Network of Climate Change Risks on Forests (FoRisk)

SNS Workshop, August 29, 2008, Umeå, Sweden

Organizers:

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Sessions and topics:

08.15 - 08.20 Opening of the meeting *Prof. Pekka Niemelä (Joensuu, Finland)*
08.20 - 09.40 Risks of pest insects on forest *Chair*: Prof. *Pekka Niemelä* (Joensuu, Finland)
  08.20 - 09.00 *Prof. Mathew Ayres* (Dartmouth, NH, USA), invited speaker: Pest insects and climate change in forest ecosystems, current knowledge and anticipated future prospects
  09.00 – 09.40 short notice by each Nordic country: Seppo Neuvonen (FIN); Bjørn Økland (NOR); Halldor Sverrisson (IS); Helena Bylund (SWE); Iben Thomsen (DK)

09.40 - 10.00 Coffee

10.00 - 11.40 Risks by pathogens *Chair: Dr. Michael Müller (Vantaa, Finland)*
  10.00 – 10.40 *Prof. Pia Barklund* (Uppsala, Sweden), invited speaker: Forest pathogens in Nordic forests, current status and future threats with a changing climate
  10.40 – 11.40 short notice by each Nordic country: Pia Barklund (SWE); Michael Müller (FIN); Halvor Solheim (NOR); Halldor Sverrisson (IS); Märt Hanso (EST); Rimvydas Vasaitis (LIT); Iben Thomsen (DK)

11.40 - 12.15 Forest risks by mammals: *Chair: Prof. Heikki Henttonen (Vantaa, Finland)*
  11.40 – 12.15 *Prof. Göran Ericsson* (invited speaker): Climate change and its effects on moose population dynamics

12.15 - 13.15 Lunch

13.15 - 14.10 Forest risks by mammals *Chair: Prof. Göran Ericsson (SLU, Sweden)*
  13.15 – 13.50 *Prof. Heikki Henttonen and Otso Huitu* (invited speaker): Role of small mammals e.g. voles in Nordic forest ecosystems in future climate
  13.50 – 14.10 short notice & discussion:
  Sauli Härkönen (FIN)

14.10 – 14.25 Coffee

14.25 – 15.45 Forest management *Chair: Prof. Sune Linder (SLU, Sweden)*
  14.25 – 15.00 *Prof. Gert-Jan Nabuurs* (Wageningen, Netherlands), invited speaker: Silviculture, forest management and forest planning actions in promoting forest health
  15.00 – 15.45 short notice by each Nordic country: Tomas Lundmark (SWE); Heli Peltola (FIN); Halldor Sverrisson (IS), Iben M. Thomsen (DK)

15.45 - 16.30 General discussion *Chair: Prof. Pekka Niemelä /Joensuu, Finland)*
  - conclusions
  - planning of future actions / continuation of the network operation / new application to SNS

16.30 End of meeting

Climate change and forest pestilence?

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Abstract

Since the early 1990s, it has been hypothesized that the projected trajectory of climate change would have rapid consequential impacts on biotic disturbance in forests. The argument was mainly based on two points: (1) even in the absence of directional changes in climate, forests throughout the world are strongly influenced by episodic events of pestilence, and (2) insects are very responsive to climatic variation because of their short generation time, high reproductive potential, and physiological sensitivity to temperature and food quality. The most likely potential pathways of ecological change include: direct effects of temperature on insects; effects of temperature, soil moisture, or cloud cover on plant defenses, nutritional suitability, and compensatory growth; and effects of temperature on community interactions between herbivores and their predators, competitors, and mutualists. There are now numerous examples of insect populations whose distribution and abundance have changed in ways that are consistent with the expected effects of climate change. Some globally noteworthy examples of recent pestilence may be attributable to climate change during the last two decades. Presumably there have been some other impacts that are positive from the perspective of traditional forest management. Biological responses have been uneven across insect species and forest systems, and have not usually been predictable in their details. There is a need for well validated models that can predict changes in biotic disturbance within forests given specific scenarios of climate change. I offer the following suggestions to facilitate progress: (1) develop, test, and refine general qualitative hypotheses that can predict when and where impacts will be large vs. small, and positive vs. negative; (2) develop programs of focused studies in systems with high importance and a high probability of consequential impacts; and (3) conduct multi-faceted tests (including meteorology, physiology, and population ecology at least) of explicit mechanisms by which climatic variation is theoretically transduced into biotic disturbance.

Pest insects in Finnish forests and climate change – a short note

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Abstract

There are several pest insect species that can be expected to become more problematic in Finland in the future. Some pest species can spread into Finland from more southern areas: e.g., the Nunn Moth (*Lymantria monacha*) has earlier been a rarity in Finland, but during the last ten years the numbers have clearly increased. Climatic change can cause native, earlier harmless species to become pests in Finland; a possible example is *Acantholyda posticalis* (Pine Web-spinning Sawfly), which has caused damage to pine forests in our west coast during the last years; the outbreaks are possibly associated with very dry summers (e.g., 2003 & 2006). Climate change, changes in forest management or other environmental changes may also increase risks from existing pests. Warmer winters are expected to increase the outbreak frequency of the European Pine Sawfly (*Neodiprion sertifer*) especially in eastern and northern Finland (Virtanen *et al.* 1996) as well as those of birch defoliating Geometrids *Epirrita autumnata* and *Operophtera brumata* (Virtanen *et al.* 1998) in Lapland. However, increasing summer temperatures can increase the efficacy of parasitoids of *Epirrita* which may result in decreased intensity of *Epirrita* outbreaks (Virtanen & Neuvonen 1999). Spruce Bark Beetle (*Ips typographus*) outbreaks may increase in a warmer climate, but especially if storms increase and damaged wood cannot be rapidly removed from forests. However, up to now Spruce Bark Beetle outbreaks have been rare in Finland, and there seems not to be large risks of subsequent tree mortality if small numbers of fallen/damaged spruce trees will be left in forests (Eriksson *et al.* 2007, 2008). The above statements are only qualitative in nature; better understanding of the population dynamical details is necessary before quantitative predictions are possible.

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Climatic responses of forest insects in Norway

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Abstract

In recent years several forest insects have been recorded as newcomers or as more abundant than before towards northern latitudes and higher elevations in Norway. Such observations are from different groups of forest insect, including herbivorous geometrids, phloeophagous bark beetles and insects in cone seed: Previously the geometrid scarce umber (*Agriopis aurantiaria*) was considered as a southerly species and had hardly been recorded from Troms before 2000, while in 2004-2007 it had mass outbreaks in mid-Troms. The bird-cherry ermine (*Yponomeuta evonymella*) has had outbreaks in mid Norway in the last three years and appeared for the first time as far north as Efjord in northern Norway, while outbreaks of this geometrid were not known outside southern Norway ten years ago. The recent outbreaks of the winter moth (*Operophtera brumata*) in Troms have been most severe close to the tree line, while previously this species was reported to occur primarily at lower altitudes. The outbreak region of the winter moth has expanded rapidly towards northeast in recent years, and the outbreak regions of the autumnal moth (*Epirrita autumnata*) has expanded into historically colder and more continental regions of northern Norway. Outbreaks of the spruce bark beetle (*Ips typographus*) have never been recorded in mid Norway; however, southern Norway was exposed to serious outbreaks in the 1970's. In the monitoring records from mid Norway in 2007 and 2008, the abundances are the highest that have been observed since the start of the time series in 1979. Along with an increased frequency of seed years for spruce in the last 40 years, the occurrence of the spruce seed moth (*Cydia strobilella*) has declined while the occurrence of spruce seed gall midge (*Plemeliella abietina*) has increased in southern Norway. Further challenges are to verify to what extent all of these observations are associated with significant long-term trends that are reflecting climatic changes, and to improve our understanding of how changes in climatic variables will affect population and evolutionary processes in different forest insect communities.

Risk of pest insects on forest trees in Iceland

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Abstract

Since 1990 the climate in Iceland has gradually become warmer. After 2000 the summers have frequently been warmer and longer than the mean in last century. As an example July in the last summers has often been around two degrees warmer than the average. This has resulted in the introduction of new insect pests and increased distribution of others.

One of the new pests is a leaf miner on birch, the moth *Eriocrania unimaculella*. This insect was first noted in South Iceland in 2003 in the village Hveragerði. Now it is spreading in Reykjavik. It has a limited distribution yet, but causes severe damage on birch foliage.

Another new pest is a leaf beetle, *Phratora vitellinae*, on willows, aspen and poplars. The adult beetle is dormant in the winter and attacks new leaves in the spring. It even damages buds before the leaves appear. During the mid summer the larvae are active in eating the lower surface of the leaves and in August and September new generation of adult beetles appears and feeds on leaves and buds into October. This insect was first discovered in Mógilsá at the foot of the mountain Esja north of Reykjavík in 2005. Since then it has been slowly spreading southwards in the Reykjavík area. This insect causes severe damage on *Populus tremula*, *Salix myrsinifolia* ssp. *borealis* and some clones of *S. phylicifolia*. To a lesser extent it damages *Populus trichocarpa*.

Other insect species which have had limited distribution, mainly in the south, are now moving north. Examples of such species are the lepidopteran species *Melanchra pisi* and *Operophtera brumata*. Both species are polyphagous, but *Melanchra pisi* is only damaging small trees. Its distribution is still restricted to the southern half of the country.

The spruce aphid, *Elatobium abietinum*, was imported into Iceland in 1959, with christmas trees. In mild autumns it has damaged spruce forests near the coast. In 2003 there was for the first time spring epidemi in Iceland. This could be more frequent with milder winters in the future.

It is difficult to estimate if the overall insect damage in Icelandic forests is increasing with warmer climate. New insect species that feed on birch can add to the grazing pressure in the native forest and possibly be a threat to forests in some localities.

Insect forest pest hazards related to climate change in Sweden

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The main concern related to a warming climate among Swedish forest entomologists is the possible reduction of the development time in the two major forest pests: the spruce bark beetle *Ips typographus* and the pine weevil *Hylobius abietis*. Warm summers in southern Sweden have occasionally resulted in two breeding generations of the spruce bark beetle, which may increase the risk for attacks on standing trees. A shorter development time in the pine weevil may increase the fraction of weevils emerging from their pupal chambers already in the autumn (instead of the following spring), resulting in increased seedling damage in planted regeneration areas.

The outbreak range of tree defoliating insects may extend into new areas. The occurrence and frequency of outbreaks will depend on how a changed climate will affect the host trees and other trophic interactions, especially with natural enemies. In the long-term perspective, the future tree species mix and any changes in forest management will be important factors to consider when predicting the risk for defoliating outbreaks in both deciduous and coniferous forests.

New, invasive species could become a problem in a warmer climate. A few new species of long horn beetles, bark beetles and moths have recently been discovered to be established in Sweden. A challenge is to prevent that insect and nematode infested wooden packing material and products are imported.

Forest Pathogens in Nordic countries, current status and future threats with a changing climate

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Abstract

Climate will change. The scenarios for the Nordic countries include higher temperatures, more precipitation during winter and less during summer, except for the most northern region. The frequencies of weather extremes are also predicted to increase which may lead to increasing risk of tree damage due to frost or drought. Decreased vitality due to frost injuries is often considered to be a decline-initiating factor in most tree species. Stress episodes make the trees more susceptible to certain pathogens and this can lead to periods of tree decline over several years, like the decade of oak decline in Sweden. Periods of hardwood decline may increase but predictions are complicated by lack of relevant knowledge.

The growing season will be prolonged both in the spring and in the autumn, while the light will stay the same and that will influence the pathogen- host- environment relationship, as several shoot- and needle infecting fungi are developing during the period when trees are dormant. The interplay between dormancy of the tissues and fungal development is thus of great interest for predicting future disease outbreaks

The following general effects of changed climatic conditions on the pathogens affecting forests in the Nordic countries can be predicted. – Organisms for which dispersal is favoured by mild weather can be predicted to increase in importance e.g. *Heterobasidion annosum*. – Organisms that are disfavored by the warmer conditions are likely to decline in importance, e.g. *Phacidium infestans*. – Organisms that are favoured by stress created by extreme weather conditions, will tend to increase in importance, e.g. *Gremmeniella abietina* and *Armillaria* spp. – The distribution ranges of some organisms that require warmer conditions than currently found in the Nordic countries may expand from continental Europe and that include southern populations of our species and southern species like *Mycosphearella pini* and *Sphaeropsis sapinea*.

New and emerging diseases can also develop because of other reasons than climate change, as for example probably ash decline in Europe.

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Short notice about tree diseases in Sweden

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Abstract

Despite uncertainties in the climate scenarios, many Swedish researchers have been involved in predicting some probable effects on the forests by the anticipated warming (Sonesson et al. 2004, Björkman et al. 2006, Eriksson 2007). Tree growth is expected to increase during a prolonged growing season. At the same time the risks for several kind of damage is likely to increase. The presentation focuses on the present situation for tree diseases and risks for increased damages because of changed climate.

Weather extremes may be more common. Such stress episodes will favour *Armillaria* species. The important pathogens *Heterobasidion annosum*, S- and P- form, will be favoured in a warmer climate. *Gremmeniella abietina* and *Lophodermium seditiosum* are causing epidemics and they can be favoured especially by warmer winters.

Since a few years there are widespread attacks by *Cronartium flaccidum* on Scots pine in northern Sweden and by *Chalara fraxinea* on common ash in southern Sweden. However, neither of those diseases seems to be connected to changing climate.

But some other diseases, new in the country, might be connected. During a few years *Stigmina juniperina* has been found associated with extensive needle-loss and even death of junipers. *Melampsoridium hiratsukanum* which attacks alder was observed the first time 1998 in Sweden, so far causing only limited damage. *Guignardia aesculi* have been noticed on *Aesculus hippocastanum* in the very south of Sweden since about 1995. Newest is *Mycospherella dearnessii* found on pine needles 2007.

New emerging or aggravated tree diseases are threatening forestry, and we have to be careful about finding the real reasons for disease development and to be cautious about using climate change as an overall explanation for new disease outbreak.

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Climate change and the health of Finnish forests

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Abstract

Finnish forestry is based largely on only four tree species, namely Scots pine, Norway spruce, silver birch and downy birch (*Pinus sylvestris, Picea abies, Betula pendula* and *B. pubescens*, respectively). Because the number of tree species is low, the consequences of an aggressive lethal disease against one species would be ecologically and economically severe. The predicted climate change will increase the risk for most biotic and abiotic forest damages.

At present, the most serious forest diseases in Finland are root and butt rot of Norway spruce and Scots pine. Forest felling on unfrozen soil promote spreading of the causal agents, *Heterobasidion parviporum* and *H. annosum,* respectively. If in future the winter season when soil is frozen is shorter damages caused by these fungi will become even more common and form an extremely serious threat to wood supply. Forests heavily infected by root and butt rot will in the future be plagued by storm damages, especially, if the frequency of storms increases.

Also numerous other fungal diseases are expected to benefit from climate change if winters are milder and precipitation increases. Summer draught periods may as well become a serious threat to trees in large areas. Drought as such may kill trees, especially Norway spruce, but drought stress will also decrease tree resistance against diseases. Another threat is caused by new alien disease agents possibly invading Finland. If in the future the climate type in Finland resembles that of currently typical in Central Europe, it can be expected that a number of new disease agents present there on same tree species will appear in Finnish forests. Moreover, present populations of disease agents may change through long-distance gene flow from foreign genotypes resulting in an ecological disturbance in the host-pathogen relationship causing difficultly predictable consequences.

Climate change risks on forest in Norway: pathogens

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Abstract

Climate change may influence in a worse manner for the forests in various ways. Some pathogens may increase their importance and new may arrive. Root and butt rot is the most serious problem in Norway spruce forests. In mean more than every fourth tree is infested when harvested. Dryer summers may give increased frequency of rot caused by *Heterobasidion*. In addition *Armillaria* spp may gain change in weather condition both as root rot and in connection with a syndrome together with drought and bark beetles. More unstable winter climate may give increase of *Gremmeniella* attack on Scots pine. Longer and warmer growth season will give many pathogens better condition. Among those is *Ophiostoma novo-ulmi* causing Dutch elm disease which is lasting in south eastern Norway at a rather low frequency and the volume of elm is not lower than for 15 years ago. In which way the newly introduced *Chalara fraxinea* will behave in Norway is uncertain, but a better growth season will probably also influence on the possibility to be spread all over Norway where ash are growing.

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Risks by pathogens in forests in Iceland

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Abstract

Since 1990 the climate in Iceland has gradually become warmer. After 2000 the summers have frequently been warmer and longer than the average in last century. As an example July in the last summers has often been around two degrees warmer than the average. Probably this has aided in the introduction of new tree pathogens and increased distribution and severity of others.

Of the new diseases the rusts are most dominant. Most of the species have introduced tree species as hosts. In 1994 *Melampsora larici-pentandrae* was discovered in Hornafjörður in South-East Iceland. It has now spread to the southern half of the country, were the host, *Salix pentandra*, is grown. In 1999 another rust species, *Melampsora larici-populina*, was found in Hveragerði in South Iceland. The host for this rust is black cottonwood (*Populus balsamifera* ssp. *trichocarpa*). This tree species has been planted in small scale in forest plantations. The rust needs larch as an alternative host. Up to now the damage has been mainly limited to South Iceland. Probably the humid climate in that area speeds up the disease cycle. The spruce rust, *Chrysomixa abietis*, was first found in 1999 in a plantation of conifers in West Iceland. It had obviously been there at least two years before. The damage is limited to Norway spruce. Rainy periods in the summer are necessary for the development for this rust.

The needle fall fungus on larch, *Meria laricis*, is also rather new in Iceland. Probably it was introduced after 1990. In some years it damages Siberian larch in the South.

It is difficult to know if warmer climate is the reason for the establishment of these pathogens, but it is known that higher temperature speeds up the disease cycle. But it is obvious that the amount of precipitation is also very important.

Alien fungal colonisers of pine needles in Estonia: A signal of climate warming?

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Abstract

The following four pathogenic to the needles of pine species (*Pinus* spp.) microfungi were registered, recently and for the first time, in Estonia:

i) ***Mycosphaerella pini*** E. Rostrup apud Munk (syn. *Scirrhia pini* Funk & A.K. Parker; anamorph *Dothistroma septospora* (G. Doroguine) Morelet),
ii) ***Mycosphaerella dearnessii*** M.E. Barr (syn. *Scirrhia acicola* (Dearness) Siggers, anamorph *Lecanosticta acicola* (Thümen) H. Sydow,
iii) ***Cyclaneusma minus*** (Pers.) DiCosmo, Peredo & Minter (syn. *Naemacyclus niveus* (Pers.: Fr.) Fuck. Ex Sacc., and
iv) ***Diplodia pinea*** (Desm.) J. Kickx (syn. *Sphaeropsis sapinea* (Fr.: Fr.) Dyko and Sutton)

The named above fungal species, first two of which were listed as well as the under-quarantine species in Estonia and in several other European countries, have been classified on other continents as dangerous or even disastrous pests of pine forests. During the last decade their ranges were known to expand rapidly towards East and North Europe. In several papers this process has been addressed to the climate warming.

In the presentation the authors introduce the results of the forest pathological investigations of the named above fungal pathogens, carried out in the Institute of Forestry and Rural Engineering of the Estonian University of Life Sciences from 2006 to 2008. A very short overview of meteorological peculiarities of the last decades, during which the colonisation presumably took place, is presented, as well.

Emerging forest diseases in south-eastern Baltic Sea region

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Starting in early and mid-1990s, large-scale decline of *Fraxinus excelsior* has been increasingly observed in Lithuania and Poland, and has been classified as a new and threatening phenomenon. In Lithuania, by 2002 over 30 000 ha of stands were affected by the dieback, resulting in mortality of approximately 60% of all ash stands state-wide, while in certain parts of the country only about 2% of *F. excelsior* remained visually healthy. Subsequently, since mid-1990s, massive dieback of *F. excelsior* has occurred further northwards in Latvia. In Poland, the disease started to occur in eastern parts (bordering Lithuania and Belarus), but subsequently spread towards south, west and north, and since 1998 decline of *F. excelsior* occurred all over the country. Trees are subjected to the dieback at various age classes, in forest stands, as landscape trees and in nurseries. No correlations were found between the extent of *Fraxinus* decline and tree age, forest site type, stand species composition and origin. The crowns of declining *Fraxinus* trees exhibit a wide range of symptoms, as wilting of leaves, necroses on buds, leaf stalks and bark, cankers on shoots, branches and stems. The newly described fungus *Chalara fraxinea*, involved in the decline, might be a natural component in a community of microfungi on *F. excelsior*, the pathogenicity of which was triggered by the environmental factors. However, it also might be a new invasive species gradually spreading over new areas along with the changing climate.

Starting in 2003, the last and probably one of the most severe waves of *Quercus robur* decline
caused serious sanitary problems in Lithuania, Latvia and Poland. In Lithuania, about 4000 ha of *Q. robur* stands were damaged in 2004, 11 000 ha in 2005, and 16 000 ha in 2006. Within this area, about 30% of trees were classed as severely damaged and dead. The symptoms included leaf necroses, dieback of shoots and branches, and wood discoloration. Rates of the decline dropped in 2007, and some of the diseased trees have recovered. In Poland, during 2005-2006 mean rates of defoliation in oak stands on a country scale were 20-90%, and over 40 000 m^3 of severely damaged and dead trees were subjected to sanitary felling. Climatic factors are regarded as inciting factors of the decline, predisposing *Q. robur* to secondary damage by oportunistic insect pests and diseases as, e.g. powdery mildew and *Phytophthora*.

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Will climate change have any impact on forest pathogens in Denmark?

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Abstract

Unlike insects, few pathogens on forest trees are influenced by temperature and precipitation to such a degree that the expected climate changes will cause major differences. However, some impacts can be foreseen, and others may be guessed at. In relation to climatic factors there can be a direct influence on the life cycle of the pathogen, and an indirect influence if trees become stressed by e.g. drought and thus are more susceptible to pathogenic fungi.

A well known pathogen in Danish conifer stands is the root and butt rot pathogen *Heterobasidion annosum*. Infection of stumps requires temperatures above 5ºC, and in general stump treatment is therefore necessary from early spring to late autumn. If winters become warmer due to climate change, the infection period may increase and thus the need for stump treatment.

Many pathogens take advantage of temporarily weakened trees, e.g. the wood destroying fungi on beech such as *Ustulina deusta*, *Meripilus giganteus*, and *Armillaria gallica*. The two former fungi are mainly a problem in parks, but can also cause problems along roads in forests. After the drought and heat wave in 2003, we have seen an increase in beech trees with severe attacks of *Meripilus giganteus*. In a few cases, the trees have caused traffic accidents by toppling across main roads through forests.

Whether we will experience problems with pathogens not yet present or important in Denmark is difficult to predict. But invasive fungal species or emerging infectious diseases (EIDs) will probably always be of concern with or without climate change.

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Climate change and its effects on moose population dynamics

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Abstract

Ecologists have focused anew on the relationships among weather, plants and herbivores because of increasing concern of how global climate change may affect herbivore populations. Several smaller-scale studies suggest that weather may act as a stochastic, density-independent factor that affects herbivores by altering feeding conditions. Here, we first focus on if and how climate may affect food quality, which in turn may affect large herbivores during all life stages. This is of particular interest for long-lived animals like moose because a superior or inferior cohort born in “good” or “bad” weather years may produce long-lasting waves in a population as these cohorts pass through their reproductive years. Furthermore, increased temperature during both winter and summer may induce additional heat stress on moose, currently adapted for cool summers (<15 °C) and cold winters (<-5°C). To illustrate this we follow the life cycle of moose from its natal stage to its adult stage during the talk.

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The changing patterns of vole fluctuations in N Fennoscandia: climate or something else, and implications to damage

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Dynamics of voles and lemmings have been monitored for decades at many locations around northern Fennoscandia. Monitoring consists both of spring and autumn sampling on permanent study sites and various experimental field approaches. A drastic change in the population dynamics of voles in northernmost Fennoscandia took place in the mid and late 1980's. During this time, the earlier "beautiful" cycles turned to primarily seasonal dynamics. Prior to the change, vole dynamics were characterized by interspecifically synchronous cycles. Particularly the deepest crash phase was synchronous in all sympatric species. In the long-term time series, linear delayed density dependence (dd) was a dominating factor, suggesting trophic interactions as a cause of cycles (Stenseth 1999). Synchronous crashes in all sympatric species, even with different food repertoires, indicate predation by weasels as a main driving factor (Henttonen et al. 1987). Still, non-linear direct dd was also clearly observed. The change in dynamics was first observed at Pallasjärvi, where the deviating patterns emerged in the early 1980’s (Henttonen et al. 1987). Since 1985-86 the earlier cyclicity turned to seasonal fluctuations. The change in dynamics occurred a little later, around 1990, at the more northern and altitudinally higher Kilpisjärvi. In northern Sweden, a similar change took place in the late 80’s (Hörnfeldt 2004). Changes in population dynamics also brought about drastic changes in the species composition of rodent communities. Overall, species with larger body size have become more uncommon. Also some features of population demography changed. The main hypotheses put forward to explain the changes involve either the role of intensive forestry, through direct habitat loss in some species (Hörnfeldt 2004), or via changes in the rodent and predator community structure (Henttonen 2000, Hansson 1999) or climate change, which affects the snow structure and subnivean space, and hence the survival of voles (Ims et al. 2008). The decline in clumsy species with large body size implies predation as a source of the observed changes. Furthermore, the decline has taken place in all habitats, also in protected areas and far (>100 km) from any forest management. However, in the southern half of Finland, the patterns have been different: even though there were some less regular patterns in the late 1990’s, strong and regular cycles have characterized most of the region during the 2000’s. If one implies climate change as the only reason for the disappearance of cycles, then one would expect cycles to disappear first in milder Central Fennoscandia, not in the north. Also, in parts of northern Sweden cycles have returned (Hörnfeldt, pers. comm.), suggesting that climate warming may not be the only or main reason for these long-term trends.

Nonetheless, if climate change proceeds as predicted, accompanied by diminishing snow cover, the diversity of prey and predator guilds will increase, thus stabilizing vole population fluctuations (cf. Hansson and Henttonen 1985). The high cyclic peak winter vole densities, when most of the damage to forestry occurs, will probably disappear, and more seasonal patterns may emerge. Consequently, cyclic occurrence of vole damage may fade out, and instead a more stable multiannual pattern will emerge (see Bierman et al. 2007). The decisive question, then, is: at what level do damages settle?

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Moose, forestry and climate change

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Abstract

Moose browsing causes economically significant damage in young Scots pine and birch stands in Finland. Although pine can be considered a medium-preferred browse species in the winter diet of moose (Bergström & Hjeljord 1987), the major proportion of consumed browse consists of pine from late autumn to early spring owing to its high availability (Cederlund et al. 1980). Birches and other deciduous trees are damaged by moose throughout the year. Climate change may affect the tree species composition and food availability, and also the distribution and abundance patterns of moose resulting in more damage to forestry unless controlled.

In recent decades in particular, the moose density has increased in Finland continuously (Torvelainen 2007). Simultaneously, increasing moose damage (i.e., twig-browsing, stem breakage, and bark stripping) has raised increasing concern amongst forest-owners and the associated industries. This concern is based on the fact that, as a long-term consequence, moose damage reduces the quality of butt logs (i.e., merchantable timber that is intended as high-quality plywoods or sawn timber), especially as a result of broken main stems (Heikkilä & Löyttyniemi 1992, Heikkilä et al. 1993, Glöde et al. 2004, Ingemarson et al. 2007). In addition to the flaws in the stem form, pith discolorations and colour changes outside the pith reduce the quality, and hence also the value of the logs, irrespective of their end use. In Finland, compensation for damage caused by moose to private forest-owners is paid from State funds (e.g., EUR 5 million in 2006).

Various chemical repellents, visual and acoustic devices, and tree sheltering methods and devices have all been used in attempts to prevent moose damage in young seedling and sapling stands. The effects of the different methods have been variable, and in many cases the methods used have generally shown little promise for the reduction of moose damage on a large-scale or long-term basis.

Different moose-related interest groups have conflicting targets with respect to the ideal moose density, and thus moose management. This has led to intense public debate on the need to search for balance not only between moose and forest management but also with nature conservation. To avoid conflicts of interest, Ministry of Agriculture and Forestry (MAF) has made preparations for drafting the new strategy for moose management in Finland. The strategy will be finalised and approved by MAF in 2012.

There is a strong need to control over-abundant moose population densities. Development of cost-effective mechanical and/or chemical preventive methods is also needed to reduce the risk of moose damage in young stands. Finally, it is also important to evaluate the effects of climate change on moose herbivory (cf., Niemelä et al. 2001), spatial and temporal changes in habitat quality (i.e., food availability and cover) and moose population dynamics. This will help in adapting to the implications of climate change may have for forestry and moose management.

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Forest management and planning in promoting European forest health under climate change

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Abstract

With approximately 175 million ha, European forests play a small but not insignificant role in mitigating climate change. Depending on the region, different mitigation measures should be employed. This can range e.g. from avoiding degradation in the Mediterranean, to reducing standing volumes and producing biomass for bioenergy in highly stocked areas. However, European forests will be affected by climate change as well, probably affecting its mitigation potential, for example via increased occurrence of extreme events. Identifying the optimal combinations between mitigation and adaptation is therefore of high importance.

We introduce our European scale forest resource analysis work with the EFISCEN model, and show climate change impact and carbon sequestration work. The presentations will show new ongoing high spatial resolution work in this field, and how this approach will contribute to a better (site and species specific) understanding of impacts of climate change. These identified impacts can finally be translated into forest management strategies that optimally combine mitigation and adaptation.

Climate change and forest management in Sweden

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Abstract

In Sweden there is a solid knowledge on how forest management systems for even-aged pure Scots pine or Norway spruce stands influence the production of stem wood. This knowledge is built on a long tradition of Swedish forest research during the last century. The research has been based on a traditional view on forest management goals, where the production economy is optimised with the basic condition that pulpwood and sawlogs are the main assortments.

Future forestry will be subjected to changing demands from market and society. An example of this, already highly topical is the increased importance of the forest as a renewable energy source for the society. Climate policy and the demands to decrease oil dependency already lead the discussions on the utilization of the forest and a strongly increased production of raw material from the forest will be needed. Thus, this changed view on energy supply creates new conditions for forestry and bioenergy becomes an important raw material assortment. Merchantable timber thereby gets a new and broader importance, which will lead to a modification of forest management on the basis of the new overall picture of the forests future role for a sustainable social change. Future forestry must secure the supply of biomass and at the same time take care of and develop the other values of the forest.

A challenge will also be to adapt management to future climate change. Such work should be concentrated to the choice of regeneration material (tree species and provenances) because this is a silvicultural treatment that must be decided early on and that will have long-term effects. An uncertain future may be handled by postponing decisions as long as possible. One way to postpone the choice of tree species is to establish mixed species stands, which can be turned into pure stands in pre-commercial thinning or thinnings when more and better data are available.

Forests that will be harvested 40-100 years from now are being established today. The long rotation periods have always been a dilemma in managing the forest, and will be so even more in the future with a changing climate. Although there is almost consensus among researchers that the climate is in fact changing, there is still uncertainty whether or not this needs to be handled by decision makers in forestry. Adaptation to future climate change may be done in several different ways, but decisions that need to be considered today are mostly related to the establishment of new stands. Three different principal regeneration strategies might be considered in order to adjust to future climate change:

- Establishment of provenances and/or tree species that are well adjusted to future climate.
- Establishment of mixed-species stands that will make it possible to postpone the final decision about tree species to a later stage when more information about the climate change is available.
- Increasing the rotation length of present stands and thereby postponing the decision about tree species.

None of these strategies, however, are without risks. Establishment of mixed-species stands is often more difficult and costly than establishment of pure stands, and may result in lower income and production in the mature stands. Planting provenances, or tree species, that are adapted to a future climate may be difficult because establishment must be done in today's climate. Increasing the rotation length of present stands may lead to greater losses due to wind throw and root rot, and may also decrease the economic return because stands are kept beyond the economically optimal rotation length.

Management of silvicultural risks related to forest management under climate change

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Abstract

Under changing climate we need to adapt the management of Finnish forests to meet the higher productivity, but also changing tree species composition and silvicultural risks characterizing these forests in the future. In southern and central Finland, climate change may create suboptimal growing environment for Norway spruce, and decline its growth. As a result, the dominance of Scots pine and birch may increase especially on less fertile sites currently occupied by Norway spruce due to their increasing competition capacity. Although in southern Finland the total growth could even decline, in northern part of the country and nationally it is estimated to increase significantly.

As a result of expected decrease in soil frost period due to climatic warming, for example the abiotic risks by wind, but also by extreme snow loading, may increase because the anchorage of trees is decreasing between late autumn and early spring when there exist highest wind speeds and snow loads. Therefore, it is essential to tend the seedling stands timely and not delay the early thinning either, in order to increase the stability of trees against wind and snow loading. Especially young Scots pine and birch stands are vulnerable to snow damage if early thinning is delayed. Similarly, late heavy thinning in Norway spruce stands makes them very liable to wind damage. However, the risks by wind-induced damage could be reduced in forest planning by aggregating clear-cuts and by avoiding them at the edge of older stands which have a high risk of damage. Similarly, by making the final cuttings earlier especially in Norway spruce stands, which are usually more vulnerable to wind damage than Scots pine and birch stands, the risks could be reduced as well.

Due to expected significant increase of forest fires in the future, there is also increasing demand to consider the fire risks in the future forest management. Similarly, the increasing risks due to pest insects, pathogens and mammals should be considered in forest management. For example, any reduction of the carrying capacity of soils in winter time due to decrease in soil frost may increase the risks of root damages and, thus, attacks of pathogens (e.g. *Heterobasion* spp.) on trees via damaged root systems or stems related to harvesting. To conclude, by proper preference of tree species (and their genetic entries) in regeneration and their silvicultural management over rotation, it could be possible to affect simultaneously the productivity of forests and abiotic and biotic silvicultural risks as well.

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Forest management and forest health in Iceland

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Abstract

The forest management in Iceland has up to now not taken forest diseases or insect pests into account. The history of forestry is very short and few traditions have developed. The pests and diseases have been very few. For example none of the root and butt rot fungi have been known as a problem in Icelandic forestry yet. This could change with warming climate and older forests.

As most of the forests are new plantations, it gives opportunity to plan the plantations in order to minimize the risk of future problems. An obvious example is not to plant larch and poplars in mixed plantations. Disease problems in Siberian larch in southern part of the country have also resulted in that planting of larch has been stopped. Needle fall and canker will probably be a problem in the expected future climate there.

Climate change and forest management in Denmark

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Abstract

Climate change impact

Climate change is expected to include higher temperatures, summer drought, and more storms for Denmark. According to this climate change scenario Norway spruce seems to present the main problem. It is the most important forest tree species in Denmark and may already be at its limits regarding summer precipitation and lack of dormancy due to frequent mild winters (Larsen *et al.*, 1993). Bioclimatic simulation models incorporation climate change correspondingly predict a rapid northward contraction of Norway spruce in Scandinavia. With intervals of 15 to 20 years Denmark experiences devastating storms, which cause heavy damage to stands with heights above 15 to 18 m. These storms are mainly affecting conifer species. The most vulnerable region in Denmark is the western part of Jutland, due to the combination of sandy soils with a low water holding capacity, frequent sea spray and wind exposure, and the predominant use of the basically unadapted Norway spruce in monoculture (Larsen and Saxe, 2001).

Forest adaptation management

Climate change will have a profound impact on forest management in Denmark - in fact, it already has: The use of Norway spruce has decreased significantly during the last decade, and this "climate change sensitive" species is now mainly been used in species mixtures. Consequently, the more "climate robust" species such as beech, oak and Douglas fir are increasingly planted. However, the main challenge is to develop strategies and operational practices in order to cope with uncertainties through risk dissipation and to increase the stability of forest ecosystems in general.

This could imply change from classical mono-species and even-aged management of stands into close-to-nature management characterised by more single tree management, incorporating and supporting natural regeneration and differentiation and aiming at structural differentiation including species mixtures and uneven aged stand structures.

This adaptation strategy is already under implementation. The National Forest programme from 2002 recommends the change to close-to-nature management, and since 2005 the state forests in Denmark are managed according to these principles (Danish Ministry of the Environment, 2005).

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