higher altitudes, as the amount of land available decreases with increasing altitude (at the mountain summit, there is no further land).

Loss of pulp quality
Although there seem to be publications on the matter, there are anecdotal reports of losses in pulp quality, and these have been attributed to climate change. For example, in Prince George, British Columbia (Canada), Canadian Forest Products Ltd. personnel have indicated that the quality of pulp will decrease if growth rates rise: they particularly favour the dense wood typical of boreal growing conditions.

Sea-level change

Sea-level is expected to change by between 9 cm and 88 cm over the next 100 years. The implications are substantial, especially for low-lying coastal regions, where there may be increased risk of flooding in coastal zones and destabilization of mangrove forests. Ahmed *et al*. (1999) provide an account of possible impacts in the mangrove forests of the Sundarbans of Bangladesh. These include not only increased saltwater incursions due to rising sea levels but also increased soil salinity due to a combination of high evapotranspiration and low-flow in winter, resulting in the loss of species preferring freshwater.

The problems associated with sea-level change associated with climate change may be aggravated by problems associated with relative sea-level change associated with the drawing down of groundwater resources, as has happened in Shanghai and Bangkok (Lal *et al*., 2001). This problem is likely to be most extreme in urban areas.

Looking at the risks

A major problem is that much research on the impacts of climate change has been sectoral – we have not looked at how the impacts in different sectors interact with each other. However, it is clear that we should not look at climate change in isolation, since the impacts will be cross-sectoral and the responses will need to be also. Until now, studies of the impacts of climate change on forests have focused almost exclusively on the biological impacts – how forests themselves will respond. The people that depend on those forests have largely been excluded from such impact studies, as have their abilities to modify the impacts. For example, concern has been expressed about the possible inability of the distribution of individual tree species to adapt sufficiently fast to a

changing climate. This fails to take into account the role that humans could play in accelerating the dispersal of those species.

Poverty alleviation

A number of mechanisms have been proposed by which forestry can contribute to the alleviation of poverty. In developing countries, joint management and co-management schemes (often used synonymously) are popular, but have met with mixed success (e.g., Zakir-Husain and Bhattacharya 2004; Glaser and Oliveira 2004). On many occasions, their failure can be related to either the reluctance of one party to cede control (often the government) or the failure to identify correctly the expectations of the party or parties entering into the agreement (Munasinghe and Hanna 1995, Hanna *et al*. 1996). In cases where they have been successful, resource degradation associated with open access has been reduced through both the benefits and the costs of managing the resource being shared.

Increasingly, emphasis is being placed on livelihoods. Livelihoods can be defined as "*A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base*" (DFID 1999, based on Chambers and Conway 1992). Climate change can interfere with livelihoods at many levels, but the amount of analysis that has been done to date is very limited. Eriksen and Næss (2003) link livelihoods to natural resource management and poverty reduction. They argue that natural resources are used as sources of livelihoods, but livelihoods represent the way that people deal with both poverty and vulnerability. As climate change will have marked effects on natural resources, climate change is intricately connected to livelihoods.

Eriksen and Næss (2003) argue that control of natural resources is important for the adaptation to climate change, and at the same time may reduce poverty. It enables people to prepare for climate change effects through, for example, investment in resistant agriculture or livestock rearing or switching to alternative sources of food. It also increases the ability of people to recover from natural disasters (Adger 2000). Forestry can help reduce this vulnerability in some situations. For example, Robledo *et al*. (2004) found that afforestation had many positive effects on a community in Bolivia. The Khuluyo community is believed to have become more resilient through a number of changes. The organization of the afforestation program, particularly through participatory techniques, led to improved planning and negotiation skills in the community. It also led to advances in ownership rights. Tree planting and management and the development of non-timber forest products such as eucalyptus oil improved local knowledge and skills and diversified local incomes, increasing the resilience of the community to extended dry seasons. The introduction of cipreces (*Cupressus macrocarpa*) and kiswara (*Buddleja coriacea*) in windbreaks has led to decreased wind and water erosion during storms, and

protection against morning frosts. The promotion of natural regeneration of aliso (*Alnus acuminata*) has improved the hydrology of microwatersheds, increasing their resilience to prolonged dry periods. The establishment of plantations of *Pinus radiata*, *Pinus patula*, *Pinus montesuma*, *Pinus pseudostrobus* and *Eucalyptus globulus* has led to increased slope stability, improved microclimates, reduced pressure on secondary forests, and economic diversification. The overall impression is of a community that now has much reduced vulnerability to climate change.

In many parts of the world, there is increasing recognition of the need for the co-management of forest resources. Generally, this involves a transfer of power from government (or, more rarely, industry) to local people. In some cases, the resulting agreements do not really cede any real control to the local people, but in others, there has been an effective transfer of control.

One form of control has been community forestry. This takes many forms, but the key to the most successful has been the active participation on people from local communities. Such participation is not universal, and in some cases, governments maintain control over the decisions that the communities can make. In others, there is clear evidence that secure tenures, strong local institutions and organizational experience can make community forests a success (Tucker 2004).

Another change has been the increasing role of agroforestry. While some agroforestry schemes have been over-ambitious, many have been successful at reducing poverty. There are numerous examples from developing countries where livelihoods have been positively impacted by agroforestry. There are indications that farmers practicing agroforestry are willing to look at novel ways of financing their efforts, as shown by the apparent success of the Scolel Té project in southern Mexico (Tipper 2002). However, the potential of such projects to help reduce poverty has been greatly limited by the decisions to limit forest carbon sequestration projects to those involving afforestation and re-forestation. This means that some of the more innovative projects will have to rely on the voluntary carbon market. This means that many of the fears expressed by Saunders *et al*. (2002) and Landell-Mills (2002) concerning the possible marginalization of the poor in relation to carbon markets appear to have been well-founded.

Although many of these evolving forms of forestry have much potential, most have failed to take into account climate change. This is a serious limitation that will greatly increase the risk of failure of such approaches.

Mitigation and adaptation

Much of the emphasis on actions to reduce the impacts of climate change have focused on the reduction of atmospheric concentrations of greenhouse gases, whether by reduced emissions or increased sinks. There has been much less

focus on adaptation to the changes that are occurring and which will occur in the future, regardless of mitigation strategies.

Adaptation is easiest for those in developed countries. It is the world's poorest, located largely in developing countries, that will be least able to adapt. There is a direct link between poverty and adaptation capacity, a link that has been known for some time (Blaikie *et al*. 1994).

Some of the biggest problems will likely be related to hazards and extreme events. Impacts on the intensity and frequency of the Asian Monsoon are predicted – when combined with increasing sea-levels, the potential for disasters in coastal areas such as Bangladesh is very high.

Kates (2000) has argued that the ability of international agencies to help local populations to adapt to climatically-induced disasters has improved. In the case of drought, there is improved early warnings of potential crop and animal losses, coordinated donor and food-aid mobilization, and the logistics to move large amounts of food to impacted areas. He points out that there are two, philosophically-opposing strategies to adaptation. The first relies on improved production technologies, including drought-resistant plants and animals, irrigation and improved ranching and grazing schemes, essentially increasing the carrying capacity of the land. The other suggests scaling down production to a carrying capacity more typical of natural conditions, and encouraging tree-planting and agroforestry. Kates suggests that history reveals that adaptation can be rapid, and that in appropriate situations the social benefits can exceed the social costs.

Many people from poor communities are being increasingly marginalized, a phenomenon that is not just restricted to developing countries. For example, in north-east British Columbia, the rapid development of resource-based industries, such as the oil and gas and forestry, has resulted in an economic boom that is not extending to the forest-dependent indigenous communities in the area. Groups such as the Saulteau, West Moberley, Prophet River and Blueberry First Nations are increasingly concerned over the loss of access to the landbase used to maintain their traditional activities. This theme is common to the case studies described by Kates (2000) from around the world.

Eriksen and Næss (2003) identify three key elements that can be used by local capacity to cope and adapt, namely institutions, natural resources and technology, and economic opportunities.

Conclusions

Although there is much talk about planning for climate change, climate change has always occurred. Climate now appears to be changing at an unprecedented rate, and many impacts are already evident. These impacts will continue – attempts to limit greenhouse gas emissions largely relate to future impacts

rather than those already occurring. Consequently, the forest sector needs to pay much more attention to climate change than it has to date.

The changes that are occurring, and which will occur in future, may be substantial. Changes in species composition will occur, and new communities may be formed. Predictions of future timber supply will be affected, whether at local or global scales. Climate change has rarely been factored into such predictions. For example, global timber supply models estimate the likely supply of timber globally, but fail to take into account the substantial changes of climate that will occur within the period that they are considering.

It will be difficult to mitigate the impacts of many of these changes, particularly as they affect society. Currently, little or no account is taken of climate change in silviculture, which remains based on the now untenable assumption that past performance is a good predictor of future performance. However, forests themselves will play a part in reducing greenhouse gas concentrations, with the reduction of deforestation rates and afforestation being particularly important. Regrettably, important opportunities for financing forest conservation and better forestry practices through processes such as the Clean Development Mechanism have largely been missed.

Given that many changes are already occurring, human populations will have no choice but to find ways to adapt. However, it is the World's poorest that will be least able to adapt, and Africa is seen as being particularly vulnerable. The goods and services provided by forests may provide alternative sources of food and income which may increase the ability of poor people to adapt. Peluso (1992) has drawn attention to the fact that some of the World's poorest people live in or adjacent to some of the World's richets forests. This provides the people with the opportunity to adapt to climate change, but only if they are allowed to do so.

Worryingly, there is a generally a lack of coordination between research, aid and development in the forest sector, with the United Kingdom's Department for International Development being a notable exception. This lack of coordination between research and overseas development will compromise attempts to alleviate poverty in the face of climate change. There is still a major need for research, but with research budgets shrinking globally, the opportunities to undertake policy-relevant research, particularly within the international arena, are limited or, in some countries, non-existent. What research there is will have to be undertaken on a very different basis to traditional research – as Sayer and Campbell (2004) argue, researchers can no longer be detached observers. They must be actors in the system, and must make long-term commitments to working with resource managers and studying the real-life problems of the people who depend on forests for their livelihoods.

There has also been a progressive and accelerating erosion of forestry skills. Recruitment into the profession has fallen catastrophically in recent years, and the increasing workloads experienced by the remaining foresters have made continuous education a low priority. As a result, there is widespread ignorance over issues such as the impacts of climate change on forestry.

Gordon *et al*. (1999) state that “Well-managed forests can better sustain the livelihood of resource-poor people in and around forests, but management must be carefully tailored to specific human and forest conditions, …and the people themselves must participate fully in decisions made in pursuit of better management (pp. 171-172)”.
The global forest policy community has spent the 13 years since the 1992 United Nations Conference on Environment and Development in a range of negotiations over statements of concern, action plans, and other documents. International conferences produce long lists of resolutions and calls for action. However, despite all the words, the actions that have been taken to reduce the vulnerability of the poor to climate change have been extremely limited.

References

ADGER, W.N. (2000) Institutional adaptation to environmental risk under the transition in Vietnam. *Annals of the Association of American Geographers* **90**: 738–758.

AHMED, A.U., SIDDIQI, N.A. and CHOUDHURI, R.A. (1999) Vulnerability of forest ecosystems of Bangladesh to climate change. In: HUQ, S., KARIM, Z., ASADUZZAMAN, M. and MAHTAB, F. (eds.) *Vulnerability and Adaptation to Climate Change for Bangladesh*. Kluwer, Dodrecht, pp. 93–111.

BALE, J.S., MASTERS, G.J., HODKINSON, I.D., AWMACK, C., BEZEMER, T.M., BROWN, V.K., BUTTERFIELD, J., BUSE, A., COULSON, J.C., FARRAR, J., GOOD, J.E.G., HARRINGTON, R., HARTLEY, S., JONES, T.H., LINDROTH, R.L., PRESS, M.C., SYMRNIOUDIS, I., WATT, A.D. and WHITTAKER, J.B. (2002) Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. *Global Change Biology* **8**: 1–16.

BLAIKIE, P., CANNON, T., DAVIS, I. and WISNER, B. (1994) *At risk: Natural hazards, people’s vulnerability and disasters*. Routledge, London. 284 pp.

BOONPRAGOB, K. and SANTISIRISOMBOON, J. (1996) Modeling potential changes of forest area in Thailand under climate change. *Water, Air, and Soil Pollution* **92**: 107–117.

CHAMBERS, R. and CONWAY, G. (1992) *Sustainable rural livelihoods: Practical concepts for the 21st century*. IDS Discussion Paper 296. IDS, Brighton. 42 pp.

CLARK, D.A., PIPER, S.C., KEELING, C.D. and CLARK, D.B. (2004) Tropical rain forest tree growth and atmospheric carbon dynamics linked to interannual temperature variation during 1984–2000. *Proceedings of the National Academy of Sciences USA* **100**: 5852–5857.

CRICK, H.Q.P. and SPARKS, T.H. (1999) Climate change related to egg-laying trends. *Nature* **399**: 423–424.

DFID (DEPARTMENT FOR INTERNATIONAL DEVELOPMENT) (1999) Sustainable Livelihoods Guidance Sheets. Available at: http://www.livelihoods.org/info/guidance_sheets_pdfs/section1.pdf. Accessed 19 March, 2005.

DIXON, R.K., SMITH, J. and GUILL, S. (2003) Life on the edge: Vulnerability and adaptation of African ecosystems to global climate change. *Mitigation and Adaptation Strategies for Global Change* **8**: 93–113.

ERIKSEN, S. and NÆSS, L.O. (2003) *Pro-poor climate adaptation. Norwegian development cooperation and climate change adaptation: An assessment of issues, strategies and potential entry points*. Centre for International Climate and Environmental Research, Oslo.

GLASER, M. and OLIVEIRA, R. da S. (2004) Prospects for the co-management of mangrove ecosystems on the north Brazilian coast: Whose rights, whose duties and whose priorities? *Natural Resources Forum* **28**: 224–233.

GOLDAMMER, J.G. and PRICE, C. (1998) Potential impacts of climate change on fire regimes in the tropics based on Magicc and a GISS GCM-derived lightning model. *Climatic Change* **39**: 273–296.

GORDON, J.C., BERRY, J.K. and SCHMIDT, R. (1999) The problem and the potential solutions. In: SCHMIDT, R., BERRY, J.K. and GORDON, J.C. (eds.) *Forests to fight poverty*. Yale University Press, New Haven, pp. 168–181.

HANNA, S.S., FOLKE, C. and MÄLER, C. (eds.) (1996) *Rights to nature. Ecological, economic, cultural and political principles of institutions for the environment*. Island Press, Washington D.C. 298 pp.

HASKELL, S.P. and BALLARD, W.B. (2004) Factors limiting productivity of the central Artic Caribou Herd of Alaska. *Rangifer* **24**: 71–78.

HOUGHTON, J.T., DING, Y., GRIGGS, D.J., NOGUER, M., VAN DER LINDEN, P.J., XIAOSU, D., MASKELL, K. and JOHNSON, C.A. (2001) *Climate change 2001: The scientific basis*. Cambridge University Press, Cambridge. 881 pp.

HULME, M. and VINER, D. (1998) A climate change scenario for the Tropics. *Climatic Change* **39**: 145–176.

JÄRVINEN, A. (1994) Global warming and egg size of birds. *Ecography* **17**: 108–110.

KATES, R.W. (2000) Cautionary tales: Adaptation and the global poor. *Climatic Change* **45**: 5–17.

KLEIN, R.J.T. (2002) *Climate change, adaptive capacity and sustainable development*. Document 3 prepared for the Informal Expert Meeting on Development and climate Change; OECD, Paris, 13–14 March 2002.

LAL, M., HARASAWA, H. and MURDIYARSO, D. (2001) Asia. In: MCCARTHY, J.J., CANZIANI, O.F., LEARY, N.A., DOKKEN, D.J. and WHITE, K.S. (eds.) *Climate change 2001: Impacts, adaptation, and vulnerability*. Cambridge University Press, Cambridge, pp. 543–590.

LANDELL-MILLS, N. (2002) Developing markets for forest environmental services: an opportunity for promoting equity while securing efficiency? In: SWINGLAND, I.R. (ed.) *Capturing carbon and conserving biodiveristy. The market approach*. Earthscan, London, pp. 272–280.

LAURANCE, W.F. (2004) Forest-climate interactions in fragmented tropical landscapes. *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences* **359**: 345–352.

LOOPE, L.L. and GIAMBELLUCA, T.W. (1998) Vulnerability of island tropical montane cloud forests to climate change, with special reference to East Maui, Hawaii. *Climatic Change* **39**: 503–517.

MUNASINGHE, M. and HANNA, S.S. (eds.) (1995). *Property rights and the environment. Social and ecological issues*. Beijer International Institute of Ecological Economics, Stockholm, and the World Bank, Washington D.C. 164 pp.

PELUSO, N. (1992) *Rich forests, poor people: Resource control and resistance in Java*. University of California Press, Berkeley. 321 pp.

PRIYA-DESHINGKAR (1998) Climate change adaptation in India: a case study of forest ecosystems in Himachal Pradesh. *International Journal of Environment and Pollution* **9**: 186–197.

ROBLEDO, C., FISCHLER, M., and PATIÑO, A. (2004) Increasing the resilience of hillside communities in Bolivia. Has vulnerability to climate change been reduced as a result of previous sustainable development cooperation? *Mountain Research and Development* **24**: 14–18.

SANZ, J.J. (2003) Large-scale effect of climate change on breeding parameters of pied flycatchers in western Europe. *Ecography* **26**: 46–50.

SAUNDERS, L.S., HANBURY-TENISON, R., and SWINGLAND, I.R. (2002) Social capital from carbon property: creating equity for indigenous people. In: SWINGLAND, I.R. (ed.) *Capturing carbon and conserving biodiveristy. The market approach*. Earthscan, London, pp. 218–230.

SAYER, J. and CAMPBELL, B. (2004) *The science of sustainable development. Local livelihoods and the global environment*. Cambridge University Press, Cambridge. 268 pp.

SIZER, N.C. and TANNER, E.V.J. (1999) Responses of woody plant seedlings to edge formation in a lowland tropical rainforest, Amazonia. *Biological Conservation* **91**: 135–142.

SOMARATNE, S., and DHANAPALA, A.H. (1996) Potential impact of global climate change on forest distribution in Sri Lanka. *Water, Air, and Soil Pollution* **92**: 129–135.

TIPPER, R. (2002) Helping indigenous farmers to participate in the international market for carbon services: The case of Scolel Té. In: PAGIOLA, S., BISHOP, J. and LANDELL-MILLS, N. (eds.) *Selling forest environmental services*. Earthscan, London, pp. 223–233.

TUCKER, C. (2004) Aiming for sustainable community forest management. The experiences of two communities in Mexico and Honduras. In: ZARÍN, D.J., ALAVALAPATI, J.R.R., PUTZ, F.E., and SCHMINK, M. (eds.) *Working forests in the Neotropics. Conservation through sustainable management*. Columbia University Press, New York, pp. 178–199.

WALSH, K. and PITTOCK, A.B. (1998) Potential changes in tropical storms, hurricanes, and extreme rainfall events as a result of climate change. *Climatic Change* **39**: 199–213.

WINKEL, W. and HUDDE, H. (1997) Long-term trends in reproductive traits of tits (*Parus major*, *P. caeruleus*) and pied flycatchers *Ficedula hypoleuca*. *Journal of Avian Biology* **28**: 187–190.

ZAKIR-HUSAIN, and BHATTACHARYA, R.N. (2004) Attitudes and institutions: Contrasting experiences of Joint Forest management in India. *Environment and Development Economics* **9**: 563–577.