Considering that European forests are increasingly impacted by recent natural disturbance developments, such as extreme weather events, outbreaks of pests and diseases, there is a need for a broader framework for climate change adaptation and pro-active disturbance-risk management. The present rate and magnitude of climate change exceeds the natural migration and adaptation capacity of tree species. Sustainable forest management (SFM) practices need to be adapted to these changing conditions by enhancing the adaptive capacity and resilience of managed as well as some currently unmanaged forests and other wooded land. Appropriate measures to support this (e.g. by increasing genetic diversity in forest regeneration, assisted migration or adopting silvicultural systems favouring structural diversity) and disturbance risk prevention should be selected based on robust scientific evidence combined with practical experience and knowledge of particular site conditions and species’ requirements.

At international and national levels, legal frameworks and policies may hamper the possibility of adapting SFM practices to the changing climatic conditions, e.g. by limiting proactive forest management or transfer of forest reproductive material. Governments and institutions at all levels should establish favourable conditions for adaptation to climate change through appropriate revision of their policies (e.g. national forest programmes), guidelines for forestry practice and legislation. For example, the Pan-European operational-level guidelines for sustainable forest management (PEOLG) endorsed by European countries in 1997 would deserve an update related to climate change adaptation needs. In addition, national/international guidelines and/or legislation regulating transfers of forest reproductive material should be revised to allow assisted migration and selection of suitable provenances considering the recent and projected changes in climate.

A changing climate, accompanied with more frequent and extreme disturbances, requires a longer time horizon for the planning of adaptation measures. The efforts of governments and all stakeholders in implementation of forward-looking adaptation measures should be further intensified, taking into account projected climate change over the time horizon of rotation periods. Possible support schemes should reflect forest owners’ longer-term commitments.

Governments and institutions at all levels should continue to revise, if appropriate, their policies and legislation, to allow pro-active approaches and management measures in different types of forests. In this respect, cross-sectoral coordination of policies is inevitable as climate change intensifies the extreme disturbance events that will affect all forests, including those in protected areas or protective forests, and only well-adapted and resilient forests may contribute to the achievement of policy objectives set by various policy domains.

Multi-stakeholder involvement is equally important as, for example, high ungulate population densities may hinder successful implementation of adaptation measures such as forest stand conversion. Wildlife and hunting policies,
therefore, need to be adjusted to enable the development of well-adapted and resilient forests. Efficient hunting strategies, ungulate density limits and reliable game monitoring will have to be implemented, otherwise the potential of natural regeneration and a diversified tree species composition in European forests would not be achieved. Game management should be accompanied by informing the public on the role of hunting in the SFM.

Another example is cross-sectoral land use planning aimed at the development of fire-smart landscapes e.g. through establishing natural firebreaks between fire-prone areas, managing the vegetation on abandoned land, reducing fuel load (e.g. understorey, grass layer, excessive small dimension deadwood) and optimising forest structures and vegetation mosaics in the landscapes. Cooperatives could also improve management of small and fragmented properties in this respect.

Sustainable pro-active forest management is crucial especially in disturbance-risk prevention (e.g. managing the fuel load in fire-prone areas or favouring species mixtures to mitigate insect outbreaks). To cope with large-scale disturbances, governments should continue their efforts towards advanced coordination of human and other resources (including infrastructure, machinery, etc.) cross-sectorally within countries and between countries, cooperating also with stakeholders along the whole timber supply chain.

Traditional disturbance-risk management measures often focus on emergency responses. If not coupled with appropriate prevention measures, effectiveness of such risk management is increasingly questioned (by both scientists and practitioners). Instead, disturbance-prevention measures should be more widely advocated and supported as they may also improve cost-efficiency in forest protection against risks. Emphasizing prevention efforts provides an opportunity to move towards effective climate change adaptation, while supporting the prevention measures may simultaneously contribute to other policy objectives such as promoting local livelihoods and local economies.

In addition to that, after large disturbances, there is an increased risk of secondary disturbances (e.g. insect outbreaks following storm damages) or ecosystem deterioration through e.g. soil erosion (after wildfires), an enhanced risk of avalanches and floods. These risks may be mitigated through appropriate preventive measures, e.g. early detection, rapid salvage fellings, extraction or debarking of windblown trees or building technical avalanche protection after the loss of protective forests.

As large disturbances of the same type rarely affect the same area more than once in the professional career of a forest manager, local expertise is often insufficient. The recent extreme disturbances, such as heat waves, droughts and others often affected regions where there was little experience in managing wildfires and pests’ outbreaks of a comparable magnitude, which may result in delayed responses, increasing the damages. Appropriate forms of knowledge exchange mechanisms are necessary to facilitate sharing of expertise on topics such as enhancing forest resilience, fostering the adaptive capacity in the forest sector, disturbance prevention, early responses to disturbance events and recovery measures as well as gathering information in order to build expert capacity and inform policy makers.

Recent restructuring of forest management bodies in many countries, often including outsourcing of forestry operations, has resulted in the loss of skilled workforce in the affected subjects and there is a general need for training and capacity building. Particularly, there is an urgent need to improve skills in disturbance management and harvesting operations among managers and forest workers. Qualified staff is necessary to implement sustainable forest management practices not damaging remaining trees, soil and the environment in planting, tending and other forestry activities implemented to adapt forest stands. Therefore, targeted education programs at forestry colleges, universities and training courses for forest managers and workers should be developed and launched as soon as possible.
The following recommendations may fit to specific forest management regimes, national specifics, site conditions, species requirements, they are not meant to be generally applicable:

- Forest stability, vitality and resilience can be enhanced through silvicultural practices making the best use of natural structures and processes, more diverse tree species composition, higher genetic, age and structural diversity - horizontally and vertically, increased individual tree stability, tree species and provenances selection.
- Disturbance risks in intensive wood-production systems may be mitigated through shorter rotation cycles (younger stands are usually more resistant) and through selection of tree species (and provenances) better adapted to the projected climate.
- When salvage cutting is carried out, it should be considered that keeping some volume of lying deadwood may protect seedlings against soil erosion, avalanches, and browsing and, at a certain stage of decay, it may provide a seedbed for natural regeneration of some tree species, which is beneficial especially on heavily weeded areas.
- Traditional and/or innovative disturbance-prevention measures, e.g. managing ground cover vegetation by livestock grazing, advanced regeneration (underplanting) and conversion of monocultures into mixed forest stands, should complement emergency responses and forest recovery.
- Fire-smart landscape management e.g. through reducing fuel load (e.g. reducing flammable biomass such as shrub and grass layers, reducing thin deadwood), establishing natural firebreaks and re-introducing management of abandoned land.
- Use of natural regeneration after disturbance events should be preferred if sufficient natural regeneration is present on the site. However, this requires a sufficient amount of seeding trees suitable for the projected climate and expected future demands of the market and society. In other cases, natural regeneration should be supplemented with planting of suitable species or provenances, including assisted migration, where appropriate.
- Water availability for remaining trees in drier climates can be increased through more intensive tending (cleaning and thinning) which will reduce trees’ competition for water. In some cases, restoration of natural water regimes by disabling artificial drainage systems may also improve water availability in forest landscapes.

Technical capacities and infrastructure need to be developed to meet the needs resulting from climate change and increased disturbance risks.

Increased capacities of the whole forest reproductive material supply chain (seed collection, storage, transport, nurseries) is vital for both sustainable forest management and coping with large-scale disturbances. Particular attention should be given to the ability of the tree nursery sector to provide sufficient quantities of suitable forest reproductive materials necessary for forest adaptation and restoration.

Timber extraction after large disturbances is very complicated and its safety is compromised. Innovative remote sensing technologies can provide support in planning of restoration activities following such events, may enable the identification of dangerous overhanging and semi-uprooted trees before entering in a damaged forest to reduce the risk of injuries. Such information can also be useful to improve the planning of the restoration processes, reduce the costs and estimate the realistic value of the damaged wood.

Saturation of wood markets due to excess wood availability following large disturbances can be challenging. Additional limiting factors may be a lack of capacity in the transport and wood-processing sectors. Information exchange, improved logistical planning and key stakeholder involvement throughout the supply chain, should be enhanced. At the same time, the effects of climate change and resulting changes in tree species composition will require investments in processing capacity for hardwood as well as new wood products and further research on its better and improved uses.
Genetics and Forest Reproductive Material

The use of appropriate forest reproductive material, selection of species, provenances and seed sources that are both suitable for the current and future site conditions and sufficiently genetically diverse to be self-sustaining in changing environmental conditions should be promoted.

Relevant national institutions should be encouraged to keep long-term records on the origin of forest reproductive material (at stand level) to make this information available for adaptive forest management. This information will allow to investigate the correlation between the performance of the stands, species and provenances and their origin, thus enabling the development of large-scale recommendations for future choice of climatically adapted forest reproductive material.

The future adaptation of forests will heavily depend on the improved availability of appropriate forest genetic resources. Countries should therefore collaborate to develop and implement a common strategy for forest genetic resources, with the aim to conserve the evolutionary potential of European tree species in a network of dynamic genetic conservation units.

Monitoring

Evidence-based climate change adaptation and pro-active disturbance risk management should be supported by intensified forest monitoring efforts (e.g. enhanced national forest inventories). Future efforts in monitoring should focus on immediate mapping of damage following large-scale disturbances or continuous monitoring of factors influencing disturbance risk, e.g. soil water deficits as early warning signal. With a broader implementation of forest adaptation practices, such as assisted migration, there will also be a need to monitor the effectiveness of the implemented adaptation measures.

Existing services based on Copernicus remote sensing data have been proven helpful in the risk and damage assessments and these services could be further improved. For the correct interpretation of remote sensing data, taking into account all national and local specifics, it will be essential to improve the collecting of national in situ information and the involvement of national experts and stakeholders.

To plan and target pro-active risk management, it is important to monitor preparedness, applied adaptation measures and the recovery progress after disturbance events.

Insect population dynamics and associated damages are currently being monitored (to a various degree) by regional and national institutions, but these data are not systematically compiled at international level. The scale and speed of recent outbreaks may require to improve international coordination on data collection. It would be also helpful to produce regular compilations of national reports on forest damage to provide countries with an international overview of the situation.

Public Awareness

In the field of forests and forestry, the public should be properly informed about impacts of climate change, extreme natural disturbances events, how foresters have reacted to past damages as well as about the progress in preparation to and prevention of future damages. Map services can be used to improve public awareness of disturbance risks, recent disturbance impacts and associated reactions and measures, e.g. to communicate the management responses to disturbances via media. Communication should explain the steps to be taken in response to the disturbance and to facilitate recovery. More efforts should be directed towards communicating the characteristics that affect forest resilience (e.g. suitability of present tree species under the projected future climate, tree species diversity) to raise awareness of the general public, but also of private owners and forest managers. As most wildfires in Europe are human induced, public awareness building (some countries refer to so-called wildfire-risk culture) is a crucial component in citizen involvement and prevention of natural hazards in forests.