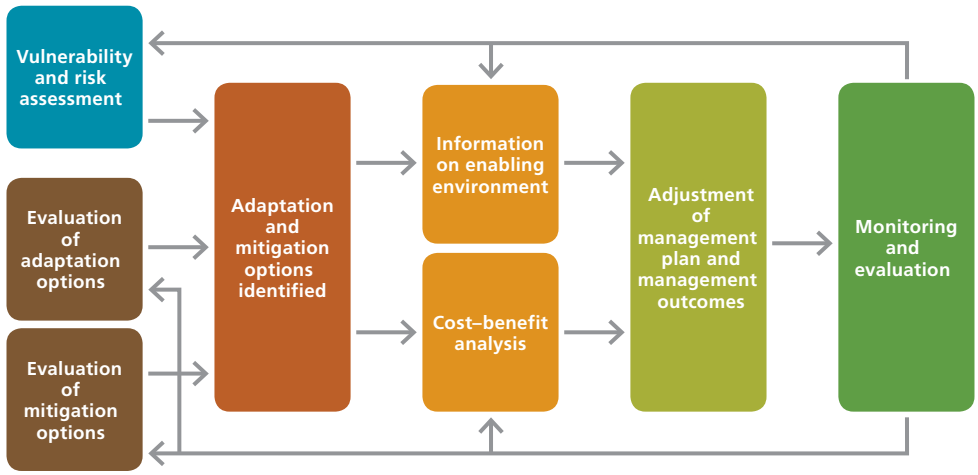
4. Management responses to climate change

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.

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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.

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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.

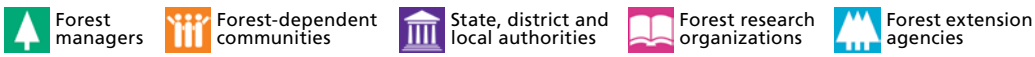
Adaptive forest management will be essential to reduce forest vulnerability and to maintain forest productivity. Adaptation measures might include, for example, the selection of heat-tolerant and drought-tolerant species in planted forests, the use of planting stock from a range of provenances, the underplanting 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)	

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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)	

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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	

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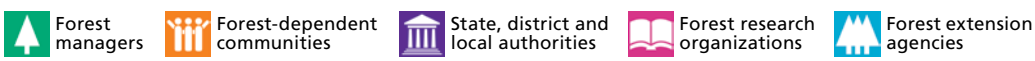
CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
	Protect fire-sensitive ecosystems through landscape planning and management, with a prevention focus	
	Modify landscape structure to impede fire spread (e.g. establish networks of fire breaks; manage for a mix of stand ages and stocking 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.

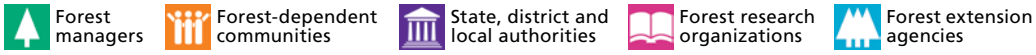
While the increase in salvage harvesting has boosted wood processing temporarily, in the longer term the beetle outbreak could have significant economic, social and cultural impacts on communities that have relied on logging and sawmilling for decades. British Columbia is investing in coalitions to increase 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	

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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

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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

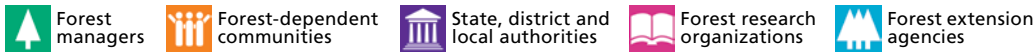
Coastal forests – such as mangroves, beach forests and some peat swamp forests and lowland moist tropical forests – play important economic, social and environmental roles. Sea-level rise due to climate change poses a threat to many natural coastal forests.

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)	

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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	

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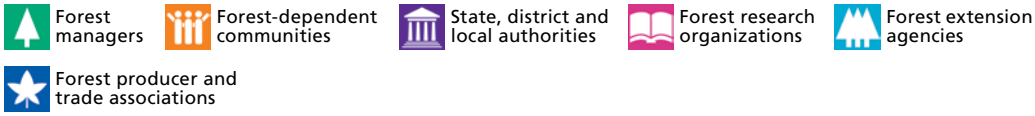
CLIMATE CHANGE IMPACTS AND RISKS	MANAGEMENT ACTIONS	RESPONSIBILITY
	Promote the multiple values of forests (i.e. cultural, economic, environmental, political, social and spiritual) for indigenous and other communities with customary tenure systems	
	Form partnerships to raise awareness about the potential 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	

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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.

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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

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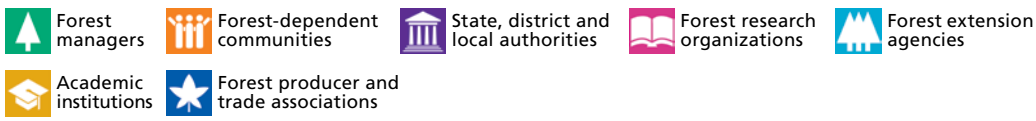
Full involvement of users of ecosystem services in adaptation planning, implementation, monitoring and evaluation is important for the success of schemes for payments for ecosystem services.

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.

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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	

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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)	

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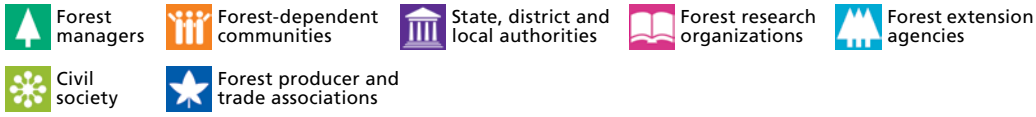
MITIGATION STRATEGY	MITIGATION OPTION	MITIGATION BENEFIT/ EFFECT ON CARBON	MANAGEMENT ACTION	RESPONSIBILITY
Substitution and carbon storage	Substituting fossil fuels and carbon-rich products with forest products (that are carbon-neutral)	Avoid GHG emissions from the burning of fossil fuels by replacing 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.