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ADAPTIVE FOREST MANAGEMENT TO CLIMATE CHANGE IN SOUTHEAST NORWAY – BASIC FRAMES, RISKS AND POSSIBILITIES

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Implemented in project EHP-CZ02-OV-1-019-2014
FRAMEADAPT Frameworks and possibilities of forest adaptation measures and strategies connected with Climate change
Activity 4: ***Adaptive Forest Management to Climate Change in Southeast Norway***

Ministry of Finance of the Czech Republic
Ministry of the Environment of the Czech Republic

ICELAND LIECHTENSTEIN NORWAY eea grants

Podpořeno grantem z Islandu, Lichtenštejnska a Norska.
Supported by grant from Iceland, Liechtenstein and Norway.

According to the IPCC (2007), adaptation is defined as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Related to forestry, two different fields of adaptation measures can be distinguished accordingly: (i) management of trees, stands, and combinations of stands in the landscape, and (ii) activities changing the socio-economic and political frame of forest management (Lindner et al. 2008).

Adaptive forest management (Walters 1986, Heinimann 2010) has been proposed to enhance the provision of forest ecosystem goods and services under uncertain future conditions such as climate change. In general, the management involves alternative management practices that enhance resilience to environmental changes by promoting diversity in tree species and stand structure (Spiecker et al. 2004), by adapting the tree species mixture to anticipated future climate conditions (Chmura et al. 2011), or by favouring certain species through planting or thinning (Temperli et al. 2012).

Climate change impacts on boreal forest stands and forestry

The predicted climate change can lead to positive as well as negative impacts. The potential positive impacts are wood production increase, biodiversity increase – colonization by other species without replacing the existing species on the landscape level. However, many identified negative impacts are an important reason for implementing the adaptive forest management.

Currently, the boreal zone lies beyond the distribution range of many pest species – a situation which could be drastically changed by the predicted increase in winter and summer temperatures. The changes are expected to increase the risk of both invading and existing pathogens and pest insects. Current limitations on spread of these populations by cold winter temperatures are expected to gradually recede. Higher temperatures in the growing season increase the risk of destructive pest increase, especially in multivoltine species. The pest species that will be positively affected by climate change are above all: bark beetles – *Ips typographus*, *Tomicus piniperda* – and some of defoliators – *Lymantria monacha*, *Lymantria dispar*, *Neodiprion sertifer*, *Epirrita autumnata* (Lindner et al. 2008). The first identification of new pathogens (e.g., *Phytophthora inflata*) and insect species, e.g., sawflies (*Acantholyda* spp.), has been recorded in Finland (Spathelf et al. 2014). Forest damage by wind or snow and consequential damage by bark beetles (*Ips typographus*) are projected to increase because of the potential decrease in soil freezing. A lack of soil frost is also expected to cause problems for tree harvesting, which should necessarily concentrate more towards the summer months implying higher risks of root damage and rot development. Earlier bud burst and delayed growth cessation are likely to increase the risk of frost damage in early spring and autumn. Summer droughts are assumed to negatively affect forests in the southern part of the Boreal region (Spathelf et al. 2014).

Various studies for Nordic countries predict increase in net primary production (NPP) by ca. 5–27 % for coniferous stands at elevated temperature condition. The increase is predicted smaller for Scots pine stands growing in a maritime climate like in Norway compared with a continental climate in central Sweden and eastern Finland (Bergh et al. 2003). The potential faster growth may be also problematic. Plants that are tall (with isohydric stomatal regulation, low hydraulic conductance and high leaf area) are most likely to die from drought stress. In general, large trees may become less competitive owing to their longer life spans and their lower fecundity relative to smaller plants (McDowell, Allen 2015). Moreover, some studies showed that at the southern part of Fennoscandia the cumulative gross primary production (GPP) and total stem wood growth would be lower under the changing climate than in the current climate due to greater water depletion via evapotranspiration and reduced soil water availability (Ge et al. 2012). Elevated temperatures lead to increased evapotranspiration and this increases the demand for water (Lindner et al. 2008). Most of the Boreal zone is currently not water-limited, but some areas in SE Norway may be threatened, because of the poor water retention capacity in the soils combined with increasing evapotranspiration in the areas.

The SE Norway is divided into four bioclimatic zones: Boreal subcontinental, Boreal oceanic, Temperate oceanic, and Temperate continental (Rivas-Martínez et al., 2004). This means that part of the area is placed in the same zones as the Czech Republic – Temperate oceanic (Bohemia and part of North Moravia) and Temperate continental (the rest of Moravia) where similar problems with Norway spruce dying were identified as in SE Norway (see below). The present forests are to a large extent formed by two conifers – *Picea abies* and *Pinus sylvestris* – and two birch species – *Betula pendula* and *B. pubescens*. The two conifers are economically the most important species and are the only species actively managed for wood production in the commercial forestry.

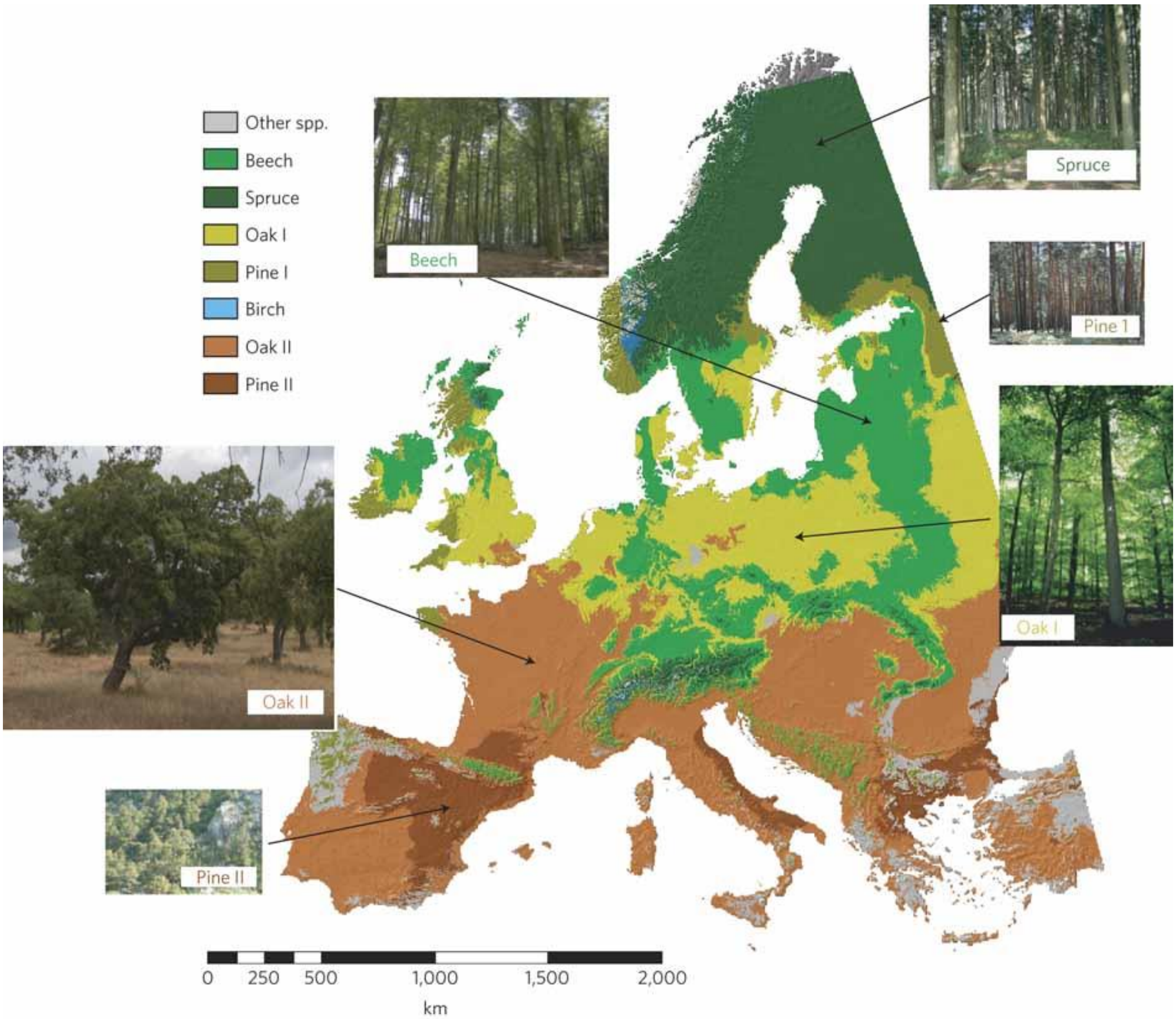

Fig. 1 The change of tree growth conditions will lead to a change in species composition (Hanewinkel et al. 2013). Southern part of Norway will not support conditions for spruce monocultures.

Changes in species distribution and competition between species are expected. *Fagus sylvatica* and other temperate hardwoods will spread to the north (Sykes, Prentice, 2012; Hanewinkel et al. 2013, see Fig. 1; Bolte et al. 2007, see Fig. 2). *Picea* forests are subject to continuing disturbance and show a more rapid shift to dominance by *Fagus* and other temperate hardwoods. Delayed immigration of new species, including *Fagus*, would favour early-successional species such as *Betula pendula* and *Quercus* spp. in a forests with reduced biomass and diversity (Sykes, Prentice, 2012).

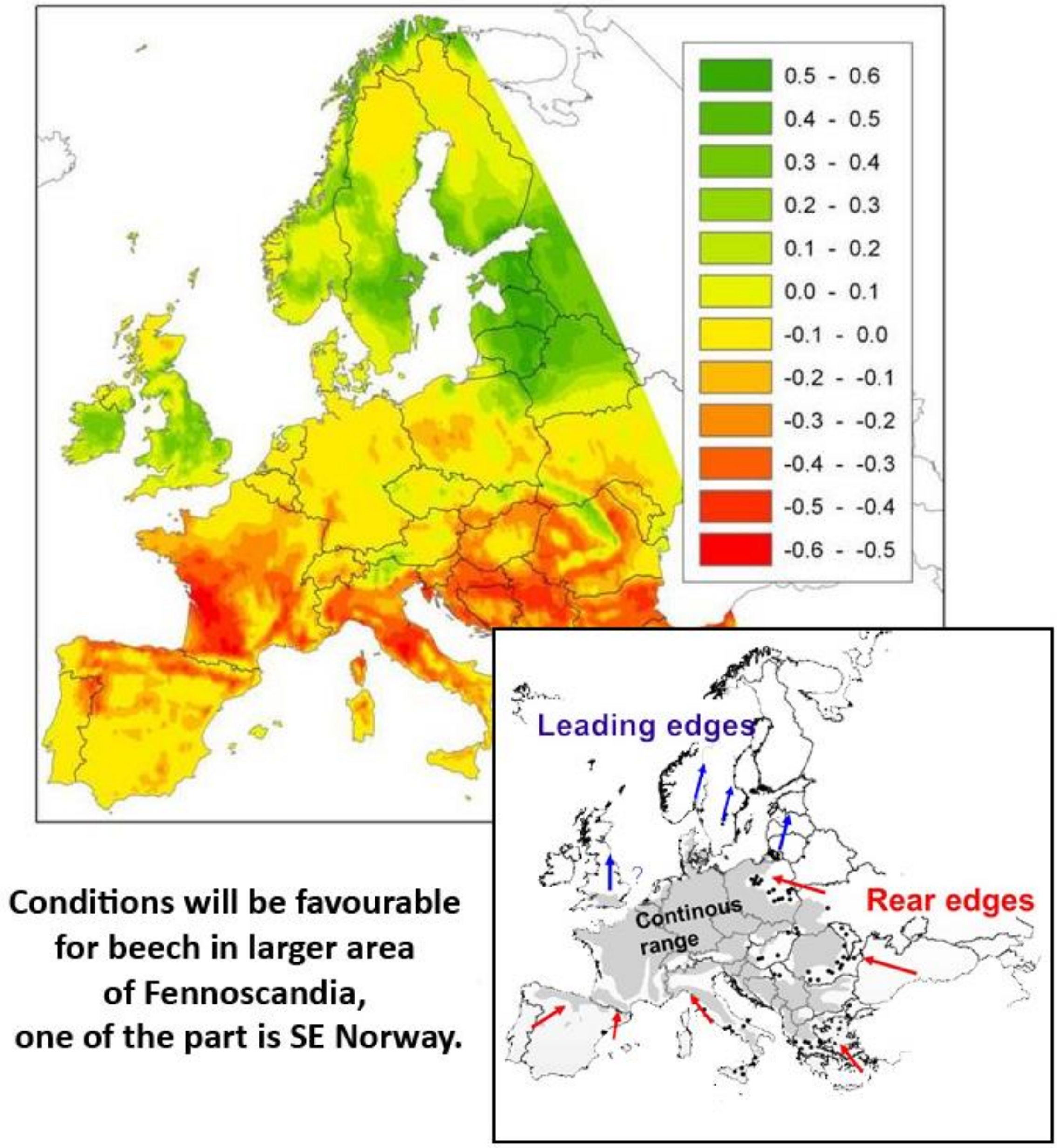

Fig. 2 upper left picture: *Difference in probability of occurrence of European beech under the A2 climate change scenario with that of the current climate, based on an ensemble projection of statistical envelope models (BIOMOD). The map thus represents the change in habitat suitability due to climate change for European beech. Green indicates an increase, red a decrease in habitat suitability relative to the current climate (Kramer et al. 2012, upper left picture;* lower right picture: *Predicted change of beech distribution (Bolte et al. 2007; Bolte, Spathelf 2013).*

Norway spruce is the economically the most important tree species in Norway and forests in the SE regions are among the most productive in the country. Climate change, especially the increase in temperature during the 20th century, has been associated with drought stress in Norway spruce stands in SE Norway (Solberg 2004). At the same time, shifts in radial growth response of coastal Norway spruce induced by climate change have been observed in central Norway (Solberg et al. 2002).
Private forest owners and commercial forest companies depend on the revenues from selling wood. However, present problems result in harvest 10–15 years before the optimal rotation age or forest breakup. This reduces the economic benefits from Norway spruce forests – costs are increasing and yields are decreasing.
A change in the factor controlling Norway spruce growth was identified within the FRAMEADAPT project (Čermák et al. 2016). Correlations between tree-ring width and climate parameters showed temporal instability in their relationship. The tree-ring width chronology reflected a significant positive April–May precipitation signal since the 1960s. Our results show that a temperature increase significantly contributed to this shift. The observed increase in spring temperatures may have resulted in increased evapotranspiration, which in turn may have significantly changed the water balance of the trees. It can be very important for radial growth, vitality and health condition of Norway spruce in the areas explored. This phenomenon is already quite common in some areas at low and middle altitudes of Continental Europe and now it can also be observed in the forests of SE Norway.

Adaptation measures

According to concept reports of the Norwegian Ministry of Climate and Environment, appropriate forest adaptation measures for Norway include good forest hygiene, the choice of tree species, the choice of resilient seed trees and stand boundaries, appropriate programmes for tending young-growth stands, and caution when thinning at a late stage and during selection cutting (Norwegian Ministry of Climate and Environment 2013). Our recommendation for SE Norway include: species composition changes, optimization of regeneration, integrated forest protection and change of tending, thinning and harvesting, especially in Norway spruce stands.

SPECIES COMPOSITION CHANGES

The measure includes:

- diversification of species composition, more species, genotypes, phenotypes, provenances;
- use of more resistant woody plant varieties;
- use of early-successional tree species in a situation when regeneration of target tree species is complicated;
- to give priority to native species;
- change of the tree species composition in areas with high fire risks – broadleaved instead of coniferous tree species.

To prevent climate-change-induced forest diebacks and declines, optimized species composition needs to be the target of an effective adaptive management strategy, especially where the difference between the current and the target species composition is magnified by past management practices. Due to uncertainty in (1) climate change predictions,

(2) the suitability of species under future climates, and (3) the future demands for forest goods and services, the target species mixture should be diverse so that forest management can be continuously adapted as time unfolds (Temperli et al. 2012).

Tab. 1 Native forest tree species in Norway and their characteristics (Skrøppa et al. 2011)

Species Scientific name	Geographic range	Occurrence	Pollination vector	Seed dispersal	Northern limit in Norway?	Genetic resource category
Picea abies	Widespread	stand	wind	Wind		vital
Pinus sylvestris	Widespread	stand	wind	Wind	yes	vital[2)]
Juniperus communis	Widespread	scattered	wind	Birds	yes	vital
Taxus baccata	Limited	scattered	wind	Birds	yes	exposed
Salix caprea	Widespread	scattered	insect	Wind	yes	vital
Populus tremula	Widespread	stand/scattered	wind	Wind		vital
Betula pendula	Widespread	stand/scattered	wind	Wind		vital
Betula pubescens	Widespread	stand/scattered	wind	Wind		vital
Alnus incana	Widespread	stand/scattered	wind	water/wind		vital
Alnus glutinosa	Medium	stand/scattered	wind	water/wind		vital
Coryllus avellana	Medium	stand/scattered	wind	mammals	yes	vital
Prunus padus	Widespread	scattered	insect	Birds	yes	vital
Fagus sylvatica	Marginal	stand/scattered	wind	Birds	yes	uncertain
Quercus robur	Limited	stand/scattered	wind	mammals/ birds	yes	uncertain
Quercus petraea	Limited	stand/scattered	wind	mammals/ birds	yes	uncertain
Acer platanoides	Limited	scattered	insect	Wind	yes	uncertain
Fraxinus excelsior	limited	stand/scattered	wind	Wind	yes	exposed
Ilex aquifolium	limited	scattered	wind	Birds	yes	exposed
Malus sylvestris	limited	scattered	insect	mammals/ birds	yes	exposed
Prunus avium	marginal	scattered	insect	Birds	yes	exposed
Tilia cordata	limited	stand/scattered	insect	Wind	yes	exposed
Ulmus glabra	medium	stand/scattered	wind	Wind	yes	threatened
Sorbus aucuparia	widespread	scattered	insect	Birds		vital
Sorbus hybrida	limited	scattered	insect	Birds	yes	exposed
Sorbus meinichii[1)]	marginal	scattered	insect	Birds	yes	exposed
Sorbus subsimilis[1)]	marginal	scattered	insect	Birds	yes	exposed
Sorbus subpinnata[1)]	marginal	scattered	insect	Birds	yes	exposed
Sorbus subarranensis[1)]	marginal	scattered	insect	Birds	yes	exposed
Sorbus neglécta[1)]	marginal	scattered	insect	Birds	yes	threatened
Sorbus lancifólia[1)]	marginal	scattered	insect	Birds	yes	threatened
Sorbus norvegica[1)]	marginal	scattered	insect	Birds	yes	exposed
Sorbus rupicola	limited	scattered	insect	Birds	yes	exposed
Sorbus intermedia	marginal	scattered	insect	Birds	yes	exposed
Sorbus aria	marginal	scattered	insect	Birds	yes	exposed

[1)] Species that are considered to endemic in Norway
[2)] *Pinus sylvestris* ssp. *lapponica* is rated as near threatened in The Norwegian Red List for Species

The definition of future optimal species composition is very complicated because woody plant reaction to changes will be also influenced by relationships between trees in forest stands. For example, the competitiveness between species can change due to alterations in temperature, CO_2 and radiation (Lindner et al. 2008). The reaction can also depend on the competition within a stand. Piutti and Cescatti (1997) found different reactions to temperature and water availability in dominant and suppressed *Fagus sylvatica*.

Some authors hypothesized that beech could be more resistant to abiotic and biotic stressors and its competitive capacity (in comparison with Norway spruce) will be increasing in conditions of climate change (Bolte et al. 2010). Dittmar et al. (2003) suppose on the basis of the evaluation of annual rings that European beech has higher resilience than spruce and will be able to cope with periods characterized by the decreased availability of water.

The increase in *Fagus sylvatica* and *Quercus petraea* proportion can be recommend in SE Norway, especially in temperate areas where problems with pure spruce stands will probably greatly accelerate. *Acer platanoides* can be a highly productive admixture in the stands. Basic target is richer tree species composition (according to site and management conditions) with native tree species (see Tab. 1).

REGENERATION

The measures include:

- natural regeneration in stands with good provenance composition – increased adaptive capacity, increased species diversity and genetic diversity, natural selection use;
- artificial regeneration as the way to introduce the absent species, suitable provenances, genotypes or phenotypes.

Forest regeneration offers an opportunity to select tree species or provenances that are believed to be better adapted or adaptable to the changing climatic conditions. On the other hand, the regeneration phase is very vulnerable in changing climate conditions, because young seedlings and plants are particularly sensitive to drought or other climatic extremes. Thus, regeneration processes and techniques may warrant modification and adaptation itself. Under a changing environment, using natural regeneration allows natural selection to take place. This will drive the population to meet the fitness optimum corresponding to the local environmental conditions (Lindner et al. 2008). The conditions reducing the risk of maladaptation must be satisfied for sufficient application of natural regeneration: (i) adequate diversity in the regeneration; (ii) maintaining population size – sufficient number of parental genitors; (iii) maintaining reproductive potential and fecundity – sufficient flowering and fruiting.

The present Norway spruce forests in SE Norway are mixtures of naturally regenerated forests and plantations of both native and non-native origins. Some of the trees are of central European provenance (Aarrestad et al. 2014). The optimization of provenance composition is a very important target of adaptation measures. In this case, the artificial regeneration is the way to change. Forest plant material produced through breeding programmes can be used across wider climatic gradients than material produced by natural reproduction. Climate change adaptation is an important element of the strategy for forest plant breeding for 2010–40 drawn up by the Norwegian Forest Seed Center (Norwegian Ministry of Climate and Environment 2013).

Norway's regulations on forest tree seed and plant material date from 1996. They are to be revised to keep with new knowledge and new legislation, for example the new regulations on foreign tree species for forestry purposes. These new regulations must be implemented in a way that takes both biodiversity considerations and adaptation of Norwegian forests to climate change into account (Norwegian Ministry of Climate and Environment 2013).

INTEGRATED FOREST PROTECTION

The measures include:

- diagnosis, prevention, control and protection;
- early identification of new pathogens and pests, invasive and quarantine species;

- development of preventive measures, especially against alien pest organisms.

A warmer climate will allow pests and diseases to become established and spread to new areas. In future, threats to woody plants and biodiversity may to a considerable degree come from as yet unknown diseases and pests (weeds, insects, bacteria, viruses, fungi, nematodes). Effective forest protection encompasses three different goals:

– *Prevention*: Measures to minimise the risk of damage occurring (e.g. 'clean' forestry practice, close-to-nature silviculture).
– *Control:* Proactive measures to minimise imminent damage and prevent directly impending secondary damage to remaining stands (e.g. quick logging and debarking of standing infested trees).
– *Protection of individual objects*: Defensive measures to prevent immediate impending damage to goods worth protecting (e.g. massive deployment of pheromone traps in beetle hotspots or application of insecticides to timber stacks).

International research projects, monitoring programmes, international cooperation and dissemination activities are very important for effective forest protection because the changed conditions and spectrum of pest organisms demand fast reactions to implement new forest protection strategies and measures.

CHANGES OF TENDING, THINNING AND HARVESTING

The measures include:

- changes of tending and thinning frequency and intensity;
- reduced clear-cut size;
- shorter Norway spruce rotation length.

The intensified tending and thinning treatments in Norway spruce stands have the following aims: (i) reduction of stand evapotranspiration – lower water losses; (ii) increased mechanical stability of tree and stands; (iii) increased forest stand tolerance against biotic and abiotic disturbances; (iv) reduction of competition for light, nutrients and water. However, as the late intensive thinning may lead to the risky decrease in stand density – the treatments must be well-timed.

The clear-cut size should decrease, so as to better adapt to the natural dynamics of the ecosystem and decrease the risk of wind damage.

We also propose to adjust the rotation length of Norway spruce based on the stand vitality and health condition. On the one hand, the earlier harvesting decreases the crop, but on the other hand, the shorter rotation length decreases the risk of stand destruction by wind, snow and pests. Wood harvesting in calamity areas leads to a lower wood price and a higher cost of harvesting.

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