ISSN 0258-6150

FAO
FORESTRY
PAPER

172

Climate change guidelines for forest managers

Front-cover photo:
Researchers for the national forest assessment in Viet Nam, supported by an FAO project, use laser technology devices to measure tree height and diameter (©FAO/Joan Manuel Baliellas)

Back-cover photo:
Forest monitoring in the Pacific Islands, which have some of the most vulnerable ecosystems to climate change (©Henry Scheyvens)

Climate change guidelines for forest managers

FAO
FORESTRY
PAPER

172

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2013

Please cite as: **FAO.** 2013. *Climate change guidelines for forest managers*. FAO Forestry Paper No. 172. Rome, Food and Agriculture Organization of the United Nations.

ISBN 978-92-5-107831-0 (print)
E-ISBN 978-92-5-107832-7 (PDF)

Contents

Figures

Boxes

Contributors

Rosário Alves
Directora Executiva
Forestis - Associação Florestal de Portugal
Rua de Santa Catarina nº753
4000 – 454 Porto
Portugal

Marcelo Arguelles
Executive Manager Brazilian Forest Service
SCEN, Trecho 2, Bl. H 70818-900
Brasília
Brazil

Susan Braatz
Senior Officer, Forests and Climate Change
FAO Forestry Department
Viale delle Terme di Caracalla
00153 Rome
Italy

Gerhard Breulmann
Planning, Monitoring & Evaluation Officer
International Tropical Timber Organization
International Organizations Center, 5th Fl.
Minato-Mirai, Nishi-Ku
Yokohama 220-0012
Japan

Jeremy Broadhead
FAO Regional Office for Asia and the Pacific
Maliwan Mansion
Phra Atit Road
Bangkok 10200
Thailand

Barney Chan
Director, eSFM Tropics
ITTO Trade Advisory Group
295, Lrg 14, Jln Kedandi
Kuching, Sarawak 93350
Malaysia

Resham Bahadur Dangi
Deputy Director General
Ministry of Forestry & Soil Conservation
Department of Forests
Babarmahal, Kathmandu
Nepal

Richard Eba-Atyi
Regional Coordinator, Central Africa
Center for International Forestry Research
c/o IITA Humid Forest Ecoregional Center
B.P. 2008, Yaoundé
Cameroon

Marta Gaworska
Former Acting Secretary General, CEPF
Liaison Office Brussels
European Forestry House
Rue du Luxembourg 66
B-1000 Bruxelles
Belgium

Fred Kafeero
Forestry Officer, Participatory Forestry
FAO Forestry Department
Viale delle Terme di Caracalla
00153 Rome
Italy

Rodel Lasco
Senior Scientist and Philippines Country Coordinator
World Agroforestry Centre
2nd Fl., Khush Hall Bldg.
International Rice Research Institute
IRRI Campus
Los Baños, 4031 Laguna
Philippines

Bas Louman
Head, Climate Change and Watershed Management Programme, CATIE
Cartago, Turrialba, 30501
Costa Rica

Inazio Martinez de Arano
Presidente Ejecutivo, Unión de Selvicultores del Sur de Europa
Larrauri, 1B – 6º
E-48160 – Derio
Spain

Mary Menton
Research Fellow, Forests and Environment Programme, CIFOR
CIP, Av La Molina 1895
12 Lima
Peru

Peter Neil
Former Regional Forest Programme IUCN Asia
IUCN Asia Regional Office
63, Soi Phromphong, Sukhumvit 39
10110 Wattana, Bangkok
Thailand

German Obando-Vargas
Professor, Universidad EARTH
Apartado 4442-1000
San José
Costa Rica

Hwan Ok Ma
Projects Manager
Reforestation and Forest Management Division
International Tropical Timber Organization
International Organizations Center, 5th Floor
Minato-Mirai, Nishi-Ku
Yokohama 220-0012
Japan

Hivy Ortiz
Forestry Officer
FAO Regional Office for Latin America and the Caribbean
Santiago
Chile

Francis E. Putz
Professor, Department of Biology
University of Florida
209 Carr Hall, PO Box 118526
Gainesville, FL 32641
USA

David Rhodes
Chief Executive
New Zealand Forest Owners Association
Level 9, 93 The Terrace
PO Box 10986
Wellington 6143
New Zealand

Simmone Rose
Forestry Officer, Climate Change and Bioenergy
FAO Forestry Department
Viale delle Terme di Caracalla
00153 Rome
Italy

Maria Ruiz-Villar
Forestry Officer
FAO Forestry Department
Viale delle Terme di Caracalla
00153 Rome
Italy

Cesar Sabogal
Forestry Officer, Forest Management
FAO Forestry Department
Viale delle Terme di Caracalla
00153 Rome
Italy

Angel Salazar Vega
PROBOSQUES
Av. José Abelardo Quiñones km 2.5
Iquitos
Loreto
Perú

Ian Thompson
Canadian Forest Service
1219 Queen St. east
Sault Ste. Marie
Ontario P6A 2E5
Canada

Bernhard Wolfslehner
EFICEEC Head of Office
European Forest Institute and University of Natural Resources and Life Science, Vienna
Feistmantelstr. 4
A-1180 Vienna
Austria

Foreword

Forests play a significant role in climate change mitigation by acting as "sinks", absorbing carbon from the atmosphere and storing it in biomass and soils, but, when cleared or degraded, they are also significant sources of greenhouse gas emissions. Forests, therefore, are important components in strategies for adapting to climate change. Without direct management interventions, climate change is likely to jeopardize forest ecosystem health, resilience, productivity, biodiversity and carbon storage, and forest degradation and loss will continue to contribute to climate change.

The strong relationship between forests and climate implies that a dramatic change in one will influence the other. This feedback could be negative in some situations and positive in others. Sustainable forest management can help reduce the negative effects of climate change on forests and forest-dependent people, and it can help ensure that forests play their role in mitigating climate change. Forest management decisions made now will affect forests many decades into the future. Thus, it is important for managers to plan now for climate change.

FAO is publishing these guidelines to support forest managers in responding to climate change challenges and opportunities at the forest management unit level. Articulating specific goals and objectives for climate change can assist forest managers to incorporate climate change considerations into forest management plans and practices. These guidelines will also be of interest to a wider range of stakeholders concerned about forests and climate change.

The guidelines are complementary to the FAO publication *Climate change for forest policy-makers*, which sets out an approach for integrating climate change into national forest programmes to support sustainable forest management. Countries are invited to use the two documents and to adapt them, as necessary, to fit national and subnational circumstances.

Eduardo Rojas-Briales
Assistant Director-General
FAO Forestry Department

Acknowledgements

This publication has been produced thanks to the generous contributions of time and expertise by a large number of experts. Initiated in 2010, the process to prepare the guidelines included national consultations in Kenya, Nepal and Peru – FAO thanks all participants in, and the people who supported, these workshops.

International expert consultations on the guidelines were convened in Kathmandu, Nepal (June 2011) and Lima, Peru (November 2011). FAO thanks all participants in those consultations for their valuable inputs. FAO also thanks Francis E. Putz for facilitating the consultations and for preparing the first and subsequent drafts of the guidelines on the basis of inputs received during the expert consultations.

The guidelines benefited from peer reviews by Marc Dumas-Johansen, Fred Kafeero, David Rhodes, Maria Ruiz-Villar and Ian Thompson.

The guidelines were evaluated in two workshops in Kenya and Peru facilitated by Donald Ogweno in Kenya and Pedro Carlos Alberto Llerena Pinto in Peru. FAO thanks both facilitators and all participants in the validation exercises (see Annex 3) for their contributions to the finalization of the document.

The FAO team responsible for the preparation of the guidelines comprised Simmone Rose, Susan Braatz and Cesar Sabogal. The document was edited by Alastair Sarre and typeset by Kate Ferrucci.

The development and production of these guidelines was made possible thanks to the generous financial contribution of the Government of Finland under the FAO-Finland Forestry Programme – Sustainable Forest Management in a Changing Climate.

Acronyms and abbreviations

CBD	Convention on Biological Diversity
CIFOR	Center for International Forestry Research
CO_2	carbon dioxide
FAO	Food and Agriculture Organization of the United Nations
FMU	forest management unit
GHG	greenhouse gas
ITTO	International Tropical Timber Organization
NGO	non-governmental organization
SFM	sustainable forest management
REDD+	reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
UNFCCC	United Nations Framework Convention on Climate Change

Executive summary

The effects of climate change and climate variability on forest ecosystems are evident around the world and further impacts are unavoidable, at least in the short to medium term. Addressing the challenges posed by climate change will require adjustments to forest policies and changes to forest management plans and practices.

In 2010, FAO prepared guidelines to support policy-makers in integrating climate change concerns into new or existing forest policies and national forest programmes. This document serves as a companion to those 2010 guidelines. It has been prepared to assist forest managers to better assess and respond to climate change challenges and opportunities at the forest management unit level. Proposed actions are intended to be relevant to all kinds of forest manager – such as individual forest owners, private forest enterprises, public-sector agencies, indigenous groups and community forest organizations. The actions are applicable in all forest types in all regions and for all management objectives. They are generic, so their adaptation to local circumstances is required.

Adaptation and mitigation are the two main responses to climate change. Mitigation addresses the causes of climate change and adaptation its impacts. In the forest sector, adaptation encompasses changes in management practices designed to decrease the vulnerability of forests to climate change and interventions intended to reduce the vulnerability of people to climate change. Mitigation strategies in the forest sector can be grouped into four main categories: reducing emissions from deforestation; reducing emissions from forest degradation; enhancing forest carbon sinks; and product substitution.

Sustainable forest management (SFM) is consistent with climate change adaptation and mitigation and provides a comprehensive framework that can be adapted to changing circumstances. Efforts to advance towards SFM have provided a wealth of knowledge, experience, best-practice guidance, tools, mechanisms and partnerships that can be applied to help meet climate change challenges and which informs this document. Using SFM as an overall framework helps ensure that adaptation and mitigation measures are synergistic and balanced with other forest management objectives and take into consideration the economic, social and environmental values of forests.

This document provides guidance on what forest managers should consider in assessing vulnerability, risk, mitigation options, and actions for adaptation, mitigation and monitoring in response to climate change. Recommended actions for climate change adaptation address impacts on: forest productivity; biodiversity; water availability and quality; fire; pests and diseases; extreme weather events; sea-level rise; and economic, social and institutional considerations. A range of mitigation actions is provided, along with guidance on the additional monitoring and evaluation that may be required in forests in the face of climate change.

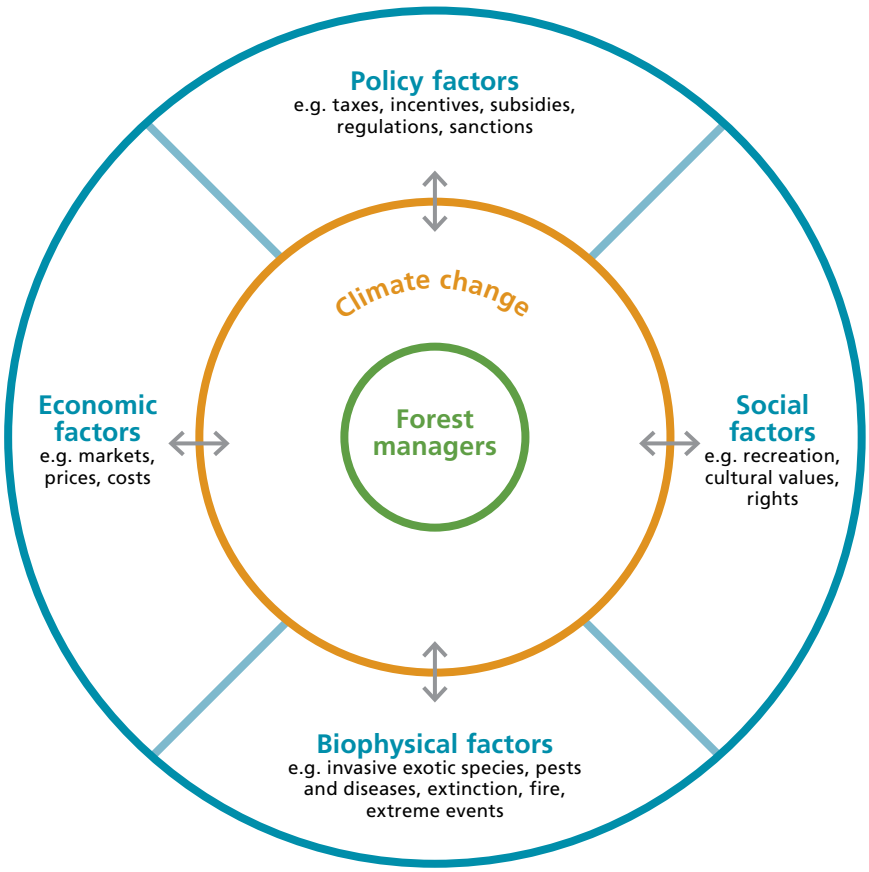
Climate change guidelines for forest managers

Sunset over forest-covered mountains, Province of Bac Kan, Viet Nam. Climate change is impairing the ability of forests to deliver critical goods and ecosystem services, to the detriment of the livelihoods of forest dwellers, forest-dependent communities and others who benefit from forests.

1. Introduction

The effects of climate change and climate variability on forest ecosystems are evident around the world and further impacts are unavoidable, at least in the short to medium term. In some cases, climate change is impairing the ability of forests to deliver critical goods and ecosystem services, such as wood and non-wood products and clean water, to the detriment of the livelihoods of forest dwellers, forest-dependent communities and others

FIGURE 1
Forest managers need to respond to a wide range of factors, all of which may be influenced by climate change



who benefit from forests. Meeting the challenges posed by climate change will require adjustments to forest strategies and changes to forest management plans and practices. Delays in taking action will increase the cost and difficulty of making those adjustments.

Climate change is only one of many factors that forest managers must deal with (Figure 1), but its impacts are projected to increase and to have wide-ranging repercussions. While some forests will benefit from increased temperatures and changes in precipitation, most will experience losses of important species, declines in yields, and increases in the frequency and intensity of storms and other disturbances. Adjusting forest management plans and practices to reduce vulnerabilities and facilitate adaptation to climate change is likely to incur additional costs, but these will probably be less than the costs of remedial action in the aftermath of climate-inflicted damage. Forest managers usually bear any increases in management costs, but they may not always benefit from the savings that are made when they take action in response to climate change. Nevertheless, well-informed forest managers will be able to benefit from financial and policy incentives to support climate change mitigation and adaptation actions, and this will help offset the additional costs of managing for climate change.

AUDIENCE AND PURPOSE

These guidelines have been prepared to assist forest managers (Box 1) to better assess and respond to climate change challenges and opportunities at the forest management unit (FMU) level. The document provides guidance on how to identify, assess and prioritize options for adjusting forest management plans and practices in response to and in anticipation of climate change. These guidelines will also be of interest to stakeholders outside the forest sector, since forest management responses to climate change will influence and be influenced by other sectors and stakeholders.

BOX 1

Forest management and forest managers

What is forest management?

Forest management encompasses the administrative, economic, legal, social and technical measures involved in the conservation, protection and use of natural and planted forests. It involves various degrees of human intervention to safeguard forest ecosystems and their functions and resources for the sustained production of goods and the provision of ecosystem services.

Who is a forest manager?

A forest manager is an individual or entity responsible for overseeing the management of forest lands or the use and development of forest resources to meet specific objectives. Individual forest managers may have formal education in forestry, equivalent qualifications or local knowledge, and experience in forest-related matters.

SCOPE

The actions outlined in these guidelines are intended to be relevant to all kinds of forest manager – such as individual forest owners, private forest enterprises, public-sector agencies, indigenous groups and community forest organizations. The actions are applicable in all forest types in all regions and for all management objectives (e.g. for production, protection, conservation and multiple use). The wide scope of the document means that, by design, the guidance it provides is generic. When recommended actions are specific to a certain type of forest owner or management objective, this is stated. FAO looks forward to collaborating with interested parties in the development of more detailed guidelines specific to particular forest types or forest managers and also encourages others to use these guidelines as a basis for developing more detailed, site-specific guidance.

CONTENT AND ORGANIZATION

The document has five chapters in addition to this introduction. Chapter 2 provides background on climate change and discusses its relevance to forests and forest managers. Chapter 3 presents an overview of sustainable forest management (SFM), adaptive management, landscape approaches, partnerships and participatory approaches, and the international framework for climate change adaptation and mitigation as it relates to forest management. Chapter 4 looks at management responses to climate change, including assessments of risk, vulnerability and options for mitigation, and offers operational guidance on management actions for climate change adaptation and mitigation. Chapter 5 provides guidance on how to monitor the impacts of climate change and on planning and evaluating adaptation and mitigation measures. Chapter 6 comprises a short conclusion. Three annexes present a glossary of terms, a list of knowledge tools and information sources, and the names of experts who participated in exercises to validate these guidelines.

Tonle Sap flood plain, Cambodia. Action is needed to prevent the degradation and loss of inundated forest habitat, which is essential for the maintenance of productive fisheries within the lake and for the capacity of communities to adapt to climate change.

2. Climate change and forests

CLIMATE CHANGE PROCESSES AND PROJECTIONS

The Earth's climate changes continually under the influence of a range of natural forces. Currently, however, observed significant and rapid changes in climate patterns worldwide are being driven by global warming caused by human activities that emit heat-trapping gases known as greenhouse gases (GHGs). Global warming is associated with increased climate variability and consequently an increased frequency of extreme events such as heat waves, severe droughts and intense storms, and it is also associated with rising sea levels. Climate change and increased climate variability are expected to have widespread economic, social and environmental repercussions. For forest managers, adapting to and mitigating climate change is likely to require major adjustments in management practices.

Forests and the global carbon cycle

Carbon dioxide (CO_2) is a key GHG, and changes to the global carbon cycle that affect the atmospheric concentration of CO_2 are crucial to the global climate. Forests play important roles as both sinks and sources of CO_2 (Box 2). Forest vegetation and soils contain about half the planet's terrestrial carbon, and terrestrial ecosystems have the potential to sequester more CO_2 than at present.

Forests absorb CO_2 through photosynthesis, store it as carbon[1] and release it through respiration, decomposition and combustion. The **carbon sink** function of a forest increases with the forest's rate of growth and the permanence with which it retains carbon.

BOX 2
Carbon sinks and sources

A **carbon sink** is a reservoir that takes up – sequesters – carbon from the atmosphere in the form of CO_2. When forests grow, they act as carbon sinks. Globally, forests are responsible for a large proportion of removals of CO_2 from the atmosphere.

A **source** of GHG emissions is any process or activity that releases GHGs into the atmosphere. Deforestation and forest degradation are major sources of GHG emissions because they cause the release, to the atmosphere, of the carbon stored in forests in the form of CO_2 and other GHGs, such as methane.

[1] The UNFCCC distinguishes five carbon pools in forests: aboveground living biomass, belowground living biomass, litter, dead wood, and soil.

Vigorous young forests may sequester a great deal of carbon as they grow. In contrast, the vegetation and soils of old-growth forests typically store large quantities of carbon but add to these stocks only slowly, if at all.

Forests are also **sources** of GHG emissions, mainly CO_2. Deforestation and forest degradation account for an estimated 17 percent of global GHG emissions.[2]

Climate change and increased climate variability have both direct and indirect effects on forests and forest-dependent people. For example, increased winter temperatures combined with fire suppression have led to massive population increases of the mountain pine beetle in Canada, resulting in the premature deaths of millions of trees. Similarly, a disturbing synergy between forest degradation caused by poor logging practices, forest fragmentation and increasingly severe droughts has rendered many Amazonian and Southeast Asian forests more fire-prone. In both boreal and tropical regions, climate change is increasing forest susceptibility to stresses that have long been present but previously posed a lesser threat. When forests and associated social systems are unable to cope with the direct and indirect stresses associated with climate change, they are said to be vulnerable to it.

The rate of climate change varies at both small and large geographical scales and generally increases with distance from the equator. Locally, the rates and directions of climate change vary with topography and proximity to large water bodies. Forest species and forest communities vary in their resistance and resilience to climate change and in their adaptive capacity. To cope with climate change, species will need to adapt to the changed conditions or migrate to areas where suitable conditions prevail. The ability of a species to migrate will depend on its capacity to disperse and on the connectivity of suitable habitat. The risks of species loss and ecosystem disruption will vary geographically and over time. It is concerning that neither climate nor species respond linearly to changing conditions but, rather, tend to react abruptly at certain thresholds or tipping points. Forest managers should keep this in mind while recognizing that thresholds are hard to predict.

Societies, and communities within them, differ in the extent to which they are vulnerable to climate change. The most vulnerable are those that are already stressed by poverty, have limited options for employment or income generation, and depend directly on rainfed agriculture or forests for their livelihoods.

ADAPTATION AND MITIGATION IN FORESTRY

Adaptation and **mitigation** are the two main responses to climate change. They are two sides of the same coin: mitigation addresses the causes of climate change and adaptation its impacts (Box 3).

In the forest sector, adaptation encompasses changes in management practices designed to decrease the vulnerability of forests to climate change and interventions intended to reduce the vulnerability of people to climate change.

---

[2] IPCC (2007) *Climate change 2007: synthesis report. Contribution of working groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. R.K. Pachauri & A. Reisinger, eds. Geneva, Switzerland, Intergovernmental Panel on Climate Change.

BOX 3
Adaptation and mitigation

Climate change **adaptation** actions consist of adjustments in natural or human systems in response to the actual or expected impacts of climate change to avoid harm or exploit opportunities.

Climate change **mitigation** actions are measures to help stabilize or reduce the concentration of GHGs in the atmosphere. They include actions to reduce human-induced GHG emissions or increase removals of GHGs from the atmosphere.

In short, adaptation addresses the risks and effects of climate change, while mitigation addresses human-induced causes of climate change.

Mitigation strategies in the forest sector can be grouped into four main categories: reducing emissions from deforestation; reducing emissions from forest degradation; enhancing forest carbon sinks; and product substitution. Substitution comprises the use of wood instead of fossil fuels for energy and the use of wood fibre in place of materials such as cement, steel and aluminium that involve the emission of larger quantities of GHGs.

Climate change mitigation measures, including in forests, are urgently needed to help reduce anthropogenic human-induced interference with the climate system, but such measures will only begin to have an effect on global mean surface temperature decades from now. For this reason, adaptation measures in forests to secure the continued delivery of forest goods and ecosystem services will be required for many years to come.

WHAT DOES CLIMATE CHANGE MEAN FOR FOREST MANAGERS?

Climate change jeopardizes the capacity of forest managers to achieve their objectives and to help meet the forest-related needs of society. Forest managers will need to adjust their management objectives and practices to reduce vulnerability and to facilitate adaptation to climate change, both of forests and of the people who depend on the goods and ecosystem services that forests provide. Forest managers should aim to optimize the potential benefits of climate change by taking advantage of policy incentives and financial support mechanisms for climate change adaptation and mitigation.

Managers aiming to minimize the impacts of climate change must deal with uncertainties in the extent and nature of climate change and climate variability, differences in the time scale of impacts, and the costs associated with changing management practices. While global climate models can project broad patterns of climate change at the global and regional levels with some certainty, projections of climate change at the subnational and especially local levels are likely to be less accurate. Climate variability and extreme climatic events are very difficult to predict with confidence. This uncertainty poses

challenges for forest managers aiming to undertake adaptation and mitigation measures. Forest managers may need to "hedge their bets" by managing for a wide range of change and adopting "no regrets" options that are consistent with good practice and will yield climate change adaptation and mitigation benefits.

Increasingly, forest managers need to be aware of the current and potential impacts of climate change. Some effects will be direct, such as on water availability and the rate of tree growth. Other effects will be the result of modified disturbance regimes (e.g. fire, pests and storms), or will be driven by economic and social changes caused by climate change, such as population movements and changes in markets (e.g. increased demand for biofuels to replace fossil fuels).

The Fouta Djallon Highlands in the centre of Guinea. Effective adaptation and mitigation strategies are required in response to climate change impacts in mountain regions.

Forest managers will also need to be aware of the incentives available to undertake climate change adaptation and mitigation measures. These may be policy incentives instituted by government, or market incentives, such as carbon credits or demand for bioenergy. Forest managers will need to understand the evolving climate-related policy, legal and regulatory environment, which is likely to change, in order to comply with new laws and regulations and to capitalize on financial opportunities.

As climatic conditions move beyond historical ranges, adaptation and mitigation will require the adjustment of management objectives, approaches and monitoring systems. Fortunately, SFM (discussed in greater detail in Chapter 3) is consistent with climate change adaptation and mitigation and provides a comprehensive framework that can be adapted to changing circumstances. Forest managers will need to factor climate change into their planning and to adjust their management practices accordingly. They will also need to put greater emphasis on risk management and to weigh the costs of changes in forest management against the likely benefits, keeping in mind that the costs of climate change adaptation measures are likely to increase, the longer they are delayed.

A rural landscape in Ecuador. Some impacts of climate change require managers to look beyond their management units. Adopting a landscape approach can help to identify forest adaptation and mitigation measures that will provide the best economic, social and environmental outcomes.

3. Sustainable forest management and related approaches for effective climate change responses

SUSTAINABLE FOREST MANAGEMENT

SFM is a universally accepted concept that guides forest policies and practices around the world. It constitutes an overarching approach to forest management, and its implementation requires, at the national or subnational levels, enabling policies, laws and institutions and, on the ground, the application of sound management practices based on good science and traditional knowledge. SFM can be applied in all types of forest, regardless of the objective(s) of management (e.g. production, conservation, protection and multiple use). In 2007, the United Nations General Assembly adopted language on SFM that describes the concept and lists the elements it encompasses (see Box 4).

Efforts worldwide to advance towards SFM have provided a wealth of knowledge, experience, best-practice guidance, tools, mechanisms and partnerships that can be applied to help meet climate change challenges. Using SFM as an overall framework helps to ensure that adaptation and mitigation measures are synergistic and balanced with other forest management objectives and take into consideration the economic, social and environmental values of forests.

BOX 4

Sustainable forest management

In Resolution 62/98, the United Nations describes SFM as a dynamic and evolving concept that "aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations".

It recognizes the seven thematic elements of SFM as:

- extent of forest resources;
- forest biodiversity;
- forest health and vitality;
- productive functions of forest resources;
- protective functions of forest resources;
- socio-economic functions of forests;
- legal, policy and institutional framework.

Recognizing that countries manage their forest estates for multiple socio-economic, productive and environmental functions, forest-related climate change adaptation and mitigation efforts on the ground require a comprehensive approach, sound policies, and appropriate legislative and governance frameworks.

Adaptive management

Adaptive management is a dynamic approach to forest management in which changing conditions are monitored and practices adapted accordingly. Adaptive management combines planning, implementation, monitoring and the modification of resource management in response to monitoring. It explicitly addresses complex and uncertain situations and is widely seen as part of an appropriate response to climate change and other environmental change.

Forest officers at work in forest in the United Republic of Tanzania. Monitoring individual trees, not just forests as a whole, is important for understanding species-specific sensitivity to climate change.

Landscape approaches

As integral parts of broader landscapes, forests and trees contribute to the stability and vitality of ecosystems and to meeting societal needs. Integrated approaches to landscape management can increase synergies among multiple land-use objectives. By considering the perspectives, needs and interests of all stakeholders, including local communities and individual land users, landscape approaches can be instrumental in developing sustainable land-use and livelihood strategies. Stakeholder dialogue is especially important as adjustments are made to land uses and management.

Some impacts of climate change require managers to look beyond their management units. Thus, adopting a landscape approach can help to identify forest adaptation and mitigation measures that will provide the best economic, social and environmental outcomes.

Partnerships and participatory approaches

Partnerships and participatory approaches recognize the importance of involving all forest stakeholders in the management or co-management of forest resources. Forest stakeholders comprise all people who depend on or benefit from forests and those who decide on, control or regulate access to forests. Partnerships and participatory approaches can operate at a range of levels, from national to local, and may include state and local authorities, forest extension agencies, forest-dependent communities, non-governmental organizations (NGOs), private-sector entities, research and academic organizations, and forest managers.

Partnerships and participatory approaches will be essential for successful management responses to climate change. Chapter 4 indicates the level of participation required for the implementation of recommended management actions. More than ever, forest managers will need to cultivate and participate in existing and new forest partnerships.

GLOBAL, REGIONAL AND NATIONAL POLICIES ON CLIMATE CHANGE

Forest managers are affected by climate change policies made at the subnational, national, regional and global levels. The United Nations Framework Convention on Climate Change (UNFCCC), which has been ratified by 195 countries, sets global climate change policy. Some regional political entities (e.g. the European Union) have set regional policies on climate change, and there are also regional cooperative programmes to support national action on climate change.[3] National climate change policies are influenced by global and regional policies but are tailored to national circumstances. Forest managers should be aware of policy developments that will affect them directly or indirectly.

Parties to the UNFCCC have agreed to undertake adaptation and mitigation actions and to report on their actions through periodic national communications and on their GHG emissions and removals through national GHG inventories. Parties to the UNFCCC are negotiating a new legal instrument designed to supersede the Kyoto Protocol that will be applicable to all parties and will take effect in 2020.

[3] For example, on REDD+ in the Congo Basin.

©FAO

A forest officer talks with community members in the municipality of Samaipata, Bolivia (Plurinational State of). Partnerships and participatory approaches will be essential for successful management responses to climate change.

In 2010, the Conference of the Parties to the UNFCCC adopted a decision on reducing emissions from deforestation and forest degradation and on the conservation of forests, sustainable management of forests, and enhancement of forest carbon stocks, usually known as REDD+. REDD+ is designed as a national (or in some cases subnational) mechanism that would provide positive incentives to countries achieving verified emissions reductions or carbon removals in forests at the national level. The accessibility of benefits from REDD+ activities to individual forest managers would depend on the arrangements in place in the country for REDD+ benefit-sharing.

Another important decision made by the Conference of the Parties to the UNFCCC in 2010 was to establish the Green Climate Fund, which is designed to provide financial support to developing countries to undertake adaptation and mitigation actions. A number of other financial mechanisms have also been established to support such actions.

Voluntary carbon markets offer a means by which forest managers can sell carbon credits for carbon sequestered by their forests. The scope for voluntary market projects in the forest sector is wide, including not only afforestation and reforestation but also, for example, forest restoration and avoided deforestation (i.e. preventing a forest from being deforested). Forestry projects are favoured by the voluntary carbon market because of their additional social and environmental benefits (known as co-benefits).

Community members engage in a participatory rural appraisal of local resources in Cambodia. The goal of vulnerability and risk assessments is to identify which groups, ecological systems and infrastructure are most vulnerable to climate change.

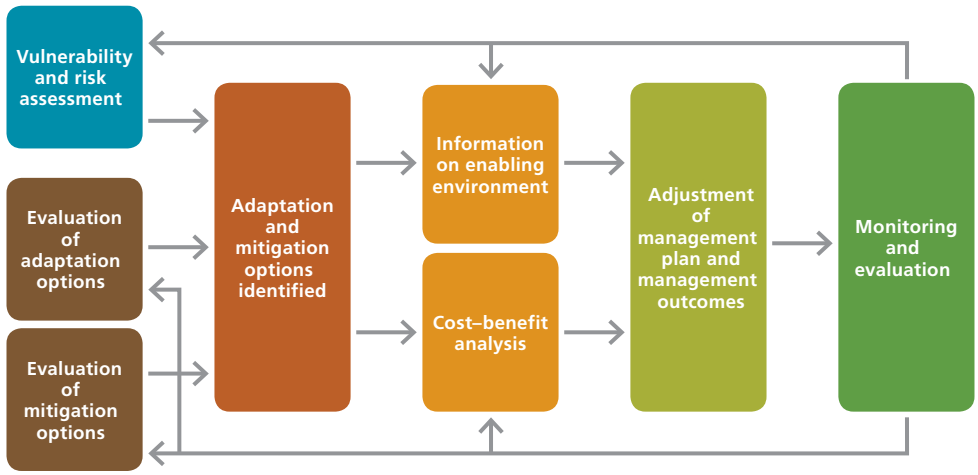
© FAO/KATA WAGNER

4. Management responses to climate change

Forest managers should assess the costs, benefits, trade-offs and feasibility of climate change adaptation and mitigation actions and consider how these might affect – positively or negatively – the achievement of management objectives. The general process for undertaking such an assessment (as shown in a simplified form in Figure 2) involves the following steps:

- Assess the risks that climate change poses to the achievement of the management objectives of the FMU (i.e. the delivery of desired forest products and ecosystem services).
- Identify the forest-dependent people and forest areas that are most vulnerable to the likely impacts of climate change.
- Identify forest management measures that would reduce the vulnerability of forest-dependent people and forest areas to climate change or would increase their adaptation capacity, and estimate the costs of implementing these measures in the FMU.
- Gather information on policies, institutions, financial and technical incentives, the availability of support for undertaking adaptation measures, and the requirements to obtain access to such incentives and support.
- Identify the available options at the FMU level for contributing to climate change mitigation, including the actions to be taken, the schedule for taking such actions, the costs involved and the mitigation benefits that could be expected to materialize.
- Gather information on policies, financial and technical incentives and the availability of support for undertaking mitigation actions and the requirements for gaining access to such incentives and support.
- Conduct a cost–benefit assessment to identify the most cost-effective adaptation and mitigation options, taking into consideration synergies and trade-offs between them.
- Adjust the forest management plan and other planning tools to accommodate the adaptation and mitigation measures and to incorporate the knowledge gained through assessments of vulnerability, risk and options for mitigation.
- Identify capacity development needs and opportunities to implement adaptation and mitigation measures.
- Adjust management practices to achieve the specified adaptation and mitigation goals.
- Adjust forest monitoring and evaluation procedures to allow for additional requirements related to the specified adaptation and mitigation actions.
- Develop mechanisms to ensure the continual adaptation of forest management in the light of monitoring and evaluation.

FIGURE 2
The process for integrating adaptation and mitigation measures into forest management plans and practices



The following sections provide guidance on what forest managers should consider in the assessment of vulnerability, risk, mitigation options, and actions for adaptation, mitigation and monitoring in response to climate change. Annex 2 presents knowledge tools and references that can guide forest managers in conducting assessments of vulnerability, risk and mitigation options as well as in modifying management practices for adaptation and mitigation.

©FAO/GIULIO NAPOLITANO

Farmers transport fuelwood alongside forests planted as part of the Great Green Wall for the Sahara and Sahel Initiative. This initiative supports the most vulnerable communities in these regions in the sustainable management and use of their natural resources while contributing to climate change mitigation and adaptation.

VULNERABILITY AND RISK ASSESSMENT OF CLIMATE CHANGE IMPACTS AND MITIGATION OPTIONS

The scope and scale of assessments of vulnerability, risk and mitigation options carried out by the forest manager will depend on the following factors:

- the focal area of the assessments;
- the time available for the assessments;
- the questions to be addressed by the assessments and the decisions the assessments should support;
- the funds available for the assessments;
- the level of support from key stakeholders;
- the value of the resources that may be at risk.

Vulnerability and risk assessments

The goal of vulnerability and risk assessments is to identify who (i.e. which groups in a population) and what (i.e. which ecological systems and human-created infrastructure) are vulnerable to climate change impacts and the risks of negative impacts. Climate change vulnerability assessments of forests and forest-dependent communities can involve a range of approaches and sources of information, such as local knowledge, expert opinion and detailed data collection and technical analyses. The first step of any such assessment is to identify the likely impacts on ecosystems and their ramifications for human well-being. Once the likely impacts have been identified, the vulnerability to them of forests and forest-dependent communities can be assessed and appropriate actions taken.

At the national level, government agencies and research institutions that collect and analyse climate-related information are likely to be involved in downscaling global and regional climate models to national and subnational levels. They are also likely to carry out vulnerability assessments for various sectors (e.g. agriculture and forestry) and population groups.

While global surface temperatures are generally rising, predicting climate change and its impacts at the local level remains very difficult. Forest managers should obtain available information from relevant government agencies and research institutions or other sources, including local meteorological data. They should also gather information about the impacts of climate change on forests from their own field observations and forest inventories, other monitoring systems, and local residents. The collected information can be used to make predictions about impacts on product yields and the provision of ecosystem services.

Vulnerability and risk assessments generally involve a climate sensitivity analysis and an evaluation of the capacity of ecosystems and communities to adapt to climate change. To analyse the sensitivity of forests and forest-dependent communities to changing climatic conditions, the forest manager, in partnership with other stakeholders, should determine:

- the current and expected stresses on the forest area;
- the known climatic conditions, and how these affect the forest area;
- the projected change in climatic conditions and the likely impact(s) of these changes on forests;

- the expected changes in stresses on a system as a result of the likely impacts of climate change.

To evaluate the capacity of a forest area and forest-dependent communities to adapt to climate change, the forest manager, in partnership with other stakeholders, should consider:

- the current capacity of a forest or forest-dependent community to adapt to climate change;
- constraints on the capacity of a forest or forest-dependent community to accommodate changes in climatic conditions;
- whether the projected rate of climate change is likely to be faster than the capacity of a forest or forest-dependent community to adapt;
- ongoing efforts in the locality to address the impacts of climate change on forests and forest-dependent communities.

The final step in vulnerability and risk assessments is to combine the findings of the climate sensitivity analysis and the evaluation of capacity to adapt to determine the extent to which forests and forest-dependent communities are vulnerable to climate change. Vulnerability and risk assessments can be qualitative (e.g. high, medium or low) or quantitative, depending on the information and resources available.

Vulnerability and risk assessments should not be considered static because existing vulnerabilities will change and new vulnerabilities will emerge as a result of:

- climate change impacts on the frequency, intensity, duration and extent of specific climatic events;
- the emergence of threats, such as new invasive species or diseases;
- new information on how climate change may affect forests;
- the implementation of adaptation and mitigation actions;
- changes in the forest-dependent community's size, economy, preferences or other factors that might influence its vulnerability to climate change.

Assessment of mitigation options

Forest managers must weigh the costs of climate change mitigation against the benefits and identify the negative and positive impacts on the achievement of other desired forest management objectives. Forest managers should aim to maximize the economic and social benefits and minimize the social and environmental costs of adjusting forest management plans for climate change mitigation.

Mitigation options available to forest managers can be grouped into four general categories:

- maintaining the area under forest by reducing deforestation and by promoting forest conservation and protection;
- increasing the area under forest (e.g. through afforestation and reforestation);
- maintaining or increasing carbon density at the stand and landscape scales by avoiding degradation and managing timber production forests so that, on average, carbon stocks remain constant or increase over time, and through the restoration of degraded forests;
- increasing off-site carbon stocks in harvested wood products (e.g. displacing fossil fuels with woodfuels).

The designation of forests for conservation (specifically as parks and other protected areas) or protection (specifically for the protection of soil and water resources), where timber extraction is prohibited or limited, cannot be considered a mitigation action unless such forests would otherwise have been cleared or degraded.

To assess mitigation options, forest managers need information on at least the following:

- national policies and regulations related to incentives to undertake (and potential disincentives for *not* undertaking) mitigation actions;
- mitigation options that are feasible, given existing forest cover and current forest management objectives;
- the potential for GHG emissions reductions (i.e. the potential to maintain or increase forest carbon stocks) over time as a result of adjusting management plans or practices;
- requirements for measuring forest carbon and verifying mitigation;
- requirements for ensuring that no "leakage" (i.e. changes in the management of an FMU that result in GHG emissions elsewhere) is occurring;
- the capacity to provide evidence that the forest manager would not have undertaken the mitigation measure anyway – i.e. that it was "additional" to business as usual in managing the forest;
- the actual and opportunity costs, and the benefits, of implementing and monitoring the mitigation actions;
- the likely positive and negative economic, social and enviromental side-effects of implementing the mitigation actions.

©FAO/AMI VITALE

Fishermen on Lake Victoria, Bondo, Kenya. Climate change impacts are cross-sectoral, which means that to prepare for them, coordination is needed among government agencies, NGOs and stakeholders in multiple sectors.

A GUIDING FRAMEWORK FOR ADAPTATION ACTIONS

After completing assessments to determine how forest ecosystems and forest-dependent communities will be affected by changing climatic conditions, the next step is to examine the management options that would reduce vulnerability, increase resilience, and enable adaptation to climate change and climate variability.

In the tables that follow, actions for climate change adaptation are presented to address risks or impacts on: forest productivity; biodiversity; water availability and quality; fire; pests and diseases; extreme weather events; sea-level rise; and economic, social and institutional considerations. These actions are intended to support forest managers and other stakeholders in dealing with the challenges of adapting to climate change. They are drawn mostly from existing forest management practices, but the aim is to give greater consideration to spatial and temporal aspects of climate change, the protection of forest communities, management measures to reduce vulnerability to expected changes and extreme climate-driven disturbances, and increased flexibility in forest management plans to deal with climate-related uncertainties and surprises.

Many impacts of climate change cannot be addressed by forest managers at the FMU or total forest area scale due to their nature, jurisdictional issues and financial costs. Effective responses to some climate change impacts will require action at a landscape, regional or national level. Climate change impacts are cross-sectoral, which means that to prepare for them, coordination is needed among government agencies, NGOs, and stakeholders in multiple sectors (e.g. natural resources, public health and safety, emergency and disaster risk management, recreation, and economic development). Some of the key stakeholder groups are defined below.

State, district or local authority
The decision-making body of government responsible for the management of forests at the state (national or subnational), district or local level.

Forest manager
An individual or entity responsible for overseeing the management of forest lands or the use and development of forest resources to meet specific objectives.

Forest-dependent community
An indigenous, tribal or local community that depends on forests for subsistence, employment and trade in the form of fishing, hunting, shifting agriculture, the gathering of wild forest products, and other activities.

Forest research organization
An entity, such as a university or research institute, whose primary goal is to conduct research or experimental development related to forests and natural resource management.

Forest extension agency
An institution in the public sector, the private non-profit sector, or the private for-profit sector that brings together specialists, experts and practitioners familiar with forest issues to help implement forest policies in the best and most efficient manner and with the aim of fulfilling the economic, social and environmental roles of forests.

Academic institution
An institution dedicated to education and research.

Forest producer and trade associations
Includes informal groups, community user groups, tree-grower associations, forest-owner associations, cooperatives and companies covering various forest products (wood and non-wood) and ecosystem services. Forest producer and trade associations range from small community-based groups of individuals to large umbrella groups and federations that represent many smaller organizations.

Civil society (NGOs, community associations, etc.)
Non-governmental and not-for-profit organizations that express the interests and values of forests and forest-dependent people based on ethical, cultural, political, scientific, religious or philanthropic considerations.

New knowledge, skills and expertise may be needed to enable timely and well-informed decision-making and action. Forest managers and other stakeholders should have sufficient knowledge and expertise to undertake vulnerability and risk assessments; design and revise management plans; implement actions to adapt to and mitigate climate change; and monitor the impacts of climate change and the outcomes of climate change actions.

Forest productivity

Climate change will affect forest growth and production directly through an increase in the concentration of atmospheric CO_2 ("carbon fertilization") and changes in climate, and indirectly through complex interactions in forest ecosystems induced by changes in temperature and precipitation. In the temperate and boreal zones, the positive effect on growth of warmer temperatures and longer growing seasons could be cancelled out by a decline in precipitation and an increase in decomposition rates. Although carbon fertilization has already increased productivity in some tropical zones, this effect is likely to be temporary. Particularly in drylands, increases in temperature are expected to increase plant stress in plants, reducing their productivity and leading to dieback.

Changes in forest productivity will affect the production of wood and non-wood forest products. This will affect the income that can be earned from commercial forests and the availability of products for forest-dependent people, who may use such products for household consumption and sale.

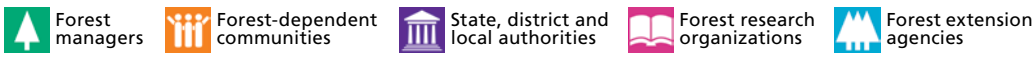
Adaptive forest management will be essential to reduce forest vulnerability and to maintain forest productivity. Adaptation measures might include, for example, the selection of heat-tolerant and drought-tolerant species in planted forests, the use of planting stock from a range of provenances, the underplanting of tree varieties adapted to expected climatic conditions, and the assisted natural regeneration of adapted species and varieties.

©FAO/VASILY MAKSIMOV

Logs are extracted from a forest in Leshoz Saba, the Russian Federation. Climate change could reduce the yields of forest products due to changes in temperature and precipitation. Forest managers may need to adjust management plans to account for reduced yields, adapt harvesting schedules, and modify silvicultural treatments, among other adaptations.

FOREST PRODUCTIVITY: recommended adaptation actions

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
Reduced yields of forest products due to changes in temperature or precipitation	Adjust management plans to account for reduced yield expectations	
	Adjust harvesting schedules (e.g. hunting seasons, cutting cycles and non-wood forest product collection)	
	Modify silvicultural treatments (e.g. thinning, pruning and vine-cutting)	
	Modify rotation lengths or cutting cycles, taking into account cost, technological and market implications	
	Match species and varieties to current and projected site and climatic conditions. In *planted forests*, use species and varieties that are adapted to new and anticipated conditions. In *natural* and *semi-natural forests*, favour varieties and species that are adapted to current and predicted future climatic conditions by selecting and retaining seed trees and through enrichment planting	
	Adapt primary management objectives to allow the use of the existing or affected crop for other purposes (e.g. switching from timber production to pulp, woodfuel or poles)	
	Invest in measures (e.g. reduce grazing and maintain organic matter) to improve soil structure and reduce water stress	
	Manage vegetation (e.g. control weeds and understorey vegetation) to reduce drought stress	
	Consider diversifying management objectives to include other products and income-generating activities	
Increased yields of forest products due to higher temperatures or precipitation	Adjust harvesting schedules (e.g. hunting seasons, cutting cycles and non-wood forest product collection)	
	Modify rotation lengths or cutting cycles, taking into account cost, technological and market implications	
	Adjust silvicultural treatments accordingly (e.g. thinning, pruning and vine-cutting)	
	Manage vegetation (e.g. control weeds and understorey vegetation) to reduce competition with target species	



Biodiversity

Forests are important repositories of terrestrial biodiversity, and this diversity will be directly and indirectly affected by changing climatic conditions. Individual species can be important for forest functioning, and the loss of biodiversity can affect the rate at which forests sequester carbon. Since forest ecosystems are important carbon sinks, the loss or deterioration of biodiversity has serious implications for climate change.

Climate change will have a variety of impacts on the distribution of forest species and populations and effects on ecosystem function and composition. In general, it is expected that forest habitats will shift towards the north and south poles and move upward in elevation. Forest biodiversity will be forced to adapt to such shifts, and there are likely to be changes in the types of forest and the composition of species. Vulnerable species and populations could be lost locally, and it is predicted that species extinctions will occur. The higher projected incidence of extreme climatic events, such as floods, storms and droughts, will further affect forest flora and fauna and leave forests more prone to disturbances such as fire and disease.

Forest managers can undertake several measures to ensure that forests maintain or improve their capacity to provide products, conserve biodiversity, safeguard species and habitats and protect soils and watersheds. These include tracking changes in flora and fauna as the climate changes, evaluating the risks to biodiversity and the associated loss of productivity, maintaining biodiversity to increase resilience, and adjusting management plans to account for these changes.

A green-billed toucan, Rhamphastos dicolorus*, in Brazil. Climate change will have a variety of impacts on the distribution of forest species and populations. Among other adaptive measures, forest managers can establish or expand and manage protected areas to conserve vulnerable species and habitat types, and protect species at the edges of their ranges.*

BIODIVERSITY: recommended adaptation actions

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
Change in the viability of species and varieties in the managed area	Adjust management plans to take into consideration changes in species distribution (e.g. reduce logging intensities and hunting pressure on affected species)	
	Manage for diverse tree composition, age and structure and understorey vegetation at the stand and landscape levels	
	Plant or promote the use of climate-adapted species and varieties	
	Establish or expand and manage protected areas to conserve vulnerable species and habitat types	
	Protect species at the edges of their ranges because they may be better adapted to new climatic conditions	
	Provide corridors of suitable size and habitat to allow species migration and otherwise maintain landscape connectivity	
	Assist the movement of species through the restoration and conservation of migration routes and the reintroduction of species	
	Adjust hunting and fishing to levels that are sustainable under new climatic conditions	
	Promote extensive grazing management for livestock to prevent overgrazing and encourage regeneration	
Species moving into a management area	Where appropriate, promote the establishment and management of beneficial species moving into a forest area	
	Put measures in place to detect and control invasive species	
Aquatic species declining	In areas of increased rainfall, decrease the risk of erosion (and consequent decrease in water quality) by increasing the protection of riparian zones and watersheds	
	Maintain or increase shade in riparian zones where increased temperatures pose a risk to aquatic species (e.g. by increasing tree cover and favouring fruit-bearing species)	

Table continues on next page

Table continued

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
	In areas of reduced rainfall, maintain connections between waterways to avoid drying up	
	Implement measures to ensure proper drainage and erosion control in areas subject to waterlogging (e.g. adjust the construction and maintenance of roads and stream crossings)	
Forest fragmentation	Maintain landscape connectivity and establish corridors through restoration and reforestation	

Forest managers; Forest-dependent communities; State, district and local authorities; Forest research organizations; Forest extension agencies

BOX 5

Matching genetic variation with the new climate in the Sahel

Knowledge of population-level environmental responses in indigenous tree species planted by small-scale farmers in Africa is receiving a boost through trials established to investigate the effects of climate change. Under the Sahelian Fruit Tree Project (SAFRUIT), for example, trials on the impacts of drought stress on important trees for smallholders, such as *Adansonia digitata* (baobab) and *Parkia biglobosa* (African locust bean), are being conducted in the semi-arid West African Sahel, a region that has become drier in recent decades. In nursery experiments, populations collected from locations with differing rainfall have been exposed to a range of watering regimes, and the responses have been measured. Data on the effects of treatments on root development, seedling vigour and other important adaptive characteristics will inform subsequent germplasm distribution strategies.

In some cases, climate change considerations for seed distribution are already being taken into account in the Sahel, such as for *Prosopis africana,* a valuable timber tree. Field trials measuring growth, survival and wood density in relation to rainfall patterns across seed collection sites led to the recommendation that germplasm transfers of the species should be undertaken in a single direction, from drier to (currently) wetter zones.

Global circulation models used to explain environmental changes in temperature and precipitation vary in their predictions of rainfall in the Sahel, with some indicating drier and others wetter conditions. Given such uncertainty, an emphasis in the region on matching seed sources to the more limiting scenario of a drier future climate would appear to be the most risk-averse option.

See www.safruit.org

Water availability and quality

Climate change will alter precipitation and runoff patterns. In large parts of the world, this will mean a reduced availability of water – in terms of quantity, quality, timing and distribution. Forested watersheds reduce storm runoff, stabilize stream banks, shade surface water, cycle nutrients and filter pollutants. The capacity of forests to provide such services, however, will be reduced as the climate changes. Water supplies stored as snow cover in high-elevation forests are particularly vulnerable to climate change and are projected to decline. Earlier spring runoff and reductions in low flows will reduce downstream water availability, and higher water temperatures and increased flooding

Integrated watershed management for sustainable soil and water resources in India. Forested watersheds reduce storm runoff, stabilize stream banks, shade surface water, cycle nutrients and filter pollutants, but their capacity to provide such services will be reduced as the climate changes. Forest managers can take an integrated approach to watershed management to reduce the impacts of climate change on water quality and quantity.

and drought will affect water quality and exacerbate water pollution. Besides these direct effects on the hydrological cycle, climate change is expected to increase the frequency, extent and magnitude of floods, droughts, forest fire and forest mortality.

Forest managers should anticipate and respond to these threats to ensure the sustained protection and provision of water-related services. Managers should use existing information to identify watersheds and water-related services that are most vulnerable to climate change. Sound forest management and the restoration of degraded areas will reduce erosion and increase slope stability and resilience to natural hazards and therefore will contribute to the provision of a regulated water flow. Adaptation strategies for the hydrological cycle should be based on landscape considerations and involve all relevant actors and sectors.

WATER AVAILABILITY AND QUALITY: recommended adaptation actions

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
Water scarcity/ stress and increased drought	Sustainably manage water resources to ensure water storage, the regulation of water flow and the provision of water to downstream users (e.g. through the protection of forest catchment areas, water harvesting and the protection of streams)	
	Promote water infiltration of the soil, the water-storage capacity of soils and water-trapping in catchments, storage lakes and irrigation channels (e.g. using check dams, retention ditches and contour and strip cropping)	
	Undertake watershed management to ensure the delivery of clean and reliable water	
	Select water-efficient and drought-resistant species and varieties for afforestation and reforestation	
	Reduce evapotranspiration and competition for water by vegetation management (e.g. thinning, pruning and planting deciduous species)	
	Maintain forests on ridge tops to promote mist and fog interception, reduce surface runoff and increase water infiltration of the soil	
	Promote afforestation and reforestation to protect against wind erosion (e.g. establish windbreaks)	

Table continues on next page

Table continued

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
Increased precipitation and changes in seasonal rainfall patterns	Adjust harvesting schedules to reduce erosion and siltation, taking into consideration the terrain, forest cover, road networks, the type of machinery used and the presence of streams and other waterways	
	Implement measures to ensure proper drainage and erosion control in areas subject to waterlogging (e.g. provide drainage channels and adjust the construction and maintenance of roads and stream crossings to ensure proper drainage)	
	Maintain or increase vegetation cover in erosion-prone and flood-prone areas (e.g. use contour and strip cropping)	
	Consider excluding harvesting in areas subject to waterlogging	
	Plant or encourage species and varieties capable of benefiting from or withstanding increased rainfall and waterlogging. In the case of mangrove forests, consider interventions to maintain salinity levels and adjust to increased alluvial deposits	

 Forest managers
 Forest-dependent communities
 State, district and local authorities
 Forest research organizations
 Forest extension agencies

Fire

The risk of forest fire is expected to increase with increased temperatures and decreased precipitation due to climate change. The consensus view among climate change scientists is that the frequency, severity and area affected by forest fire will increase. Forest fires are a substantial source of emissions of GHGs and particulate matter and are closely linked to deforestation and forest degradation.

Integrated fire management is an essential part of climate change adaptation and mitigation strategies. It encompasses fire prevention, preparedness and suppression, and forest restoration after fire. Forest managers will need to intensify and adapt their fire management practices in response to climate change.

Promoting fire-smart landscapes that are resistant to fire spread and resilient to its occurrence is an important part of fire management. This may be done, for example, by treating fuels in fire-prone vegetation types or by decreasing the importance of those vegetation types in the landscape.

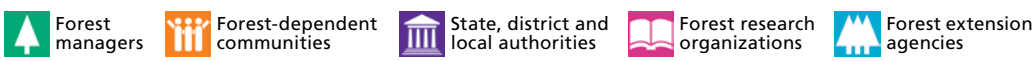
FIRE: recommended adaptation actions

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
Increase in the number, frequency, size or severity of wildfire	Obtain available information on the increased risk of fire due to climate change (e.g. from research organizations, forestry associations and agencies, and local and regional governments)	
	Assess the impacts of climate change on fire occurrence and behaviour at the landscape level	
	Support the development of policies and plans for forest fire management	
	Ensure the inclusion of integrated fire management in local and regional planning	
	Integrate fire management considerations with forest management planning (e.g. assess the quantities of potential fuel during monitoring to assess fire risk)	
	Establish or improve early-warning and rapid-response systems for fire using electronic (e.g. cell phone, radio, television and email) and social media, as well as traditional communication means	
	Employ an integrated fire management approach that emphasizes landscape planning	

Table continues on next page

Table continued

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
	Protect fire-sensitive ecosystems through landscape planning and management, with a prevention focus	
	Modify landscape structure to impede fire spread (e.g. establish networks of fire breaks; manage for a mix of stand ages and stocking densities; thin stands; create mosaics of controlled burns; select fire-tolerant species)	
	Maintain and restore appropriate fire regimes to increase forest resistance to severe fire	
	Use prescribed burns and "let burn" policies in fire-maintained ecosystems for fuel management and to achieve ecological management objectives	
	Minimize the harmful environmental impacts of fire suppression activities	
	Undertake salvage logging to remove dead or damaged trees that pose a fire risk	
	Promote fire-smart landscapes (e.g. by planting fire-resistant tree species as firebreaks)	
	In production forests, employ reduced impact logging to limit logging gap size and minimize logging damage and waste to reduce vulnerability to fire	
	Reduce or avoid the burning of logging residues in fire-prone areas	
	In areas where slash-and-burn agriculture poses a fire risk, encourage the modification of burning practices (e.g. restrict burning to seasons where the risk of fire is low)	
	Avoid draining peatlands and other wetlands with organic matter-rich soils	
	Recognize, respect and promote the use and dissemination of traditional and ancestral fire management practices	
	Monitor methods and techniques for fire management for future planning, and assess the results of these methods	



Integrated fire management should be addressed at the landscape level. For example, agricultural burnings should take place before the peak of the dry season and before surrounding landscapes become fire-prone. This type of management is often beyond the scope of forest managers, who are encouraged to engage with local and community groups and networks at the landscape level. It is imperative that all stakeholders are involved in fire management.

BOX 6

The Ferny Creek Bushfire Alert System

The Ferny Creek Bushfire Alert System (FCBAS) in Victoria, Australia, is an emergency communication system that broadcasts via three independent, strategically located sirens. Operational in declared fire-danger periods, the purpose of the FCBAS is to sound an alarm when, according to predetermined criteria, there is a potential threat to the community. This is necessary because steep, densely forested terrain severely restricts visibility and normal visual warnings of bushfires. The alert is intended to provide residents with essential extra minutes in which they can implement their predetermined fire-safety plans. A systemic community education campaign has proved to be highly effective.

The FCBAS is an example of using a combination of old and new technologies and its strength is its simplicity. An abundance of "quality" information is available to the community, and the siren system provides a simple "quantity" message. It acts as an initial alert, prompting people to inform themselves about the cause of the alarm and to implement fire-safety plans. FCBAS is not a signal to evacuate. The siren system has alternative power supplies and battery backup, meaning that a loss of electricity supply will not compromise the alert capability.

The community has its own initiatives to expand its education on the alert system and its knowledge base on fire management, so that all responses to a siren and a bushfire emergency will be appropriate and planned. The importance of understanding bushfire safety messages is explained to new residents. Reliable, up-to-date information is provided to ensure fire preparedness, management and prevention.

The FCBAS project was evaluated by the Victorian Office of the Emergency Services Commissioner and has provided a benchmark for community warning systems within Victoria. The FCBAS provides opportunities for the engagement and empowerment of the local community. It enables partnerships between local emergency service agencies and local, state and federal governments, and it encourages residents to understand their individual roles in fire management.

Members of the Khargistai-Bayanburd Forest User Group clear tree branches from the forest floor to prevent fire. The risk of forest fire is expected to increase with increased temperatures and decreased precipitation due to climate change. Forest managers should employ an integrated fire management approach that emphasizes landscape planning, promotes fire-smart landscapes and protects fire-sensitive ecosystems.

Pests and diseases

Climate change, particularly extreme weather events, can affect forest pests and the damage they cause *directly* by influencing their development, survival, reproduction and spread and by altering host defences and susceptibility, and *indirectly* by altering ecological relationships such as changing the abundance of competitors, parasites and predators. Insects and diseases may be early indicators of local climate change, and there are already numerous examples where insect and pathogen lifecycles or habits have been altered by local or larger-scale climate change (e.g. mountain pine beetles in North America and pine and oak caterpillars in Europe).

The management of pests and the prevention of their spread will help ensure that forests remain healthy in the face of climate change. The most effective way to deal with forest pests is through integrated pest management, which can be defined as a combination of ecologically and economically efficient and socially acceptable prevention, observation and suppression measures designed to maintain pest populations at acceptable levels. Prevention may include the selection of species and varieties to suit site conditions; and the use of natural regeneration and planting and thinning practices that reduce pest populations and favour natural enemies. The careful monitoring of pest populations, for example through visual inspection and trapping systems, will help determine when control activities are needed.

A beetle from the Cerambicidi family, of which there are about 20 000 species, all of them leaf-eaters. The larvae of Cerambicidi feed mainly on wood from trees and can cause serious damage to wood quality. There is likely to be an increased risk of outbreaks of forest pests due to climate change. Forest managers can take a number of steps to minimize this risk, such as conducting regular surveys for the early detection of outbreaks, identifying vulnerable forest areas, and employing integrated pest management to prevent and suppress attacks.

Given that pest and disease outbreaks generally extend across FMU boundaries, forest managers need to communicate and cooperate with each other and with other local and regional stakeholders. For integrated pest management to be effective, all forest workers must be trained to recognize, monitor and control outbreaks, and a formal plan and approach should be in place.

BOX 7

Catastrophic forest disturbances

The mountain pine beetle, *Dendroctonus ponderosae*, is a native bark beetle of the lodgepole pine forests of western Canada. Beetle populations build periodically to outbreak levels but, since the late 1990s, populations have grown at an unprecedented rate, attacking more than 13 million hectares of forest in the province of British Columbia. The epidemic has multiple causes, including climate change and forest management interventions. By 2015, it is expected that the mountain pine beetle will have caused the death of more than three-quarters of lodgepole pines in British Columbia – amounting to more than 900 million m^3 of timber. In British Columbia, therefore, climate change is no longer theoretical – the impacts are being felt now.

The mountain pine beetle outbreak has had many negative environmental impacts. For example, local water tables and hydrological cycles as well as plant and animal habitats have been affected. Interior forests have become a carbon source rather than a sink and are expected to remain so until 2020.

In the central area of the outbreak, efforts to contain the spread of the mountain pine beetle shifted quickly towards maximizing recovery of the economic value of killed trees. In the worst-affected areas, harvesting has focused on stands where pine represented more than 70 percent of the available timber volume. Allowable harvest levels have been raised temporarily, and policies have been changed to facilitate harvesting in these areas. Operators have moved from adjacent non-affected areas to harvest the beetle-attacked trees.

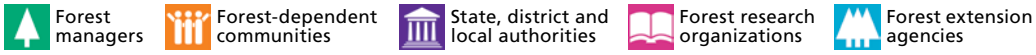
While the increase in salvage harvesting has boosted wood processing temporarily, in the longer term the beetle outbreak could have significant economic, social and cultural impacts on communities that have relied on logging and sawmilling for decades. British Columbia is investing in coalitions to increase community resilience by diversifying economic opportunities. These efforts are designed to provide long-term stability in a way that reflects local aspirations.

The mountain pine beetle epidemic has broadened the thinking and approach of British Columbia's forest managers. It has highlighted the potential for unintended consequences of human intervention in natural systems and the impacts of climate change, and it has increased recognition of the need to develop resilience in ecosystems, people and communities.

Source: www.fao.org/docrep/011/i0670e/i0670e04.htm

PESTS AND DISEASES: recommended adaptation actions

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
Increased outbreaks of insects, pathogens and invasive native and exotic plant species	Conduct regular surveys to facilitate the early detection and assessment of outbreaks	
	Identify forest areas vulnerable to pests and diseases (e.g. map vulnerable forest areas)	
	Employ integrated pest management to prevent and suppress attacks	
	Adjust harvesting schedules to harvest affected or vulnerable stands to reduce the risk of pest outbreaks	
	Minimize damage to trees during harvesting, silvicultural interventions and fires to minimize the risk of pest outbreaks	
	Maintain stand and tree health to increase resistance (e.g. by thinning to reduce water stress)	
	Encourage the introduction and maintenance of mixed-species stands to increase resistance to pest invasion and resilience	
	In forest stands, introduce and retain genotypes and varieties that are resistant and resilient to pest attack	
	Avoid pest infestations by using good phytosanitary practices (e.g. the use of gloves when handling seeds and seedlings)	
	Avoid the introduction of pests and diseases by humans, domesticated animals and heavy equipment	
	Properly dispose of infected harvesting and silvicultural waste (e.g. by controlled burning or the use of residues for bioenergy production)	
	Support awareness-raising and training exercises for forest workers to promote the early detection and management of pest and disease outbreaks	



Extreme weather events

The frequency and intensity of disturbances such as storms, floods, droughts and periods of extreme heat are projected to increase due to climate change. Forest managers can reduce the risks posed by such disturbances by maintaining stands with diverse age classes (see *Forest productivity* and *Biodiversity* above), and they can increase protection against financial losses by anticipating and preparing for disturbance events. Forest managers should also be aware of landscape-scale and interdisciplinary adaptation efforts.

Fields in Sindh Province, Pakistan, inundated by floodwaters that affected almost 20 million people in 2010. The frequency and intensity of disturbances such as storms, floods, droughts and periods of extreme heat are projected to increase due to climate change. Forest managers can reduce the risks posed by such disturbances by, for example, protecting headwaters through watershed protection and management interventions, maintaining natural vegetation in riparian zones, and designing and building infrastructure with larger safety factors.

EXTREME WEATHER EVENTS: recommended adaptation actions

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
Increased flood frequencies and intensities	Improve early-warning systems and the level of communication among local stakeholders	
	Protect headwaters through watershed protection and management interventions	
	Ensure unimpeded water flows by keeping rivers, creeks and streams free of debris and blockages	
	Maintain natural vegetation in riparian zones and avoid the channelization of headwater streams	
	Design and build infrastructure with larger safety factors (e.g. forest roads with proper drainage and dams with higher storage capacity)	
	Ensure the adequate maintenance of road networks, particularly in areas with steep slopes	
	Avoid the use of heavy equipment on steep slopes and riparian areas	
	Avoid soil compaction to maintain infiltration rates and the water-storage capacity of the soil	
Increased storm intensities and frequencies	Adjust rotation lengths and cutting cycles to minimize the risk of storm-induced damage (e.g. landslides or runoff due to reduced vegetation cover)	
	Modify harvesting regimes to improve species and stand stability	
	Avoid clear-cutting in vulnerable areas	
	Maintain or increase species and structural diversity in ecosystems to promote resistance to storm damage and resilience following damage	
	In areas experiencing increased snowfall and ice storms, consider favouring hardwood species over conifers to reduce the risk of breakage from snow and ice	
	Select wind-resistant species and promote the development of multilayered canopies	

Table continues on next page

Table continued

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
Increased likelihood and size of landslides	Adhere to established road-siting and harvesting regulations and best practices for steep slopes and other areas prone to landslides and erosion (e.g. codes of practice and guidelines)	
	Maintain continuous vegetation cover on steep slopes	
	Promote multilayered root systems by encouraging growth (e.g. through natural regeneration or planting) of deep-rooted and shallow-rooted species	
	Practice contour planting	
	Avoid soil disturbance in unstable areas	
Increased risk of coastal surges	Maintain and restore mangroves and other coastal forests as buffers	

Forest managers; Forest-dependent communities; State, district and local authorities; Forest research organizations; Forest extension agencies

©FAO/GIAMPIERO DIANA

Climate change increases the risk of landslides in the mountain regions. Understanding how this risk may change in the future and, in particular, the influence of a changing climate on the magnitude and frequency of damaging landslides will be of value to forest managers.

Sea-level rise

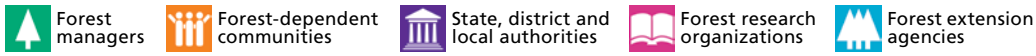
Coastal forests – such as mangroves, beach forests and some peat swamp forests and lowland moist tropical forests – play important economic, social and environmental roles. Sea-level rise due to climate change poses a threat to many natural coastal forests.

The management of coastal forests requires an integrated, multidisciplinary approach known as integrated coastal area management. Coastal forest protection and restoration are important to mitigate the impacts of climate change, while adaptive management will be needed to ensure the continued existence of coastal forests.

Newly planted mangrove seedlings in Indonesia. Sea-level rise due to climate change poses a threat to many natural coastal forests, but forest managers can take steps to reduce this threat, such as employing salt-tolerant species for restoration, reforestation and afforestation.

SEA-LEVEL RISE: recommended adaptation actions

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
Sea-level rise and storm surges	Protect or increase freshwater and sediment inputs from inland sources	
	Employ salt-tolerant species for restoration, reforestation and afforestation	
	Remove impediments to the migration of plant and animal species, or assist species in migration (e.g. managed relocation)	
	Improve early-warning systems and communication among local stakeholders	



BOX 8

Community-based tsunami early warning system in Peraliya, Sri Lanka

In Sri Lanka, initiatives have been launched to establish a centralized tsunami early-warning system. To bridge the gap between the national and the local levels, however, complementary community-based early-warning systems are also needed. Community-based systems would receive information from the National Early Warning Centre and disseminate it and sound alarms in the communities.

One community-based system is the Community Tsunami Early Warning Centre (CTEC) in the village of Peraliya on the southwest coast of Sri Lanka, an area devastated by the December 2004 tsunami. Peraliya drew media attention in the aftermath of that tsunami because a train toppled by the tsunami claimed more than 2 000 lives. CTEC currently covers five villages directly through its public-address system, and it has extended its service to the entire district of Galle through its Community Focal Point (CFP) network.

CTEC conducts community awareness and educational programmes to equip the public with knowledge and skills for emergency preparedness, and it has established volunteer teams in line with the CFP network. The volunteers in these teams have been trained to take action in an emergency and equipped with skills such as basic life support, first aid and fire preparedness. Evacuation areas have been identified and tsunami warning signs have been established as part of the community contingency plan.

CTEC has information and communications technology facilities to link with national and international warning agencies and the media. Youth selected from the community continuously monitor the system for emergency information and warnings. Operational procedures have been developed that are to be followed in an emergency.

CTEC is managed by the volunteer force in the local community of Peraliya, with the support of interested stakeholders.

Social considerations

Climate change presents a risk not only to the composition, health and vitality of forest ecosystems but also to the social systems linked to forests. Decreased forest ecosystem services, especially water-cycle regulation, soil protection and the conservation of biodiversity, may imply increased social vulnerability. Millions of people in rural areas use forests to help meet subsistence needs, including for food, fuel, timber, medicines and income. For many indigenous people, forests are also central to cultural identity and spiritual beliefs. Many urban areas are equally dependent on forest ecosystem services, such as those related to water supply and recreation.

Using a tropical-creeper climbing strap, a Pygmy honey-tapper nears a beehive in forest in the Republic of the Congo. Actions to reduce the negative impacts of climate change will achieve best results if they contribute to the adaptive capacities of local people. Forest managers should target actions to address increased food insecurity and the deterioration of livelihoods for the most vulnerable, such as the poor, women and other marginalized groups.

Climate change will affect many of the services provided by forests, with direct and indirect social impacts. For example, vector-borne diseases (e.g. malaria) are projected to increase in some regions as temperatures increase and precipitation patterns change, with possible implications for the popularity of forest-based recreation and the perceived value of forests to society.

It is crucial that forest managers include social considerations in adjusting their management plans for climate change. Actions to reduce the negative impacts of climate change will achieve best results if they contribute to the adaptive capacities of local people.

SOCIAL CONSIDERATIONS: recommended adaptation actions

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
Food security and livelihoods: changes in food production, access, availability, quality and quantity; poverty exacerbated and livelihoods negatively affected	Develop new or adjust existing integrated land-use plans designed to maintain or increase food security and local livelihoods under changed climatic conditions	
	Target actions to address increased food insecurity and the deterioration of livelihoods for the most vulnerable, such as the poor, women and other marginalized groups	
	Enable and support the involvement of local communities in forest management to increase direct livelihood benefits	
	Adjust forest management plans to increasingly provide for local community needs – e.g. by promoting the planting of multipurpose trees, incorporating woodfuel production in planning, and promoting agroforestry and aquaculture systems	
	Establish buffer zones around forests for multiple uses by communities	
	Permit the harvesting of forest foods (e.g. wild meat and plants) by local people in times of food shortages and famines	
	Support the development of local forest enterprises based on wood and non-wood production and processing	
	Invest in local development to improve climate change adaptation in communities (e.g. improved efficiency in the use of wood energy)	

Table continues on next page

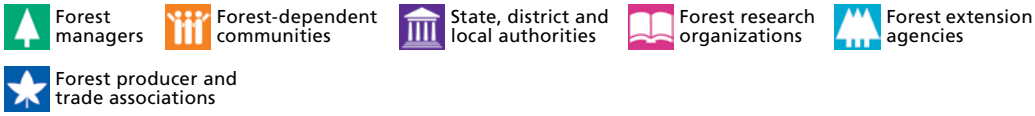
Table continued

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
	Invest in the development of local capacities to deal with the impacts of climate change	
	Identify and develop ecotourism activities to provide jobs and income for local people	
	Ensure effective communication, knowledge distribution, risk awareness and cooperation among the full range of stakeholders	
Health: increase in disease; water shortages; malnutrition; fire and smoke-related hazards	Protect water sources within forests (e.g. lakes, creeks and rivers) to prevent outbreaks of water-borne diseases among forest workers and local communities	
	Adhere to safety regulations for forest-related activities	
	Build partnerships to improve access to health care for forest workers and forest-dependent communities	
	Increase awareness of heightened risks of disease (e.g. malaria and water-borne diseases) and heat stress	
	Ensure that effective health warning systems are in place and that precautions are taken to reduce the exposure of forest workers and local communities to disease and (in the case of forest fire) smoke inhalation	
	Promote good nutrition by providing forest workers with balanced diets and information on nutrition	
Increased pressure on forest resources due to economic decline or decreased land productivity (e.g. for agriculture)	Protect forest from unauthorized activities such as agricultural encroachment, illegal logging and poaching	
	Regulate the use of forest products to improve the efficiency of use and thus minimize overharvesting	
	Promote agroforestry schemes and other income-generating activities	
	Recognize, respect and safeguard forest tenure and use rights (both statutory and customary), particularly those of indigenous peoples and local communities	

Table continues on next page

Table continued

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
	Promote the multiple values of forests (i.e. cultural, economic, environmental, political, social and spiritual) for indigenous and other communities with customary tenure systems	
	Form partnerships to raise awareness about the potential effects of land-use change on communities and ecosystems	
	Monitor and assess the sale of private lands, the objectives of buyers, the projected uses of the land and the resultant impacts	
Changes in the timing of harvests or duration of harvesting cycles	Revise worker contracts and agreements in line with changing harvesting schedules	
Seasonal or permanent migration for employment	Identify potential changes in labour availability and take these into account in the planning phase (e.g. plan year-round activities to ensure minimal movement of employees)	
	Be aware of negative impacts on women, children and the elderly in terms of access to land and forest resources due to the out-migration of men seeking jobs elsewhere, and implement measures to safeguard the livelihoods of these vulnerable people	



Economic considerations

Climate change will have economic impacts on the forest sector and consequently on forest management. These effects may be positive or negative. Warmer temperatures and increased concentrations of atmospheric CO_2 may increase forest productivity under certain conditions. On the other hand, the increased incidence of forest fire is expected to affect the supply of forest products and ecosystem services and lead to higher costs for fire management and control. An increase in the incidence of pests and the frequency and intensity of extreme weather events could increase damage to financially valuable stands and disrupt industrial operations, resulting in, for example, a reduction in the period of favourable conditions for timber harvesting and transport. In addition, increased precipitation and storm events could damage road networks and stream-crossing structures.

Climate change may require alterations to longstanding timber harvesting schedules, upgrades to logging infrastructure, the use of adaptable harvesting and transportation equipment and techniques, and changes in silvicultural methods. Such changes could increase forest management costs and, in some cases, may require substantial capital investments in infrastructure, equipment and training. Forest managers should use economic models to estimate the costs of implementing versus not implementing adaptation actions.

ECONOMIC CONSIDERATIONS: recommended adaptation actions

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
Heightened risk of economic loss	Assess the potential costs and benefits of making changes to forest management plans, using the most reliable climate projections and associated impacts on forest goods and ecosystem services	
	Adjust forest management plans to avoid or minimize financial losses	
	Identify funding opportunities for research, product diversification, value-added processes and the implementation of innovative monitoring arrangements (e.g. community-based)	
	Identify markets for new products and alternative opportunities for current products	
	Identify markets that reward biodiversity conservation as an integral aspect of forest management	
	Support local initiatives to promote the role of forest management in the provision of water-related ecosystem services through integrated watershed management	

Table continues on next page

Table continued

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
	Raise awareness about the causes and economic consequences of biodiversity loss	
	Explore market opportunities for species affected by pests, diseases, fire, storms and other climate change-related disturbances	
	Explore opportunities for forest insurance to offset the risk of damage from climate change-related disturbances	
	Engage policy-makers in dialogue on the increased risks and costs associated with climate change	
	Build strategic alliances to address industry-wide risks, improve competitive positioning, gain entry to new markets, supplement critical skills, and share the risks and costs of climate change impacts	
	Promote incentives to implement response systems for fires, pests and diseases (e.g. provide farmers and communities with subsidized prices for woodfuel in exchange for information on response measures)	
Changes in policies and markets	Be aware of new policies, regulations and financial instruments of relevance to the forest sector that provide financial incentives for climate change mitigation (e.g. REDD+, Clean Development Mechanism, Joint Implementation[4] and voluntary carbon markets)	
	Explore existing and new climate change-driven requirements and opportunities (e.g. carbon markets, policy changes and new monitoring and reporting) that may affect forest operations and markets	
	Before engaging in any financial incentive scheme or selling forest carbon, be fully aware of the rules of engagement and cost implications (e.g. ownership rights to forest carbon)	
	Encourage local and state authorities to support (e.g. through the provision of incentives) the increased production and use of bioenergy through bioenergy plantations and more efficient technology (e.g. improved stoves)	

[4] See glossary for explanations of these terms.

Table continues on next page

Table continued

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
	Promote the increased use of sustainably produced wood and other forest products as environmentally friendly construction materials and renewable energy sources	
	Advise policy-makers on the benefits of schemes for payments for ecosystem services and encourage them to establish such schemes	
	Involve users and beneficiaries of ecosystem services in schemes for payments for those ecosystem services and promote local schemes	
	Identify funding for research and development on species that are resilient to climate change	
	Create business models that encourage payments for biodiversity services	

Forest managers
Forest-dependent communities
State, district and local authorities
Forest research organizations
Forest extension agencies
Forest producer and trade associations

©FAO/ANDREA PERLIS

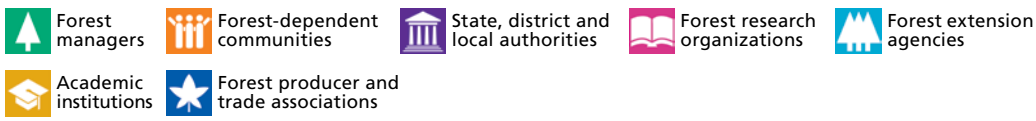
Full involvement of users of ecosystem services in adaptation planning, implementation, monitoring and evaluation is important for the success of schemes for payments for ecosystem services.

Institutional considerations

Coping with climate change in the forest sector will require adjusting institutional structures and arrangements. This includes defining adequate national policy and legislative frameworks and assigning and coordinating responsibilities within the governance structures of countries and regions. Mechanisms are needed to ensure that information on new policies is disseminated and understood. This will facilitate iterative planning through participatory, integrated approaches and strong stakeholder engagement, especially on landscape-scale management actions. Institutions and decision-making must remain flexible in order to deal with the uncertainties of potential impacts of climate change.

INSTITUTIONAL CONSIDERATIONS: recommended adaptation actions

CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
New climate change policies and strategies that create new obligations and opportunities for forest managers	Remain well informed on policy changes and their implications for forest management through public information sources, direct contact with forestry officials, and forest producer and trade associations	
	Work through forest associations and other means to provide information to policy-makers on the impacts of climate change and climate change policy responses on forest management, with the aim of influencing decision-making	
	Support forest associations in their work on climate change and encourage the strengthening of their capacity in this area	
	Build strategic alliances with relevant stakeholders for benefits related to information dissemination, technical advances and policy representation	
The need to incorporate the results of research on forests and climate change into forest management decisions	Access available information and services of forest research and extension agencies and academic institutions; engage with these institutions to encourage relevant and effective research, extension and communication	



BOX 9

Taking back the mangroves with community management

Three decades ago, the resources of coastal fishing villages in Trang Province in southern Thailand were being assaulted on all sides, from trawlers trespassing into their fishing zones to charcoal concessionaires clearing the mangrove forests. As catches fell, desperate local fishers turned to destructive fishing methods, took work on trawlers and were involved in clearing remaining mangroves. Yadfon, a small, non-governmental development organization, began working with villagers to protect their mangrove forests, triggering a regeneration of the community, economy and fishing industry.

The coastal villages of Trang Province once subsisted on the rich coastal fisheries as well as on other activities such as rubber-tapping and livestock-raising. Mangrove forests provided medicines, thatch for housing, and materials for other purposes such as fishing gear. In the 1960s, however, large trawlers began fishing the coasts of southern Thailand, violating the 3 km coastal zone and encroaching on the villagers' fishing grounds. Their fishing gear and destructive methods damaged coral, scraped seabeds and extracted young fish that had not yet reproduced.

At the same time, mangrove forests were opened up to logging concessionaires, who began cutting them to make charcoal briquettes for barbecues. The harvesting method stipulated by the government was not followed, and usually entire concessions were logged in one go. This not only denied villagers the benefits of common resources, it also left them to deal with huge environmental costs.

In 1986, with Yadfon as the go-between, representatives from the village of Leam Markham met with provincial forestry authorities to create a 235-acre, community-managed forest and sea-grass conservation zone, the first of its kind in Thailand. Boundaries were marked clearly on signs, sea grass was replanted in the lagoon, and mangrove seedlings were planted in degraded areas. An inter-village network emerged as a way of sharing information and exchanging ideas.

Community mangrove forests (CMFs) are the cornerstone of Yadfon's work with villages. Today, there are about ten CMFs, all modelled on the CMF in Leam Markham, ranging in size from 12 to 700 hectares. Each forest is managed by the group of villages surrounding or depending on the forest. Representatives of villagers sit on community committees to oversee forest management. While each forest has its own rules, none allows shrimp farms within forest boundaries. There is general agreement that shrimp farms are dangerous to mangroves, although there are many shrimp ponds in government-managed forests. Over the years, the village-managed mangrove forests have begun to regenerate, and the coastal fisheries have revived. Villages that are already managing CMFs have been active in advising those villages with newer CMFs and those who want to create them.

Source: www.ecotippingpoints.org/our-stories/indepth/thailand-mangrove-restoration-community-management.html

A GUIDING FRAMEWORK FOR MITIGATION ACTIONS

Climate change mitigation actions in the land-use sectors fall into two broad categories: reducing GHG emissions by sources (reducing emissions), and increasing GHG removals by sinks (increasing removals of GHGs from the atmosphere). Mitigation options available to forest managers can be grouped into four general categories:

- maintaining the area under forest by reducing deforestation and promoting forest conservation and protection;
- increasing the area under forest (e.g. through afforestation and reforestation);
- maintaining or increasing carbon density at the stand and landscape scales by avoiding forest degradation and managing timber production forests so that, on average, carbon stocks remain constant or increase over time; and through the restoration of degraded forests;
- increasing off-site carbon stocks in harvested wood products (e.g. displacing fossil fuels with woodfuels and replacing construction materials such as concrete, steel, aluminium and plastics with wood).

The designation of forests for conservation (specifically as parks and other protected areas) or protection (specifically for the protection of soil and water resources), where timber extraction is prohibited or limited, cannot be considered a mitigation action unless such forests would otherwise have been cleared or degraded.

Forest area can be increased through planting, seeding and assisted natural regeneration, and through natural succession. Afforestation leads to increases in the carbon pools held in aboveground and belowground biomass and in dead organic matter.

Activities to maintain or increase stand-level forest carbon stocks include reduced impact logging and sustained-yield management in timber production forests; maintaining partial forest cover and minimizing the loss of the dead organic matter and soil carbon pools by reducing high-emission activities such as soil erosion and slash burning. Replanting after harvesting or natural disturbances accelerates growth and reduces carbon losses relative to natural regeneration. Retaining additional carbon on the site will delay revenues from harvesting, and forest managers should consider carefully the benefits and costs of this approach.

Another mitigation action is the use of harvested wood products. When wood is transformed into long-lived products, such as buildings and furniture, the products can act as a reservoir of carbon for centuries. While forest managers are generally not involved in energy production or product substitution, they do respond to policy changes and market signals. For example, policies in the European Union to increase the use of biofuels for energy generation are affecting how foresters in the region manage their forests.

Forest managers should consider the various available mitigation options and actions in light of their management objectives, the presence of unforested or degraded land, pressures on the land (e.g. from encroachers or fire), and laws, regulations or other governance factors that affect the range of available land uses and forest management actions.

Forest managers may be motivated to carry out climate change mitigation actions as a result of:

- government policies and programmes that encourage mitigation actions or penalize those who do not undertake such actions;
- accessible carbon markets and other financial incentives;
- concerns about the environmental well-being of current and future generations.

The motivation and ability to contribute to climate change mitigation vary with the type of forest manager (e.g. in the public or private sector), existing forest management objectives and management plans, and a range of other factors. Forest managers should weigh the costs of carrying out mitigation actions against the benefits, financial and otherwise.

©FAO/DIANA GIAMPIERO

Climate change is expected to increase the risk of economic losses. Among other things, forest managers can encourage the uptake of fuel-efficient stoves for cooking, such as this one in Bangladesh. The introduction of efficient technologies can have economic, social and environmental benefits.

Participants clear brush and define a fire line in an assisted-natural-reforestation project area in Danao, the Philippines. Forest managers can help mitigate climate change by expanding forest area on degraded land.

Voluntary markets for carbon credits from forestry projects tend to favour projects that have social and environmental benefits in addition to mitigation benefits. The agreement reached by the UNFCCC in 2010 on REDD+ indicates that countries should adhere to social and environmental safeguards in implementing REDD+ programmes and should report information on those safeguards.

Forest managers aiming to carry out climate change mitigation measures under the UNFCCC or voluntary markets should know the rules and standards concerning social and environmental safeguards and co-benefits. In most cases, it will be to the advantage of forest managers to maximize social and environmental benefits, not only for access to carbon markets and REDD+ incentive schemes, but also because many mitigation actions also have adaptation benefits. Forest managers may wish to consider these and identify other win–win or win–win–win forest management practices.

Mitigation strategies and options, and corresponding forest management actions

MITIGATION STRATEGY	MITIGATION OPTION	MITIGATION BENEFIT/ EFFECT ON CARBON	MANAGEMENT ACTION	RESPONSIBILITY
Reduction of emissions	Reducing deforestation	Avoid carbon emissions from deforestation	Work with relevant authorities and stakeholders to address the causes of deforestation (e.g. agricultural encroachment and infrastructure development)	
			Have forest designated as a conservation area (i.e. included in the country's protected-area system) or for the provision of ecosystem services and adjust management accordingly	
	Reducing forest degradation (i.e. loss of forest carbon or decreases in a forest's capacity to sequester carbon)	Avoid emissions associated with reducing the aboveground biomass and other carbon pools in existing forests	Practice reduced impact logging (i.e. well-planned harvesting by trained crews and supervision by forest managers) to sustain levels of forest carbon and carbon sequestration	
			Encourage and/or assist in law enforcement against illegal logging and the illegal harvesting of non-wood forest products	
			Encourage sustainable levels of fuelwood collection	
			Increase carbon stocks in forests by reducing or eliminating timber harvesting and other uses	
			Avoid overgrazing (by both domestic and wildlife species) and the overharvesting of wood and non-wood forest products	

Table continues on next page

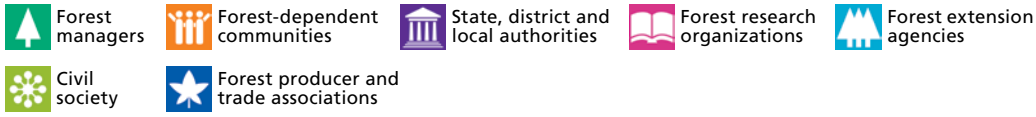
Table continued

MITIGATION STRATEGY	MITIGATION OPTION	MITIGATION BENEFIT/ EFFECT ON CARBON	MANAGEMENT ACTION	RESPONSIBILITY
			Develop and implement integrated fire management systems, including fire monitoring outside the FMU	
			Develop and implement integrated pest management systems	
Increase of GHG removals	Increasing forest carbon stocks	Increase carbon stocks by expanding the area of forest (i.e. increasing the carbon content of the landscape)	Establish forest through planting or deliberate seeding on degraded land not classified as forest but which originally had forest	
			Restore managed forest through assisted natural regeneration or planting on land classified as forest	
			Encourage the natural expansion of forests through natural succession or assisted natural regeneration on land under other land uses (e.g. forest succession on land previously used for agriculture)	
		Increase carbon stocks by increasing the density of carbon per hectare of forest	Restore degraded forest (by planting or encouraging natural regeneration)	
			Increase the rotation period for timber harvesting	
			Increase tree cover on agricultural land (e.g. through agroforestry)	

Table continues on next page

Table continued

MITIGATION STRATEGY	MITIGATION OPTION	MITIGATION BENEFIT/ EFFECT ON CARBON	MANAGEMENT ACTION	RESPONSIBILITY
Substitution and carbon storage	Substituting fossil fuels and carbon-rich products with forest products (that are carbon-neutral)	Avoid GHG emissions from the burning of fossil fuels by replacing them with forest-based renewable energy sources	Produce bioenergy sustainably to substitute for fossil fuels (e.g. through energy plantations on agriculturally marginal or degraded areas)	
			Promote the use of technologies that reduce fuel consumption (e.g. improved stoves)	
		Avoid GHG emissions associated with the manufacture and use of carbon-rich products by replacing them with renewable products	Substitute steel, concrete, aluminum, plastics and other materials with wood products, the production, processing and transport of which have a lower carbon footprint	
			Support the manufacture of long-lived forest products (e.g. furniture and construction materials) to increase carbon storage	



Adaptation, socio-economic and environmental benefits of forest mitigation actions

FOREST MITIGATION ACTION	ADAPTATION BENEFIT	SOCIO-ECONOMIC BENEFIT	ENVIRONMENTAL BENEFIT
Forests designated as conservation areas (included in the country's protected-area system) or placed in a conservation easement	Availability of species and genetic material for adaptation over the long term and allowing the use of such areas as safety nets in times of emergency	Availability of forest products, recreation opportunities, etc., especially for local communities	Biodiversity conservation; maintenance of forest functions and ecosystem services
Forests designated as protected areas for soil and water conservation	Protection of steep slopes and other areas vulnerable to increased erosion due to climate change	Cleaner and more reliable water supply; cleaner air	Reduction of erosion risk and improved water supply and water quality
	Protection of vegetation in riparian strips to reduce the vulnerability of aquatic ecosystems to increased temperatures and also erosion from storms	Maintenance of opportunities for local people to collect fish and other products	Improved habitat for aquatic species
Wildfire management systems intensified	Avoided degradation that renders areas more vulnerable to climate change	Maintenance of production of forest products and forest ecosystem services	Avoided loss of plant and animal species
Afforestation and reforestation	The use of native species and local provenances that are well adapted to current and future site conditions to reduce vulnerability to climate change	Production of various products that can support the livelihoods of local people (if harvesting is permitted)	Biodiversity enhanced by establishing multiple species (instead of monocultures), using species that will benefit local wildlife, and creating wildlife corridors
Natural expansion of forests encouraged, and forests restored	Restoration of ecosystem functions important for adaptation	Provision of employment in restoration projects, production of various forest products (if harvesting is permitted) and improvement of forest ecosystem services	Biodiversity enhanced

A lab technician measures the carbon content of soil samples at the Sokoine University of Agriculture, the United Republic of Tanzania, as part of a national forest inventory. Once the need to monitor is recognized, the question of what to monitor must be addressed.

5. Monitoring and evaluation

Forest managers may need to carry out additional monitoring to guide their climate change adaptation and mitigation actions. Changes to existing monitoring systems may be required, depending on: whether the government requests additional information to inform national adaptation and mitigation programmes and reporting to the UNFCCC; the adaptation and mitigation actions the manager has chosen to carry out; and whether the forest manager's existing monitoring system is sufficient to supply new information needs. Monitoring both the effects of climate change and the effectiveness of management responses is central to the adaptive management approach (i.e. learning from experience by experimenting with different management schemes). Those engaged in climate change mitigation activities that require the measurement, validation and reporting of mitigation benefits will also need to monitor changes in forest carbon and, in many cases, the social and environmental impacts of activities. These additional monitoring requirements could be a significant burden for forest managers who may, however, be able to use existing databases, criteria and indicator processes and forest certification schemes as a framework for monitoring.

The climate change-related methods used by forest managers will depend on the risk and vulnerability of the forest resources, the financial and technical resources available, and the spatial scale of the operation. Large-scale industrial forest managers tend to have more comprehensive inventory systems, including permanent sample plots and possibly remote sensing capabilities. Managers with smaller FMUs, and community forest managers, tend to have simpler monitoring systems, ranging from field inventories to systematic observation and the more informal collection of information.

Irrespective of the scale of monitoring required, forest managers should involve local people and traditional methods using participatory approaches. Local communities may not have received suitable training and are likely to have varying skills, expertise, societal roles and interests.

Once the need to monitor is recognized, the question of what to monitor must be addressed. Monitoring for adaptation purposes will require the collection of data on indicators of climate-induced impacts (e.g. on forest productivity, forest health and forest pests – see Chapter 4). Many of these data will normally be collected in standard forest inventory systems.

For biodiversity, the ideal species for monitoring are those that are expected to be vulnerable to climate change and that are also easy to census. Ideally, such species will also be species of special concern.

For water monitoring, dry season base flows and suspended sediments during periods of low flow might be the most appropriate indicators, and macro-invertebrates in streams can serve as good indicators of ecological integrity.

For fire susceptibility, monitoring fuel loads and moisture content are the first steps in assessment.

Social factors related to vulnerability and the benefits of adaptation measures are unlikely to be included in standard forest inventories. Forest managers required to provide such information should develop social indicators that can be monitored, either by their own systems or by the use of other sources of data (e.g. census data or rural development databases maintained by government).

A forest ranger takes soil samples at Megeni Kitasha in the Rombo District in Moshi, the United Republic of Tanzania. Under climate change, forest managers may need to carry out additional monitoring to guide their climate change adaptation and mitigation actions.

[5] www.climate-standards.org

Forest monitoring in response to climate change

MONITORING	OPTIONS
What to monitor?	Climate variability and climate change
	The most significant impacts of climate change on forests and people, especially the most vulnerable of these
	The impacts of the measures taken in response to climate change. Prioritize actions, beginning with the most relevant
	Ongoing relevant research in the area (i.e. local) and further afield
	The data, human (e.g. knowledge and skills) and financial resources required to respond to impacts
	The dissemination of research results, best practices and lessons learned from climate change actions
	The development, revision and implementation of policy measures
How to monitor?	Establish the baseline and indicators to record changes
	Record changes, including possible reasons for changes
	Define the boundaries of the forest area to be monitored
	Integrate additional monitoring needs into existing inventory or other monitoring systems
When to monitor?	Establish fixed timelines for monitoring (e.g. 2 or 3 years). These may be revised: • when there are observed changes in climate, or when a policy changes • if change is occurring rapidly and the impacts are significant. If the forest area is within a carbon market project, carbon monitoring will be needed about every 5 years
Who should monitor?	*Changes in climate:* researchers; forest officers; forest agencies; forest managers; communities; local NGOs; meteorological departments (local, subnational and national); agricultural and extension officers; agricultural organizations (e.g. crops and livestock, water resources); wildlife management authorities; local and state authorities
	Significant climate change impacts: researchers; district forest officers; forest agencies; forest managers; communities; local NGOs; meteorological departments (local, subnational and national); agricultural and extension officers; agricultural organizations (e.g. crops and livestock, water resources); wildlife management authorities; local and state authorities
	Impacts of the measures taken: researchers; district forest officers; forest agencies; forest managers; communities; local NGOs; agriculture and extension officers; agricultural organizations (crops and livestock, water resources); wildlife management authorities; local and state authorities

Table continues on next page

Table continued

MONITORING	OPTIONS
	Current research: researchers
	Policy frameworks: researchers; district forest officers; forest agencies; forest managers; communities; local NGOs
Cost of monitoring?	Governments must invest in basic weather monitoring. Other costs can be shared among forest owners, forest managers and other stakeholders in the area
	Evaluate different monitoring approaches for cost-effectiveness

Forest managers who need to report on mitigation actions or who are endeavouring to access carbon markets (e.g. projects under the Clean Development Mechanism or REDD+) will need to monitor forest carbon. In particular, such forest managers will have monitoring–verification–reporting obligations to demonstrate the additional carbon benefits of their management. They will also need to provide evidence that the action does not result in carbon-releasing activities beyond the boundaries of their management areas (i.e. leakage) and that any carbon stocks lost in a project area (e.g. from timber harvesting or forest fire) are replaced (i.e. permanence). Access to carbon markets can be improved by demonstrating the delivery of social and environmental benefits from activities that reduce emissions of GHGs – the Climate, Community and Biodiversity Alliance[5] has developed standards for this purpose. The need to demonstrate social and environmental benefits from mitigation projects and to provide assurances that such projects do not have negative impacts will often require additional monitoring. In regard to biodiversity impacts, for example, particular species or populations may need to be monitored.

Managers may also need to monitor impacts on social factors, such as equity, effectiveness and efficiency (i.e. cost–benefit analyses that include consideration of the distribution of costs, risks and benefits), and on vulnerable groups, such as indigenous people, forest communities and women.

Growing concern about the unintended consequences of management actions implemented for climate change mitigation means that managers should be vigilant in their monitoring of social and environmental parameters. They should also watch for developments in climate change policy and laws that will affect management and their reporting to government. Forest managers should also stay up to date with ongoing relevant research.

Monitoring expertise is often available locally (e.g. community-based management). In many cases, innovative arrangements will have to be put in place that incorporate local expertise and that can be supported by other institutions (e.g. local and regional governments and institutions). In some cases (e.g. for forest carbon monitoring for mitigation projects), some aspects of monitoring will need to be outsourced (e.g. to organizations with specialized laboratories or to academic institutions with undergraduate

and graduate researchers). Where possible, expert knowledge from academic, practitioner and resource-user communities should be combined to increase monitoring power and provide the resource management platform needed to face climate change threats. No matter who is doing the monitoring, managers need to be closely involved to ensure that it satisfies real needs and is cost-effective. In all cases, there are substantial advantages in coordinating with other forest managers and other institutions in a given region.

Just as important as monitoring the outcomes of climate change-related management is a thorough assessment of the mechanisms through which the outcomes are being achieved and how they vary in different contexts (e.g. forest type, forest tenure and type of threat). Impact evaluation will greatly enrich the capacities of forest managers to understand and react to factors that increase the risks and vulnerabilities of the forests for which they are responsible.

An entomologist deploys a trap to monitor the presence of gypsy moth, Lymantria dispar, *near Fort Collins, United States of America. Monitoring both the effects of climate change and the effectiveness of management responses is central to the adaptive management approach.*

A forest officer measures the diameter of a tree in Nicaragua. Robust forest monitoring and reporting systems are key aspects of forest-based responses to climate change.

6. Conclusion

Forests provide a wide range of goods and ecosystem services that are important for human well-being, food security, poverty alleviation and livelihoods. Climate change, combined with deforestation, forest degradation and population pressure, threatens the continued provision of such forest goods and ecosystem services. Although uncertainty exists about the magnitude and timing of the impacts of climate change on forest ecosystems, sufficient scientific information is available to begin taking action now.

- Climate change is expected to affect the distribution of forest types and tree species, forest productivity, site and soil condition, stand structure, and changes in disturbance regimes such as the incidence, severity and impact of wildfire, invasive species, insects, diseases, floods, drought, temperature extremes, landslides and storm surges.
- Climate change, therefore, provides forest managers with a major and potentially formidable challenge. By modifying management plans and practices, however, forest managers can help slow the rate of climate change, help society adapt to climate change, retain the many other values of forests, and ensure that such forests continue to deliver their many goods and ecosystem services.
- Measures to ensure forest adaptation are compatible and often identical with established SFM practices to meet the economic, social and environmental needs of stakeholders. For example, maintaining structural and compositional diversity makes sense in the face of a wide range of biotic and abiotic risks, including those associated with climate change.
- SFM practices can help reduce the economic, social and environmental vulnerability of forests and forest-dependent people to climate change by generating multiple benefits, including the provision of goods and ecosystem and cultural services.
- Climate change mitigation programmes are emerging that can help meet the costs of actions to reduce GHG emissions due to deforestation and forest degradation and to increase the stock of carbon in forests.
- Forest managers should assess the cost-effectiveness of climate change adaptation and mitigation options and identify the most feasible given the availability of technical capacity and the supportiveness of the policy environment.
- Robust forest monitoring and reporting systems are key aspects of forest-based responses to climate change. These systems will provide timely warnings of extreme events and climate change impacts and useful information on the effectiveness of management responses.
- Combining forest monitoring and existing knowledge of possible climate change impacts in vulnerability and risk assessments is an important step in developing a climate change strategy.
- Monitoring will probably require additional technical and human resources.

Specific strategies and actions on climate change will differ by location, forest productivity, local management objectives and the extent and nature of expected climate change impacts. Managers need to continue their efforts to understand climate change threats and opportunities as they emerge.

Annexes

Kapchorwa District, Uganda.

Annex 1
Glossary[6]

Adaptation
The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.
www.ipcc.ch/pdf/glossary/ar4-wg2.pdf

Adaptive capacity
The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damage, to take advantage of opportunities, and to cope with the consequences.
www.ipcc.ch/pdf/glossary/ar4-wg2.pdf

Adaptive management
The process by which research and learning is continuously incorporated in management planning and practice. Specifically, the integration of design, management and monitoring to systematically test assumptions in order to adapt and learn.
www.fao.org/agriculture/crops/core-themes/theme/spi/soil-biodiversity/initiatives/adaptive-management/en/

Afforestation
Establishment of forest through planting and/or deliberate seeding on land that, until then, was not classified as forest.
www.fao.org/docrep/017/ap862e/ap862e00.pdf

Agroforestry
Traditional or modern land-use systems in which trees are managed together with crops and/or animal production systems in agricultural settings.
www.fao.org/forestry/9469/en/

Aquaculture systems
The breeding and rearing of fish, shellfish, etc., or the growing of plants for food in special ponds.
www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=689

[6] This glossary has been compiled from various sources to assist readers in using these guidelines. The definitions given here are not necessarily official FAO definitions.

Biodiversity The variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, among species and of ecosystems.
www.fao.org/docrep/017/ap862e/ap862e00.pdf

Biodiversity conservation The designation of a forest area primarily for the conservation of biodiversity. Includes, but is not limited to, areas designated for biodiversity conservation within a protected area.
www.fao.org/docrep/017/ap862e/ap862e00.pdf

Biofuel Fuel produced directly or indirectly from biomass such as fuelwood, charcoal, bioethanol, biodiesel, biogas (methane) or biohydrogen. However, most people associate biofuel with liquid biofuels (bioethanol, biodiesel and straight vegetable oil).
www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Factsheet_BIOENERGY.pdf

Buffer zone An area between a core protected area and the surrounding landscape or seascape which protects the network from potentially damaging external influences and which is essentially a transitional area.
www.cbd.int/doc/publications/cbd-ts-23.pdf

Carbon market A popular (but misleading) term for a trading system through which countries may buy or sell units of GHG emissions in an effort to meet their national limits on emissions, either under the Kyoto Protocol or under other agreements, such as that among member states of the European Union. The term comes from the fact that CO_2 is the predominant GHG, and other gases are measured in units called "CO_2 equivalents".
http://unfccc.int/essential_background/glossary/items/3666.php

Carbon sink Any process, activity or mechanism which removes a GHG, an aerosol or a precursor of a GHG from the atmosphere. Forests and other vegetation are considered sinks because they remove CO_2 through photosynthesis.
http://unfccc.int/essential_background/convention/background/items/2536.php

Carbon source

Any process, activity or mechanism that releases a GHG, an aerosol or a precursor of a GHG or aerosol into the atmosphere (e.g. forest fires).
http://unfccc.int/essential_background/convention/background/items/2536.php

Clean Development Mechanism

A mechanism established in the Kyoto Protocol to allow countries with emission-reduction or emission-limitation commitments under the Kyoto Protocol to implement emission-reduction projects in developing countries.
http://unfccc.int/kyoto_protocol/mechanisms/clean_development_mechanism/items/2718.php

Climate change

A change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.
http://unfccc.int/essential_background/convention/background/items/2536.php

Climate variability

Variation in the mean state and other parameters (such as standard deviation and the occurrence of extremes) of the climate at any temporal or spatial scale beyond those of individual weather events. May be due to natural processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).
www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=689

Coastal forests

Interface or transition areas between land and sea, including large inland lakes. Coastal forests are dynamic and diverse in function and form and do not lend themselves well to definition by strict spatial boundaries. Unlike watersheds, there are no exact natural boundaries that unambiguously delineate coastal forests.
www.fao.org/forestry/icam/4302/en/

Contour planting

The alignment of planting rows and tillage lines at right angles to the normal flow of runoff. Contour planting creates detention storage within the soil surface horizon and slows the rate of runoff, thus giving water time to infiltrate into the soil. The effectiveness of contour planting for water and soil conservation depends on the

	design of the system as well as on soil, climate, slope, aspect and land use. *www.fao.org/docrep/T1696e/t1696e02.htm*
Cutting cycle	The planned time interval between major harvesting operations within the same stand of trees (usually in uneven-aged stands). *http://woodlandstewardship.org/?page_id=2347*
Deforestation	The conversion of forest to other land use or the permanent reduction of the tree canopy cover below the minimum 10 percent threshold. *www.fao.org/docrep/017/ap862e/ap862e00.pdf*
Degradation	The reduction of the capacity of a forest to provide goods and services. *www.fao.org/docrep/017/ap862e/ap862e00.pdf*
Disturbance regime	An environmental fluctuation and destructive event that disturbs forest health, structure, and/or changes resources or physical environment at any given spatial or temporal scale. *ftp://ftp.fao.org/docrep/fao/008/A0400E/A0400E00.pdf*
Early-warning system	A system of data collection and analysis to monitor people's well-being (including security), in order to provide timely notice when an emergency threatens and thus to elicit an appropriate response. *www.fao.org/ag/againfo/programmes/en/lead/alive_toolkit/pages/pageD_whatEWS.html*
Ecosystem service	Ecological process or function having monetary or non-monetary value to individuals or society at large. *www.ipcc.ch/publications_and_data/ar4/wg2/en/annexessglossary-e-o.html*
Extreme weather event	An event that is rare within its statistical reference distribution at a particular place. An average of a number of weather events over time (e.g. rainfall over a season) that is itself extreme. The characteristics of what is called extreme weather may vary from place to place. *www.ipcc.ch/publications_and_data/ar4/wg2/en/annexessglossary-e-o.html*

Fire-smart landscape	A landscape designed to mitigate the likelihood of large, high-intensity, high-severity fires and the risk associated with such fires. Can maximize the positive ecological effects of fire while reducing its negative economic and social impacts. *http://srd.alberta.ca/Wildfire/FireSmartLandscapes/documents/taskforce_final_tor.pdf*
Forest	Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. Does not include land that is predominantly under agricultural or urban land use. *www.fao.org/docrep/017/ap862e/ap862e00.pdf*
Forest carbon stock	The quantity of carbon in a "pool", meaning a reservoir or system that has the capacity to accumulate or release carbon. Examples of carbon pools are: living biomass (including aboveground and belowground biomass); dead organic matter (including dead wood and litter); and soils (soil organic matter). *ftp://ftp.fao.org/docrep/fao/008/A0400E/A0400E00.pdf*
Forest-dependent communities	Communities of people living inside or near forests who are directly reliant on forests for their livelihoods. Includes indigenous people and people from minority ethnic groups. May also include people engaged in forest-based commercial activities such as trapping, collecting minerals and logging. *www.fao.org/docrep/w7732e/w7732e04.htm*
Forest fragmentation	Any process that results in the conversion of formerly continuous forest into patches of forest separated by non-forested lands. *www.cbd.int/forest/definitions.shtml*
Forest management	The administrative, economic, legal, social and technical measures involved in the conservation, protection and use of natural and planted forests. Involves various degrees of human intervention to safeguard a forest ecosystem and its functions and resources. *www.fao.org/docrep/w4345e/w4345e04.htm*

Forest management plan	Translates national or regional forest policies into a thoughtfully prepared and well coordinated operational programme for a forest and for regulating forestry activities for a set time period through the application of prescriptions that specify targets, action and control arrangements. It is an indispensable part of a forest management system and should regulate protection, inventory, yield determination, harvesting, silviculture, monitoring and other forest operations. *www.fao.org/docrep/w8212e/w8212e00.htm*
Forest management unit (FMU)	A clearly demarcated area of land covered predominantly by forests, managed to a set of explicit objectives and according to a long-term forest management plan. May vary in size from a fraction of a hectare to hundreds and even thousands of hectares. May include subunits managed for differing goals. *www.fao.org/docrep/003/x6896e/x6896e0e.htm*
Forest manager	An individual or entity responsible for the planning, implementation and monitoring of forest management measures.
Forest productivity	The capacity of a forest to produce specific products (e.g. biomass, timber and non-wood forest products) over time as influenced by the interaction of vegetative manipulation and abiotic factors (e.g. soil and climate). *www.termwiki.com/EN:forest_productivity*
Global warming	The recent and ongoing global average increase in temperature near the Earth's surface. *www.epa.gov/climatechange/glossary.html*
Green Climate Fund	A fund established by the UNFCCC in 2010 to provide simplified and improved access to funding for countries' mitigation and adaptation actions. *http://unfccc.int/resource/docs/2011/cop17/eng/09a01.pdf*
Greenhouse gases (GHGs)	Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. This property causes the greenhouse effect.

	Water vapour, CO_2, nitrous oxide, methane and ozone are the main GHGs in the Earth's atmosphere. *www.ipcc.ch/publications_and_data/ar4/wg1/en/annexessglossary-e-o.html*
Intergovernmental Panel on Climate Change	The leading international body for the assessment of climate change. Established by the United Nations Environment Programme and the World Meteorological Organization in 1988 to provide the world with a clear scientific view on the current state of knowledge on climate change and its potential environmental and socio-economic impacts. *www.ipcc.ch/organization/organization.shtml#.UYVTdaJHJuI*
Integrated fire management	The integration of science and fire management with socio-economic elements at multiple levels. Implies a holistic approach to addressing fire issues that considers biological, environmental, cultural, social, economic and political interactions. *www.fao.org/forestry/firemanagement/en/*
Invasive species	Species that are non-native to a particular ecosystem and whose introduction and spread in such an ecosystem cause, or are likely to cause, sociocultural, economic or environmental harm, or harm to human health. *www.fao.org/forestry/aliens/en/*
Joint Implementation	A market-based implementation mechanism defined in Article 6 of the Kyoto Protocol allowing Annex I countries or companies from these countries to implement projects jointly that limit or reduce emissions, or enhance sinks, and to share the emissions reduction units. *www.ipcc.ch/ipccreports/tar/wg3/index.php?idp=463*
Kyoto Protocol	An international agreement that stands on its own, and requires separate ratification by governments, but is linked to the UNFCCC. Among other things, it sets binding targets for the reduction of GHG emissions by industrialized countries. *http://unfccc.int/essential_background/glossary/items/3666.php*

Landscape connectivity The degree to which a landscape facilitates or impedes the movement of species between resource patches. *www.cbd.int/doc/meetings/cop/cop-11/information/cop-11-inf-19-en.pdf*

Landscape management The process of formulating, articulating and developing a set of strategies geared to enhancing a specific landscape and improving the quality of human life, as part of a sustainable development approach using the appropriate instruments and implementing the programmes and actions set out in a landscape management project. *www.coe.int/t/dg4/cultureheritage/heritage/landscape/reunionconf/6econference/CEP-CDPATEP(2011)13_en.pdf*

Land-use change A change in the use or management of land by humans, which may lead to a change in land cover. *www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_appendix.pdf*

Leakage The portion of cuts in GHG emissions by developed countries (countries trying to meet mandatory limits under the Kyoto Protocol) that may reappear in other countries not bound by such limits. *http://unfccc.int/essential_background/glossary/items/3666.php#L*

Mangrove forest Trees and shrubs growing below the high-water level of spring tides, where their root systems are regularly inundated with saline water. *www.fao.org/forestry/mangrove/en/*

Mitigation A human intervention to reduce the sources or enhance the sinks of GHGs. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings, and expanding forests and other carbon sinks to remove greater amounts of CO_2 from the atmosphere. *http://unfccc.int/essential_background/glossary/items/3666.php#L*

Multiple use	Forest area designated primarily for more than one purpose and where no single purpose is considered as the predominant designated function. *www.fao.org/docrep/017/ap862e/ap862e00.pdf*
Natural forest	A forest composed of indigenous trees and not classified as planted forest. *ftp://ftp.fao.org/docrep/fao/003/Y1997E/FRA%20 2000%20Main%20report.pdf*
Payment for ecosystem services	A voluntary transaction where a well-defined ecosystem service (or a land-use likely to secure that service) is "bought" by a (minimum one) ecosystem service buyer from a (minimum one) ecosystem service provider if and only if the ecosystem service provider secures ecosystem service provision (conditionality). *www.cifor.org/publications/pdf_files/OccPapers/OP-42.pdf*
Peatland	Wetland with a thick waterlogged organic soil layer (peat) made up of dead and decaying plant material. Includes moors, bogs, mires, peat swamp forests and permafrost tundra. *www.wetlands.org/?TabId=2737*
Permanence	The longevity of a carbon pool and the stability of its stocks, given the management and disturbance environment in which it occurs. *www.ipcc.ch/ipccreports/sres/land_use/index.php?idp=13*
Photosynthesis	The process by which green plants, algae and some bacteria take CO_2 from the air (or bicarbonate from water) to build carbohydrates. *www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_appendix.pdf*
Planted forest	Forest composed predominantly of trees established through planting or deliberate seeding. *www.fao.org/docrep/017/ap862e/ap862e00.pdf*
Production forest	Forest designated primarily for the production of wood, fibre, bioenergy and/or non-wood forest products. *www.fao.org/docrep/017/ap862e/ap862e00.pdf*

Protected area	An area dedicated to the protection and maintenance of biodiversity, and of natural and associated cultural resources, and managed through legal or other effective means. *www.fao.org/docrep/017/ap862e/ap862e00.pdf*
Reduced impact logging	A method of harvesting trees with minimal damage to remaining trees and degradation of the forest site through the use of pre-harvesting, harvesting and post-harvesting planning and design. Not a fixed prescription but rather an adaptation of the best possible harvesting techniques to suit local site and market conditions. *www.fao.org/forestry/harvesting/11834/en/*
Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon (REDD+)	An instrument agreed by the UNFCCC to provide incentives to countries achieving verified emissions reductions or atmospheric GHG removals through forestry interventions. *http://unfccc.int/methods/redd/items/7377.php*
Reforestation	Re-establishment of forest through planting and/or deliberate seeding on land classified as forest. *www.fao.org/docrep/017/ap862e/ap862e00.pdf*
Resilience	The amount of change a system can undergo without changing state. *www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=689*
Riparian zone	The interface between terrestrial and aquatic environments that provides important chemical, physical and biologic functions within a watershed, including processing nutrients, delivering woody debris and organic matter to a stream, providing shade, stabilizing soils, regulating microclimate, and many other important functions. *www.fao.org/docrep/008/a0039e/a0039e05.htm*
Risk assessment	An impact assessment that considers the uncertainty associated with the consequences of climate variability or climate change in a specific area of interest. *http://climatechange.worldbank.org/content/note-3-climate-risk-assessment-concepts-and-tools*

Semi-natural forest	Forest or other wooded land of native species, established through planting, seeding or assisted natural regeneration. *ftp://ftp.fao.org/docrep/fao/008/A0400E/A0400E00.pdf*
Silviculture	The science and art of cultivating (such as growing and tending) forest crops. *ftp://ftp.fao.org/docrep/fao/008/j4290e/j4290e.pdf*
Soil conservation	The protection of soil from erosion and other types of deterioration so as to maintain soil fertility and productivity. Generally includes watershed management and water use. *http://stats.oecd.org/glossary/detail.asp?ID=2502*
Stakeholder dialogue	An interactive, working communication process that involves all types of stakeholders in decision-making and implementation efforts. *http://siteresources.worldbank.org/EXTGOVACC/Resources/MultiStakeholderweb.pdf*
Substitution	Any use of wood that replaces other inputs of production in providing an equivalent service or function (e.g. using wood instead of fossil fuels or wood instead of non-wood materials). *www.cepe.ch/download/staff/reinhard/miti_substitution_paper_final.pdf*
Sustainable forest management (SFM)	A dynamic and evolving concept that aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations. *www.un.org/esa/forests/pdf/session_documents/unff7/UNFF7_NLBI_draft.pdf*
United Nations Framework Convention on Climate Change (UNFCCC)	An international agreement adopted on 9 May 1992 in New York and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community, with the ultimate objective of achieving the "stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". *www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_appendix.pdf*

Vulnerability The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. A function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity.
www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_appendix.pdf

Vulnerability assessment An evaluation with three main goals: to identify the degree of future risks induced by climate change and sea-level rise; to identify the key vulnerable sectors and areas within a country; and to provide a sound basis for designing adaptation strategies and their implementation.
www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=636

Water conservation The control and management of subsurface drainage water, through, for example, source reduction through sound irrigation water management; shallow water-table management; groundwater management; and land retirement.
www.fao.org/docrep/005/y4263e/y4263e08.htm

Wind erosion The movement of material by the wind, which occurs when the lifting power of moving air is able to exceed the force of gravity and the friction that holds soil particles to the surface (e.g. the movement of sand dunes).
ftp://ftp.fao.org/agl/agll/docs/mmsoilc.pdf

Pinus caribaea *plantation in Jamaica*

Road, stream and forest area, Indonesia. Aerial photographs can provide information on structural changes of forest canopies over time.

Annex 2
Knowledge tools

GENERAL

Forest management and climate change: stakeholder perceptions (2012)
To facilitate the development of *Climate change guidelines for forest managers*, a survey was conducted through which forest stakeholders provided their views and perceptions on factors that influence the ability of forest managers to respond to climate change. This publication presents the results of the survey.
www.fao.org/docrep/015/md510e/md510e00.pdf

Forest management and climate change: a literature review (2012)
This document summarizes knowledge and experiences in forest management as a response to climate change based on a literature review and a survey of forest managers. Part of the FAO-led process to prepare the *Climate change guidelines for forest managers*, the document examines climate change impacts on forests and forest managers throughout the world. It also reviews the main perceived challenges that climate change poses for forests and their managers. It summarizes experiences in preparing for and reacting to climate change in different types of forest. Finally, it indicates a number of gaps in enabling conditions (related to knowledge, institutional setting and culture) that hamper forest managers in responding effectively to climate change and its impacts.
www.fao.org/docrep/015/md012e/md012e00.pdf

Forests and climate change toolbox (2010)
This toolbox was developed by the Center for International Forestry Research to build understanding and technical proficiency on issues of climate change and forests, including mitigation, adaptation, carbon accounting and markets, and biofuels. The toolbox consists of a series of PowerPoint presentations with accompanying notes.
www.cifor.cgiar.org/fctoolbox/

The sustainable forestry handbook: a practical guide for tropical forest managers on implementing new standards (2004)
This handbook provides a clear and concise guide to the practicalities of implementing international standards for SFM. It is targeted at forest managers and explains in clear terms what the standards require forest managers to do and how they might go about implementing them.
www.earthscan.co.uk/?TabId=1060 (*for purchase*)

VULNERABILITY ASSESSMENTS

An assessment of the vulnerability of Australian forests to the impacts of climate change (2011)
This document seeks to provide an improved understanding of current knowledge of the likely biophysical and socio-economic consequences of climate change for Australia's native and planted forest regions. It assesses the vulnerability of Australian forests from the perspective of both resource use and ecosystem services, identifying particularly vulnerable forests and communities in major forest areas. The document also provides information on what is being done in Australia to understand and manage climate-related risk in relation to forests, and it offers guidance on key gaps to assist climate change adaptation.
www.nccarf.edu.au/content/assessment-vulnerability-australian-forests-impacts-climate-change

A system for assessing vulnerability of species (SAVS) to climate change (2011)
The SAVS is a simple and flexible tool designed for managers to assess the relative risk of individual species to population declines in response to projected changes in climate and related phenomena. The SAVS uses an easily completed questionnaire based on predictive criteria that translate the responses of terrestrial vertebrate species into scores indicating vulnerability or resilience to climate change. The SAVS also includes methods for calculating uncertainty, detailed instructions for scoring a species and guidelines for tool application.
www.fs.fed.us/rm/pubs/rmrs_gtr257.pdf

Climate change in a living landscape: conceptual and methodological aspects of a vulnerability assessment in the Eastern Cordillera Real of Colombia, Ecuador and Peru (2011)
This document by the Worldwide Fund for Nature presents the results of combined vulnerability analyses (biological, hydrological and socio-economic). The results demonstrate the need for actions oriented at maintaining the continued provision of ecosystem services as well as the biological and cultural riches of the region. Priority adaptation measures include actions to develop and strengthen the capacities and production systems of local communities and institutions, with the aim of maintaining and recovering ecosystem resilience, strengthening a regional policy framework with considerations of vulnerability and adaptation to climate change, and strengthening the capacity to generate and disseminate information necessary to increase citizen participation in decision-making processes.
http://awsassets.panda.org/downloads/cc_ecr_final_web.pdf

Methods and tools for assessing the vulnerability of forests and people to climate change (2009)
This working paper by the Center for International Forestry Research provides an overview of methods and tools suitable for assessing the vulnerability of forests,

forest ecosystem services and forest-dependent people or sectors to climate change. It provides a typology of methods and tools and gives examples.
www.cifor.cgiar.org/publications/pdf_files/WPapers/WP43Locatelli.pdf

A framework for assessing vulnerability of forest-based communities to climate change (2007)
This publication presents a general framework for and approach to assessing the vulnerability of forest-based communities to climate change and the potentially increased risks associated with such change. It identifies specific elements that should be considered in assessing vulnerability and outlines a series of steps that researchers and communities can follow to systematically determine sources of vulnerability to climate change.
www.resourcesnorth.org/downloads/NOR-X-414_web.pdf

Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change (2005)
This compendium provides a synthesis of key information about available frameworks and tools for assessing climate change vulnerability and adaptation options, special features of each framework or tool, and information about how to obtain documentation, training, or publications supporting each tool.
http://unfccc.int/files/adaptation/methodologies_for/vulnerability_and_adaptation/application/pdf/consolidated_version_updated_021204.pdf

ADAPTATION

Managing forests as complex adaptive systems: building resilience to the challenge of global change (2013)
This book links the emerging concepts of complexity, complex adaptive systems and resilience to forest ecology and management. It explores how these concepts can be applied in various forest biomes with their differing ecological, economic and social settings and history. Individual chapters stress different elements of these concepts based on the specific setting and expertise of the authors. Regions and authors have been selected to cover a diversity of viewpoints and emphases, from silviculture and natural forests to forest restoration, and from boreal to tropical forests.
www.routledge.com/books/details/9780415519779/ (*for purchase*)

Responding to climate change in national forests: a guidebook for developing adaptation options (2011)
This guidebook is a summary of current knowledge on climate change adaptation taken from educational syntheses, specific tools, facilitated dialogues, workshops and case studies. It focuses specifically on topics and approaches that are relevant to and compatible with resource management in national forests and potentially on other federal lands. The guidebook is intended to assist the transition to climate-smart approaches in resource management. It is not intended to be a comprehensive account

of all scientific and management efforts on climate change adaptation but rather a compilation of information and lessons learned that will inform adaptation planning and practice on national forests.
www.fs.fed.us/pnw/pubs/pnw_gtr855.pdf

weADAPT climate change explorer (2011)
This is an online platform focused on adaptation (and the synergies between adaptation and mitigation) targeting practitioners, researchers and policy-makers and providing them with access to information and possibilities to share experiences and lessons learned.
http://weadapt.org/

European forestry in the face of climate change: EUSTAFOR guidelines (2010)
The aim of this paper is to provide guidance to EUSTAFOR members on how forests can be managed to provide maximum benefits in terms of climate change mitigation and adaptation. The guidelines form a common framework of recommendations for EUSTAFOR members, focusing on the carbon balance. They come within the framework of the Pan European Operational-level Guidelines for SFM. The guidelines are voluntary and have been developed for state forests. They support synergies in implementing the United Nations Forum on Forests, the UNFCCC, the Convention on Biological Diversity, the United Nations Convention on Combating Desertification and other relevant forest-related international commitments.
www.eustafor.eu/failid/File/EustaforClimateReport2010_2.pdf

Adaptation of forests to climate change: some estimates (2010)
This paper focuses on the anticipated impacts of climate change on forests broadly and on industrial wood production in particular, and presents case studies from Brazil, South Africa and China. The aim is to identify likely damage and possible mitigating investments or activities. The results provide perspective on and estimates and projections of the impacts of climate change on forests and forestry in various regions and countries.
www.rff.org/documents/RFF-DP-10-06.pdf

Adaptation of forests and people to climate change: a global assessment report (2009)
This report produced by the International Union of Forest Research Organizations assesses the interrelations among forest ecosystems, the services they provide, and climate change; the past and future impacts of climate change on forest ecosystems and the people that depend on these ecosystems; and the management and policy options for adaptation.
www.iufro.org/download/file/4485/4496/Full_Report_pdf/

Making forests fit for climate change: a global view of climate-change impacts on forests and people and options for adaptation (2009)
This publication is based on a comprehensive assessment of scientific information about climate-change impacts and how forests and people can adapt to it. It also provides essential information for enhancing the adaptive capacity of both forests and people in the face of climate change.
www.iufro.org/download/file/4486/4496/Policy_Brief_ENG_final_pdf/

CRiSTAL (2009)
The Community-based Risk Screening Tool – Adaptation and Livelihoods (CRiSTAL) is designed to help project planners and managers integrate climate change adaptation and risk reduction into community-level projects.
www.iisd.org/cristaltool/

Impacts of climate change on European forests and options for adaptation (2008)
This study compiles and summarizes knowledge about the observed and projected impacts of climate change on forests in Europe and reviews options for forests and forestry to adapt to climate change.
http://ec.europa.eu/agriculture/analysis/external/euro_forests/full_report_en.pdf

Adapting to climate variability and change: a guidance manual for development planning (2007)
This manual was developed to assist project managers in understanding how climate change may affect their project outcomes and in identifying adaptation options to integrate into the design for more resilient projects.
http://pdf.usaid.gov/pdf_docs/PNADJ990.pdf

Climate adapt: European climate adaptation platform (CLIMATE-ADAPT)
This platform aims to support Europe in adapting to climate change, especially by providing access and information on expected climatic changes, the current and future vulnerability of regions and sectors, including forestry, national and transnational adaptation strategies, and potential adaptation options.
http://climate-adapt.eea.europa.eu/data-and-downloads?searchtext=&searchsectors=BIODIVERSITY&searchtypes=GUIDANCE

MOTIVE
The project on models for adaptive forest management (MOTIVE) investigates adaptive management strategies that address climate and land-use change. It also examines the impacts of these changes with respect to a broad range of forest goods and ecosystem services.
http://motive-project.net/

PRODUCTION AND ECOSYSTEM SERVICES

Revised ITTO guidelines for the sustainable management of natural tropical forests (2012)

These guidelines produced by the International Tropical Timber Organization (ITTO) are designed to assist forest managers, policy-makers and other stakeholders to manage, conserve and sustainably use natural tropical forests. They provide a reference on technical issues at the macro or landscape scale and the micro or FMU scale. The guidelines are designed to be applied in the management of production forest, although many of the principles, guidelines and recommended actions can and should also be applied to forest protection. They are designed to encourage multipurpose forest management practices that, if applied over the long term, will sustain the yields of multiple products from, maintain the provision of ecosystem services by, and safeguard the values of tropical forests for the benefit of multiple stakeholders.
www.itto.int/calls_proposals/id=2853

Guidelines on sustainable forest management in drylands of sub-Saharan Africa (2010)

These guidelines produced by FAO are intended to guide forestry decision-makers and managers in prioritizing the issues and aspects that need to be addressed to improve forest planning and management in drylands and as a result contribute to the well-being of local populations and enhance their social, cultural, environmental and economic benefits.
www.fao.org/docrep/012/i1628e/i1628e00.pdf

Incentives to sustain forest ecosystem services: a review and lessons for REDD (2009)

This publication presents a summary of a review of the design and performance of selected payments for ecosystem services and other incentive-based initiatives in four major tropical forest regions – the Amazon Basin, the Congo Basin, the miombo woodlands of eastern and southern Africa, and Southeast Asia. The report focuses on a number of critical issues for the design and implementation of national and subnational REDD activities, with a focus on the role of performance-based incentive mechanisms and key enabling conditions for their effective implementation.
http://pubs.iied.org/pdfs/13555IIED.pdf

Effects of management on timber production and carbon stocks in a boreal forest ecosystem under changing climate: a model-based approach (2007)

In this paper, a process-based growth and yield model was used to investigate the sensitivity of timber production and carbon stocks to management under different climate scenarios at the level of the FMU. The effects of initial age class distributions of an FMU on timber production and carbon stocks under different management

and climate scenarios were also examined and the implications on the cost of carbon sequestration over the next 100 years presented.
www.metla.fi/dissertationes/df42.pdf

Voluntary guidelines for the responsible management of planted forests (2006)
These non-legally binding FAO guidelines may be adopted and applied to planted forests in all ecogeographical zones and in countries, regions and landscapes at all stages of economic development. They are applicable to planted forests that fulfil productive functions for the provision of wood, fibre and non-wood forest products or protective functions for the provision of ecosystem and social services. They cover all aspects of planted forests, from policy development and planning to the technical considerations of planted forest management. The guidelines establish a framework to support dialogue in the formulation of policies, laws, regulations and strategic and management plans that, in turn, will help improve enabling conditions and enhance capacity and capability in planted forest management.
www.fao.org/docrep/009/j9256e/j9256e00.htm

ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests (2002)
These guidelines by ITTO highlight the increasing importance of degraded and secondary forests in tropical landscapes. They provide a set of principles and recommended actions to promote and encourage the management, restoration, rehabilitation and sustainable use of degraded and secondary forests as a component of sustainable social and economic development.
www.itto.int/policypapers_guidelines/

FAO model code of forest harvesting practice (1996)
The FAO model code is intended to promote harvesting practices that will improve standards of forest use, reduce environmental impacts, help ensure that forests are sustained for future generations and improve the economic and social contributions of forestry as a component of sustainable development. It examines harvesting planning, the implementation and control of harvesting operations, harvesting assessment, the communication of results to the planning team, and the development of a competent and properly motivated workforce. Information is also provided on the potential consequences that might be expected from a failure to implement these practices.
www.fao.org/docrep/V6530E/V6530E00.htm#Contents

BIODIVERSITY

Wildlife in a changing climate (2012)
This FAO publication analyses and presents how climate change affects or will likely affect wild animals and their habitats. Although climate change has already been observed and monitored over several decades, there are few long-term studies on how the phenomenon is affecting wildlife. There is growing evidence, however, that climate change significantly exacerbates other major human-induced pressures, such as encroachment, deforestation, forest degradation, land-use change, pollution and the overexploitation of wildlife resources. Case studies are presented that describe some of the body of evidence in some instances and provide projections of likely scenarios in others.
www.fao.org/forestry/30143-0bb7fb87ece780936a2f55130c87caf46.pdf

REDD+ and biodiversity (2011)
This document has been prepared by the Secretariat of the Convention on Biological Diversity (CBD) with a view to providing technical and scientific information on designing and implementing REDD+ activities in a way that does not run counter to the objectives of the CBD and supports the implementation of the programme of work on forest biodiversity. More specifically, the document aims to outline: the potential benefits of REDD+ for biodiversity and indigenous and local communities; the importance of biodiversity and indigenous and local community co-benefits for the long-term success of REDD+; possible risks of REDD+ for biodiversity and indigenous and local communities with a view to contributing to the development or improvement of appropriate policy recommendations; the ways in which the CBD can contribute to the success of REDD+; and the potential ways in which REDD+ can contribute to the objectives of the CBD.
www.cbd.int/doc/publications/cbd-ts-59-en.pdf

Climate change and forest genetic resources: state of knowledge, risks and opportunities (2011)
This FAO paper reviews and examines the impacts of climate change on genetic resources of organisms that are important for human well-being, and the potential role of these resources in mitigating and adapting to climate change. It focuses on forest genetic resources in the context of trees in natural forests, plantations and agroforestry systems. The paper consists of a review of the current state of knowledge and the identification of gaps and priorities for action.
www.fao.org/docrep/meeting/023/mb696e.pdf

Climate change and African forest and wildlife resources (2011)
This book prepared by the African Forest Forum systematically presents climate change in the context of African forests, trees and wildlife resources. It includes information on the broader aspects of climate change and variability, an overview of climate change on African wildlife resources, and socio-economic and policy

considerations for talking about climate change issues within the forest sector.
www.afforum.org/component/docman/doc_download/46-climate-change-and-african-forest-and-wildlife-resources.html

Sustainable forest management, biodiversity and livelihoods: a good practice guide (2009)
This publication by the CBD Secretariat addresses the linkages between forestry, biodiversity and development/poverty reduction. The summaries and examples show how biodiversity and sustainable economic development can go hand in hand.
www.cbd.int/development/doc/cbd-good-practice-guide-forestry-booklet-web-en.pdf

Mountain biodiversity and climate change (2009)
This publication of the International Center for Integrated Mountain Development reviews the impacts of climate change on mountain ecosystems and the consequences for the rest of the world. It discusses the present situation and approaches towards a common future strategy for mountain biodiversity conservation.
http://books.icimod.org/uploads/tmp/icimod-mountain_biodiversity_and_climate_change.pdf

Forest resilience, biodiversity, and climate change: a synthesis of the biodiversity/resilience/stability relationship in forest ecosystems (2009)
This paper by the CBD Secretariat reviews the concepts of ecosystem resilience, resistance and stability in forests and their relationship to biodiversity, with particular reference to climate change.
www.cbd.int/doc/publications/cbd-ts-43-en.pdf

ITTO/IUCN guidelines for the conservation and sustainable use of biodiversity in tropical timber production forests (2009)
These guidelines were prepared by ITTO and the International Union for Conservation of Nature and distinguish two levels of intervention. At one level, the guidelines set out those general approaches to forest management that will have wide application in ensuring that biodiversity values are maintained and should be adopted universally. At the other level, they review practical experience and provide advice that managers and decision-makers might draw on in designing locally applicable guidelines, codes of practice, regulations and silvicultural practices.
www.itto.int/policypapers_guidelines/

Connecting biodiversity and climate change mitigation and adaptation: report of the second ad hoc technical expert group on biodiversity and climate change (2009)
This CBD document examines the observed and projected impacts of climate change on biodiversity, the links between biodiversity and climate change adaptation and mitigation, the links between biodiversity and climate change mitigation with a

particular focus on land-use activities and reducing emissions from deforestation and forest degradation, and provides information on techniques for valuing biodiversity. It highlights that applying these techniques can quantify costs and benefits, opportunities and challenges and thus improve decision-making on climate change-related activities.
www.cbd.int/doc/publications/cbd-ts-41-en.pdf

Climate change and forest genetic diversity: implications for sustainable forest management in Europe (2007)
The publication reviews current understanding of how forest trees will cope with and adapt to climate change, and discusses the implications for SFM in Europe.
www.euforgen.org/fileadmin/bioversity/publications/pdfs/1216.pdf

Ecological monitoring of forestry management in the humid tropics: a guide for forestry operators and certifiers with emphasis on high conservation value forests (2004)
This publication provides guidance to the global effort on the sustainable management of high conservation value forests (HCVF) using valid criteria for production and conservation. The general objective is to provide operators and certifiers of tropical forests with methodological procedures that are practical and relevant to the ecological monitoring of certified forestry activities in HCVF (following Forest Stewardship Council protocols and standards).
http://awsassets.panda.org/downloads/wwfca_monitoreo.pdf

WATER AVAILABILITY

Water, climate change and forests: watershed stewardship for a changing climate (2010)
This report describes adaptation opportunities associated with forest management, specifically in the context of water and aquatic ecosystems. The first two sections describe the importance of forests to water resources in the United States of America and summarize observed and projected effects of climate change on the hydrologic cycle and forested watersheds.
www.fs.fed.us/pnw/pubs/pnw_gtr812.pdf

Forests and water (2008)
This FAO publication explains the role of forests in the hydrological cycle, with a particular focus on critical "red flag" forest situations such as mountainous or steep terrain, river and coastal areas and swamp ecosystems. It also addresses the protection of municipal water supplies and emerging systems of payments for watershed services. The publication highlights the need for holistic management in complex watershed ecosystems, taking into account interactions among water, forest and other land uses, as well as socio-economic factors.
ftp://ftp.fao.org/docrep/fao/011/i0410e/i0410e00.pdf

The new generation of watershed management programmes and projects (2006)
This FAO publication has been prepared primarily for field-level watershed management practitioners and local decision-makers involved in watershed management at the district or municipality level. It provides information on the new generation of watershed management using examples from France, Italy, Kenya, Nepal and Peru.
www.fao.org/docrep/009/a0644e/a0644e00.htm

FIRE

Climate change, carbon sequestration and forest fire protection in the Canadian boreal zone (2011)
This report reviews the potential influence of climate change on fire regimes in boreal forests and associated peatlands and the implications for managing fires in those ecosystems. It also discusses the role of boreal forest and peatland fires in cycling carbon through both the release of carbon (in the form of GHGs) in combustion, and the subsequent uptake of carbon in post-fire vegetation renewal.
www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@climatechange/documents/document/stdprod_088316.pdf

Wildland fire management: handbook for trainers (2010)
This handbook supports the implementation of the *Voluntary Guidelines for Fire Management*, targeting field trainers and instructors. Together with the *Voluntary Guidelines*, the handbook forms the basis for a programme of institution-strengthening and capacity-building in fire management, particularly in developing countries.
www.fao.org/docrep/012/i1363e/i1363e00.htm

Assessment of forest fire risks and innovative strategies for fire prevention (2010)
This publication presents the outcomes of the Workshop on the Assessment of Forest Fire Risks and Innovative Strategies for Fire Prevention, which was held on 4–6 May 2010 in Greece. It reviews the current national forest fire prevention systems in European countries and identifies innovative strategies, best practices and possible policy instruments in relation to forest fire prevention in Europe.
www.foresteurope.org/filestore/foresteurope/Publications/pdf/FOREST_EUROPE_Forest_Fires_Report.pdf

Fire management voluntary guidelines: principles and strategic actions (2006)
These voluntary guidelines set out a framework of priority principles that will aid the formulation of policy, legal, regulatory and other enabling conditions and strategic actions for more holistic approaches to fire management. They have been tailored primarily for land-use policy-makers, planners and managers in fire management, including states, the private sector and NGOs. The guidelines cover the positive and negative social, cultural, environmental and economic impacts of natural and planned fires in forests, woodlands, rangelands, grasslands and agricultural and rural/urban landscapes. The scope includes early warning, prevention, preparedness

(international, national, subnational and community), safe and effective initial attack on fire incidents, and landscape restoration in the wake of wildfire.
ftp://ftp.fao.org/docrep/fao/009/j9255e/j9255e00.pdf

PESTS AND DISEASES

Guide to implementation of phytosanitary standards in forestry (2011)
This guide is intended to help reduce human-facilitated pest spread and its impacts. It provides easy-to-understand information on international standards for phytosanitary measures and the role of forest management practices in implementing phytosanitary standards and facilitating safe trade.
www.fao.org/forestry/foresthealthguide/en/

Climate change impacts on forest health
This paper reviews the current state of knowledge on the effects of climate change on forest pests and their implications for forest health protection and management. Because of the relatively limited research that has been dedicated specifically to forest pests, information on non-forest pests is also included to enable a better understanding of the potential impacts of climate change on forest health.
ftp://ftp.fao.org/docrep/fao/011/k3837e/k3837e.pdf

EXTREME WEATHER EVENTS

Climate change and extreme weather events (2000)
This assessment sponsored by the Worldwide Fund for Nature reviews scientific knowledge on climate change and its impacts regarding the weather, particularly weather extremes. It addresses the extent to which the human influence on the climate can be measured, the short- and long-term expectations and the potential impact on the future climate of measures to reduce net GHG emissions.
http://awsassets.panda.org/downloads/xweather.pdf

SEA-LEVEL RISE

Practical measures to tackle climate change: coastal forest buffer zones and shoreline change in Zanzibar, Tanzania (2009)
This report of the United Nations Educational, Scientific and Cultural Organization presents the results of analyses of change (over 50 years) to coastal forests and practical actions to mitigate the unwanted effects of the change.
www.unesco.org/csi/climate-frontlines/PracticalMeasuresZanzibar_Ebook.pdf

Managing mangroves for resilience to climate change (2006)
This paper provides an overview of mangrove ecosystems, the benefits of mangroves to people, and the human and global threats that compromise mangrove ecosystems. It describes the impacts of climate change on mangroves and outlines tools and strategies that enhance mangrove resilience.
http://data.iucn.org/dbtw-wpd/edocs/2006-041.pdf

Sea-level rise and coastal forests on the Gulf of Mexico (1999)
This report reviews literature pertaining to the response of coastal forests on the Gulf of Mexico to sea-level rise. It discusses the effects of sea-level rise on non-mangrove and mangrove forests, and the responses of coastal trees to increased flooding and salinity.
http://coastal.er.usgs.gov/wetlands/ofr99-441/OFR99-441.pdf

SOCIAL RESPONSES

Pathways to climate change resilience: guidebook for Canadian forest-based communities (2011)
This guidebook emphasizes tools to facilitate community-based climate change adaptation in small communities (communities of less than 15 000 people) in Canadian forest environments. The guidebook will be pilot-tested in selected Canadian model forests, where communities will use the guidebook to support climate change adaptations. The learning from this testing will be used to increase the usefulness of the guide for forest-based communities.
www.modelforest.net/pubs/Pathways_to_Climate_Change_Resilience_FINAL_Feb_2011.pdf

Forests and society: responding to global drivers of change (2010)
An increasing number of complex global environmental and socio-economic drivers of change affect forests and society. This new book presents and discusses the challenges and opportunities related to the global drivers of change and the ways to reduce their adverse effects and to take advantage of the benefits and opportunities they might bring.
www.iufro.org/science/special/wfse/forests-society-global-drivers/

ECONOMIC RESPONSES

The implications of carbon financing for pro-poor community forestry (2007)
The emergence of new financing mechanisms associated with the rise of carbon markets brings potential for increased investment in forestry. This paper explores the implications of these mechanisms for community forestry and suggests ways in which such finance may contribute to the pro-poor outcomes of community forestry. The paper also provides an opportunity for those working on the design of carbon-financing mechanisms to draw on the experience of community forestry in structuring appropriate benefit systems.
www.odi.org.uk/resources/details.asp?id=438&title=implications-carbon-financing-pro-poor-community-forestry

Climate funds update
This is an independent website that provides information on the growing number of international funding initiatives designed to help developing countries address the challenges of climate change.
www.climatefundsupdate.org

MITIGATION

Understanding community-based REDD+: a manual for indigenous communities (2011)
This manual prepared by the International Work Group for Indigenous Affairs and Asia Indigenous Peoples Pact is based on and seeks to promote in a holistic way an approach to REDD+ that respects and promotes the rights of indigenous peoples, as provided for in the United Nations Declaration on the Rights of Indigenous Peoples, the social and cultural systems of indigenous peoples and their values and practices, and the environment.
www.aippnet.org/home/images/stories/A-Manual-for-Indigenous-Communities-20120117174234.pdf

Estimating the opportunity costs of REDD+: a training manual (2011)
This manual addresses the calculation of costs and benefits of the various land-use alternatives in relation to their carbon stocks. As required data are generally not readily available, the manual also includes information on data collection, analysis and evaluation. Although sections of the manual are relevant for subnational or project analysis, it is not intended to calculate compensation for farmers or landowners at a given site.
www.asb.cgiar.org/PDFwebdocs/OppCostsREDD_Manual_v1%203_low-res.pdf

Developing social and environmental safeguards for REDD+: a guide for a bottom-up approach (2010)
This guide describes a process for developing REDD+ social and environmental safeguards in Brazil that is based on the broad participation of all parties involved, including the private sector, environmental organizations, representatives of indigenous peoples and local communities, smallholders, and research institutions.
www.forest-trends.org/documents/files/doc_2573.PDF

The REDD opportunities scoping exercise (2009)
This publication by Forest Trends provides a tool for classifying and prioritizing potential REDD+ subnational activities and for assessing critical constraints to project development, especially those associated with the legal, political and institutional framework for carbon finance. The ROSE tool was developed and refined during 2009 in the course of conducting case studies in Ghana, the United Republic of Tanzania and Uganda.
www.forest-trends.org/documents/files/doc_2431.pdf

Guidebook to markets and commercialization of forestry CDM projects (2007)
This guide provides information to project developers about markets and the commercialization of certified emissions reductions obtained by forestry projects. The guide takes the reader through the development stages of a Clean Development Mechanism forestry project; the specific characteristics of forestry certified emissions

reductions, and the demand for this type of credit.
www.katoombagroup.org/~katoomba/documents/tools/GuidebooktoMarketsand CommercializationofCDMforestryProjects.pdf

Community forest management as a carbon mitigation option: case studies (2006)
This publication by the Center for International Forestry Research presents the results of community-based forest management initiatives that were undertaken to explore opportunities and challenges for smallholder farmers in developing countries to participate in schemes to mitigate climate change.
www.communitycarbonforestry.org/Case%20study%20bookWeb.pdf

REPORTING

Forest carbon accounting: overview & principles (2009)
This guide presents the main principles, practices and challenges for carbon accounting in the forest sector. In order to be accessible, the report is not overly technical and should not, therefore, be considered as a stand-alone guide to forestry carbon accounting. It does, however, present guidance for good practice in accounting and indicates further sources of guidance.
www.undp.org/climatechange/carbon-finance/Docs/Forest%20Carbon%20 Accounting%20-%20Overview%20&%20Principles.pdf

Revised ITTO criteria and indicators for sustainable management of tropical forests including reporting format (2005)
This is a tool for monitoring, assessing and reporting on forest management in tropical countries. The document includes a simplified set of indicators and a shortened format for reporting.
www.itto.int/direct/topics/topics_pdf_download/topics_ id=9630000&no=1&disp=inline

Forest and clouds in East Kalimantan, Indonesia.

Annex 3
Participants in the validation workshops

KENYA

Jan Vandenabeele	Better Globe Forestry
Langoya Council Dickson	CAMDA Consult
Simmone Rose	FAO
Edward Kilawe	FAO
John Ngatia	FAO
Judy Chege	FAO
Dan Rugabira	FAO
Kanyinke Sena	Forest Action Network
Prof. Donald Ogweno	Kenya Forest College
Carolyne Wanjiku	Forestry Society of Kenya
Samuel Ihure	Kenya Forest Service
Anthony Muysoka	Kenya Forest Service
Paul Ndungu Karanja	Kenya Forest Service
Joseph Kamondo	Kenya Forest Service
Dr. Joshua Cheboiywo	Kenya Forestry Research Institute
Simon Gathara	Kenya Meteorological Department
Peter Mbadi	Kenya Tea Development Authority
George Oselu	Kenya Tea Development Authority
Alice Kaudia	Ministry of Environment
Gideon Gathaara	Ministry of Forestry and Wildlife
Adata Margaret	Ministry of Water and Environment, Uganda
Mwajuma Abdi	National Alliance of Community Forestry Associations
Florian Mkeya	Tanzania Forest Service
Edgar Masunga	Tanzania Forest Research Institute

PERU

Percy Recavarren	AIDER
Cristina Del Águila Arévalo	AMPA
Elizabeth Silvestre	CAN
Haydeé Suárez	CESVI
Mary Menton	CIFOR
Oseas Barbarán	CONAP
Manuel de los Heros	Consultor independiente

PERU (continued)

María Capatinta	FAO
José Dancé	FAO
Jorge Elgegren	FAO
Alfredo Gaviria	FAO
Tatiana Lapeyre	FAO
Carlos A. Llerena	FAO
Carla Ramírez	FAO
Cesar Sabogal	FAO
Ángel Salazar	IIAP
Ymber Flores	INIA
Roberto Kometter	Intercooperation
Carlos Linares	MINAG
Sara Yalle	MINAG
Eduardo Durand	MINAM
Daniel Matos	MINAM
Javier Arce	Rainforest Alliance
Jorge Eliott	Soluciones Prácticas (ITDG)
Walter Roncal	UNC
Marco Chota	UNU
Greta Román	WWF
Patricia Huertas	UTC
Berioska Quispe	UTC
Jaziel Blanco	UTC
Jhaqueline Contreras	UTC
Patricia Durán	UTC

FAO FORESTRY PAPERS

1	Forest utilization contracts on public land, 1977 (E F S)
2	Planning forest roads and harvesting systems, 1977 (E F S)
3	World list of forestry schools, 1977 (E F S)
3 Rev.1	World list of forestry schools, 1981 (E F S)
3 Rev.2	World list of forestry schools, 1986 (E F S)
4/1	World pulp and paper demand, supply and trade – Vol. 1, 1977 (E F S)
4/2	World pulp and paper demand, supply and trade – Vol. 2, 1977 (E F S)
5	The marketing of tropical wood in South America, 1976 (E S)
6	National parks planning, 1976 (E F S)
7	Forestry for local community development, 1978 (Ar E F S)
8	Establishment techniques for forest plantations, 1978 (Ar C E* F S)
9	Wood chips – production, handling, transport, 1976 (C E S)
10/1	Assessment of logging costs from forest inventories in the tropics – 1. Principles and methodology, 1978 (E F S)
10/2	Assessment of logging costs from forest inventories in the tropics – 2. Data collection and calculations, 1978 (E F S)
11	Savanna afforestation in Africa, 1977 (E F)
12	China: forestry support for agriculture, 1978 (E)
13	Forest products prices 1960-1977, 1979 (E F S)
14	Mountain forest roads and harvesting, 1979 (E)
14 Rev.1	Logging and transport in steep terrain, 1985 (E)
15	AGRIS forestry – world catalogue of information and documentation services, 1979 (E F S)
16	China: integrated wood processing industries, 1979 (E F S)
17	Economic analysis of forestry projects, 1979 (E F S)
17 Sup.1	Economic analysis of forestry projects: case studies, 1979 (E S)
17 Sup.2	Economic analysis of forestry projects: readings, 1980 (C E)
18	Forest products prices 1960-1978, 1980 (E F S)
19/1	Pulping and paper-making properties of fast-growing plantation wood species – Vol. 1, 1980 (E)
19/2	Pulping and paper-making properties of fast-growing plantation wood species – Vol. 2, 1980 (E)
20	Forest tree improvement, 1985 (C E F S)
20/2	A guide to forest seed handling, 1985 (E S)
21	Impact on soils of fast-growing species in lowland humid tropics, 1980 (E F S)
22/1	Forest volume estimation and yield prediction – Vol. 1. Volume estimation, 1980 (C E F S)
22/2	Forest volume estimation and yield prediction – Vol. 2. Yield prediction, 1980 (C E F S)
23	Forest products prices 1961-1980, 1981 (E F S)
24	Cable logging systems, 1981 (C E)
25	Public forestry administrations in Latin America, 1981 (E)
26	Forestry and rural development, 1981 (E F S)
27	Manual of forest inventory, 1981 (E F)
28	Small and medium sawmills in developing countries, 1981 (E S)
29	World forest products, demand and supply 1990 and 2000, 1982 (E F S)
30	Tropical forest resources, 1982 (E F S)
31	Appropriate technology in forestry, 1982 (E)
32	Classification and definitions of forest products, 1982 (Ar E F S)
33	Logging of mountain forests, 1982 (E F S)
34	Fruit-bearing forest trees, 1982 (E F S)
35	Forestry in China, 1982 (C E)
36	Basic technology in forest operations, 1982 (E F S)
37	Conservation and development of tropical forest resources, 1982 (E F S)
38	Forest products prices 1962-1981, 1982 (E/F/S)

39 Frame saw manual, 1982 (E)
40 Circular saw manual, 1983 (E)
41 Simple technologies for charcoal making, 1983 (E F S)
42 Fuelwood supplies in the developing countries, 1983 (Ar E F S)
43 Forest revenue systems in developing countries, 1983 (E F S)
44/1 Food and fruit-bearing forest species – 1. Examples from eastern Africa, 1983 (E F S)
44/2 Food and fruit-bearing forest species – 2. Examples from southeastern Asia, 1984 (E F S)
44/3 Food and fruit-bearing forest species – 3. Examples from Latin America, 1986 (E S)
45 Establishing pulp and paper mills, 1983 (E)
46 Forest products prices 1963-1982, 1983 (E/F/S)
47 Technical forestry education – design and implementation, 1984 (E F S)
48 Land evaluation for forestry, 1984 (C E F S)
49 Wood extraction with oxen and agricultural tractors, 1986 (E F S)
50 Changes in shifting cultivation in Africa, 1984 (E F)
50/1 Changes in shifting cultivation in Africa – seven case-studies, 1985 (E)
51/1 Studies on the volume and yield of tropical forest stands – 1. Dry forest formations, 1989 (E F)
52/1 Cost estimating in sawmilling industries: guidelines, 1984 (E)
52/2 Field manual on cost estimation in sawmilling industries, 1985 (E)
53 Intensive multiple-use forest management in Kerala, 1984 (E F S)
54 Planificación del desarrollo forestal, 1984 (S)
55 Intensive multiple-use forest management in the tropics, 1985 (E F S)
56 Breeding poplars for disease resistance, 1985 (E)
57 Coconut wood – Processing and use, 1985 (E S)
58 Sawdoctoring manual, 1985 (E S)
59 The ecological effects of eucalyptus, 1985 (C E F S)
60 Monitoring and evaluation of participatory forestry projects, 1985 (E F S)
61 Forest products prices 1965-1984, 1985 (E F S)
62 World list of institutions engaged in forestry and forest products research, 1985 (E F S)
63 Industrial charcoal making, 1985 (E)
64 Tree growing by rural people, 1985 (Ar E F S)
65 Forest legislation in selected African countries, 1986 (E F)
66 Forestry extension organization, 1986 (C E S)
67 Some medicinal forest plants of Africa and Latin America, 1986 (E)
68 Appropriate forest industries, 1986 (E)
69 Management of forest industries, 1986 (E)
70 Wildland fire management terminology, 1986 (E F S)
71 World compendium of forestry and forest products research institutions, 1986 (E F S)
72 Wood gas as engine fuel, 1986 (E S)
73 Forest products: world outlook projections 1985-2000, 1986 (E F S)
74 Guidelines for forestry information processing, 1986 (E)
75 Monitoring and evaluation of social forestry in India – an operational guide, 1986 (E)
76 Wood preservation manual, 1986 (E)
77 Databook on endangered tree and shrub species and provenances, 1986 (E)
78 Appropriate wood harvesting in plantation forests, 1987 (E)
79 Small-scale forest-based processing enterprises, 1987 (E F S)
80 Forestry extension methods, 1987 (E)
81 Guidelines for forest policy formulation, 1987 (C E)
82 Forest products prices 1967-1986, 1988 (E F S)
83 Trade in forest products: a study of the barriers faced by the developing countries, 1988 (E)
84 Forest products: World outlook projections – Product and country tables 1987-2000, 1988 (E F S)

85 Forestry extension curricula, 1988 (E F S)
86 Forestry policies in Europe, 1988 (E)
87 Small-scale harvesting operations of wood and non-wood forest products involving rural people, 1988 (E F S)
88 Management of tropical moist forests in Africa, 1989 (E F P)
89 Review of forest management systems of tropical Asia, 1989 (E)
90 Forestry and food security, 1989 (Ar E S)
91 Design manual on basic wood harvesting technology, 1989 (E F S) (Published only as FAO Training Series, No. 18)
92 Forestry policies in Europe – An analysis, 1989 (E)
93 Energy conservation in the mechanical forest industries, 1990 (E S)
94 Manual on sawmill operational maintenance, 1990 (E)
95 Forest products prices 1969-1988, 1990 (E F S)
96 Planning and managing forestry research: guidelines for managers, 1990 (E)
97 Non-wood forest products: the way ahead, 1991 (E S)
98 Timber plantations in the humid tropics of Africa, 1993 (E F)
99 Cost control in forest harvesting and road construction, 1992 (E)
100 Introduction to ergonomics in forestry in developing countries, 1992 (E F I)
101 Management and conservation of closed forests in tropical America, 1993 (E F P S)
102 Research management in forestry, 1992 (E F S)
103 Mixed and pure forest plantations in the tropics and subtropics, 1992 (E F S)
104 Forest products prices 1971-1990, 1992 (E F S)
105 Compendium of pulp and paper training and research institutions, 1992 (E)
106 Economic assessment of forestry project impacts, 1992 (E F)
107 Conservation of genetic resources in tropical forest management – Principles and concepts, 1993 (E F S)
108 A decade of wood energy activities within the Nairobi Programme of Action, 1993 (E)
109 Directory of forestry research organizations, 1993 (E)
110 Proceedings of the Meeting of Experts on Forestry Research, 1993 (E F S)
111 Forestry policies in the Near East region – Analysis and synthesis, 1993 (E)
112 Forest resources assessment 1990 – Tropical countries, 1993 (E)
113 Ex situ storage of seeds, pollen and in vitro cultures of perennial woody plant species, 1993 (E)
114 Assessing forestry project impacts: issues and strategies, 1993 (E F S)
115 Forestry policies of selected countries in Asia and the Pacific, 1993 (E)
116 Les panneaux à base de bois, 1993 (F)
117 Mangrove forest management guidelines, 1994 (E)
118 Biotechnology in forest tree improvement, 1994 (E)
119 Number not assigned
120 Decline and dieback of trees and forests – A global overview, 1994 (E)
121 Ecology and rural education – Manual for rural teachers, 1995 (E S)
122 Readings in sustainable forest management, 1994 (E F S)
123 Forestry education – New trends and prospects, 1994 (E F S)
124 Forest resources assessment 1990 – Global synthesis, 1995 (E F S)
125 Forest products prices 1973-1992, 1995 (E F S)
126 Climate change, forests and forest management – An overview, 1995 (E F S)
127 Valuing forests: context, issues and guidelines, 1995 (E F S)
128 Forest resources assessment 1990 – Tropical forest plantation resources, 1995 (E)
129 Environmental impact assessment and environmental auditing in the pulp and paper industry, 1996 (E)
130 Forest resources assessment 1990 – Survey of tropical forest cover and study of change processes, 1996 (E)
131 Ecología y enseñanza rural – Nociones ambientales básicas para profesores rurales y extensionistas, 1996 (S)
132 Forestry policies of selected countries in Africa, 1996 (E F)

133 Forest codes of practice – Contributing to environmentally sound forest operations, 1996 (E)
134 Estimating biomass and biomass change of tropical forests – A primer, 1997 (E)
135 Guidelines for the management of tropical forests – 1. The production of wood, 1998 (E S)
136 Managing forests as common property, 1998 (E)
137/1 Forestry policies in the Caribbean – Volume 1: Proceedings of the Expert Consultation, 1998 (E)
137/2 Forestry policies in the Caribbean – Volume 2: Reports of 28 selected countries and territories, 1998 (E)
138 FAO Meeting on Public Policies Affecting Forest Fires, 2001 (E F S)
139 Governance principles for concessions and contacts in public forests, 2003 (E F S)
140 Global Forest Resources Assessment 2000 – Main report, 2002 (E F S)
141 Forestry Outlook Study for Africa – Regional report: opportunities and challenges towards 2020, 2003 (Ar E F)
142 Cross-sectoral policy impacts between forestry and other sectors, 2003 (E F S)
143 Sustainable management of tropical forests in Central Africa – In search of excellence, 2003 (E F)
144 Climate change and the forest sector – Possible national and subnational legislation, 2004 (E)
145 Best practices for improving law compliance in the forest sector, 2005 (E F R S)
146 Microfinance and forest-based small-scale enterprises, 2005 (Ar E F S)
147 Global Forest Resources Assessment 2005 – Progress towards sustainable forest management, 2006 (E F S)
148 Tendencias y perspectivas del sector forestal en América Latina y el Caribe, 2006 (S)
149 Better forestry, less poverty – A practitioner's guide, 2006 (Ar E F S)
150 The new generation of watershed management programmes and projects, 2006 (E F S)
151 Fire management – Global assessment 2006, 2007 (E)
152 People, forests and trees in West and Central Asia – Outlook for 2020, 2007 (Ar E R)
153 The world's mangroves 1980–2005, 2007 (E)
154 Forests and energy – Key issues, 2008 (Ar C E F R S)
155 Forests and water, 2008 (E F S)
156 Global review of forest pests and diseases, 2009 (E)
157 Human-wildlife conflict in Africa – Causes, consequences and management strategies, 2009 (E F)
158 Fighting sand encroachment – Lessons from Mauritania, 2010 (E F)
159 Impact of the global forest industry on atmospheric greenhouse gases, 2010 (E)
160 Criteria and indicators for sustainable woodfuels, 2010 (E)
161 Developing effective forest policy – A guide, 2010 (E F S)
162 What woodfuels can do to mitigate climate change, 2010 (E)
163 Global Forest Resources Assessment 2010 - Main report (Ar C E F R S)
164 Guide to implementation of phytosanitary standards in forestry, 2011 (C E F R)
165 Reforming forest tenure – Issues, principles and process, 2011 (E S)
166 Community-based fire management – A review (E)
167 Wildlife in a changing climate (E)
168 Soil carbon monitoring using surveys and modelling – (E)
169 Global forest land-use change 1990–2005 (E F S)
170 Sustainable management of *Pinus radiata* plantations (E)
171 Edible insects – Future prospects for food and feed security (E)

Ar – Arabic
C – Chinese
E – English
I – Italian
F – French
P – Portuguese
S – Spanish
R – Russian

Multil – Multilingual
* – Out of print

FAO Forestry Papers are available through the authorized FAO Sales Agents, directly from Sales and Marketing Group, FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy, or at www.fao.org/forestry/58718/en/.

172
FAO FORESTRY PAPER

Climate change guidelines for forest managers

The effects of climate change and climate variability on forest ecosystems are evident around the world and further impacts are unavoidable, at least in the short to medium term. Addressing the challenges posed by climate change will require adjustments to forest policies, management plans and practices.

These guidelines have been prepared to assist forest managers to better assess and respond to climate change challenges and opportunities at the forest management unit level. The actions they propose are relevant to all kinds of forest managers – such as individual forest owners, private forest enterprises, public-sector agencies, indigenous groups and community forest organizations. They are applicable in all forest types and regions and for all management objectives.

Forest managers will find guidance on the issues they should consider in assessing climate change vulnerability, risk and mitigation options, and a set of actions they can undertake to help adapt to and mitigate climate change. Forest managers will also find advice on the additional monitoring and evaluation they may need to undertake in their forests in the face of climate change.

This document complements a set of guidelines prepared by FAO in 2010 to support policy-makers in integrating climate change concerns into new or existing forest policies and national forest programmes.

ISBN 978-92-5-107831-0 ISSN 0258-6150
9 789251 078310
I3383E/1/07.13