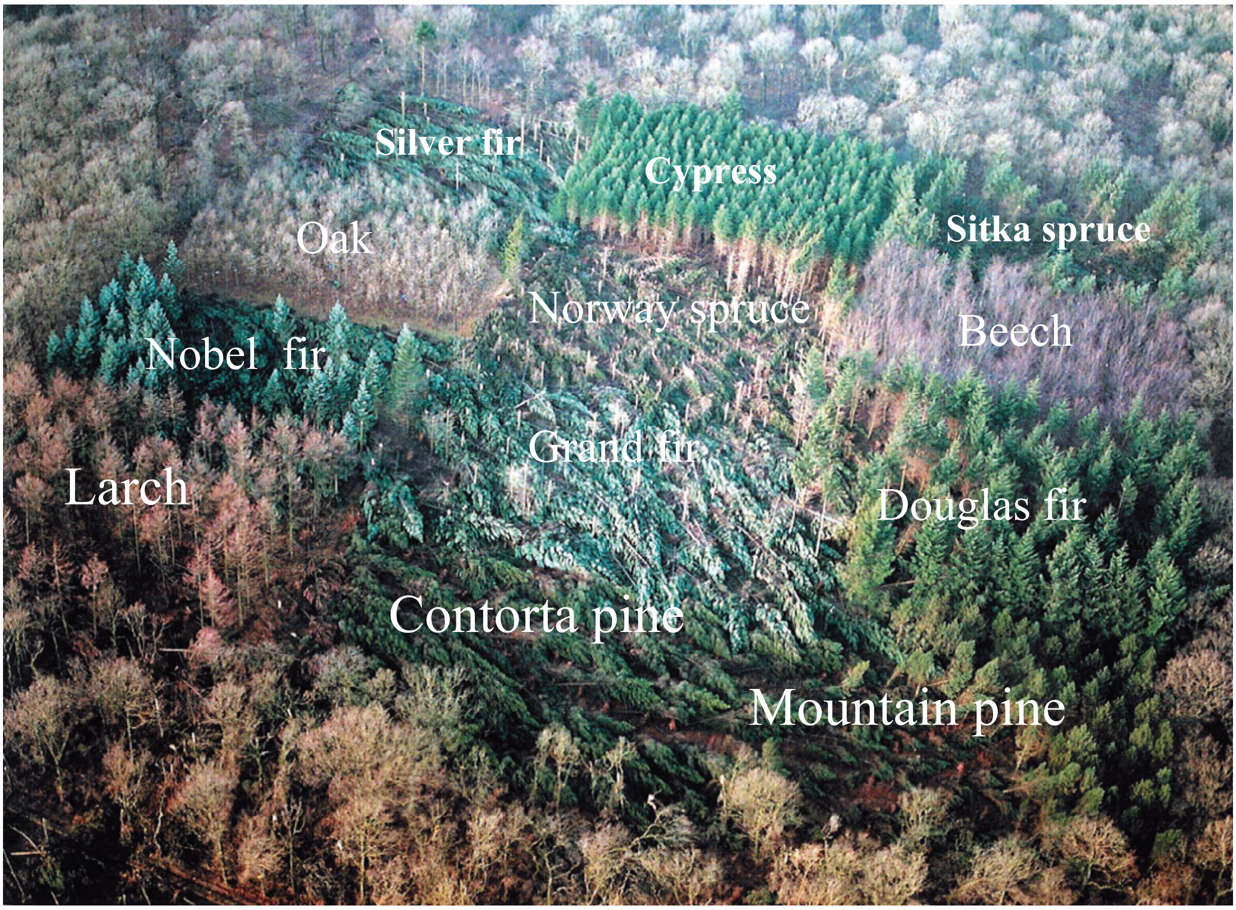
Denmark: Country report

in the frame of COST Action FP0703 ECHOES:

Expected Climate cHange and Options for European Silviculture



Species trial at Lindet Forest District after the gale of Dec. 3, 1999

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Introduction

Forests and forestry in Denmark

Denmark has 570.800 ha of forest, equivalent to just over 13 percent of the total land cover. If we compare with the EU as a whole, Denmark is a forest deprived country. The distribution of forest in Denmark varies from region to region. Originally, most of Denmark was covered by forest, but after centuries of uncontrolled logging and deforestation for agriculture, the forest area around 1820 was down to only 2 to 3 percent.

Since, considerable efforts have been undertaken to establish more woodland. New forests have especially been established in the heath and dune areas in central and western Jutland. In 1989 the government decided on a long term plan to double the Danish forest area within one tree generation. This implies that the forest area at the end of the 21 century will be about 1 million hectares or somewhat over 20% of the territory.

The original Danish forests consisted mainly of deciduous trees - especially beech and oak. Over the past 200 years of forest management - including the large forest plantings in Central and West Jutland – the species distribution changed radically. Today over 50 % of the forested area is covered with conifers such as Norway spruce (17.1 %) and Sitka spruce (6.1%). Deciduous forest covers equivalent only 43.7 %, with beech (12.9 %) and oak (9.6 %) as the most common species (Table 1).

Forest area (ha)	**570.801**	**in %**
Open areas	7.682	
Forested	563.119	100,0
Temporarily non forested	11.871	2,1
Broadleaves	248.580	43,7
Beech (*Fagus silvatica*)	73.504	12,9
Oak (*Quercus robur* and *Quercus petraea*)	54.766	9,6
Sycamore maple (*Acer pseudoplatanus*)	19.882	3,5
Ash (*Fraxinus excelsior*)	19.621	3,4
Other broadleaves (birch, hornbeam a.o.)	81.807	14,3
Conifers	293.912	51,5
Norway spruce (*Picea abies*)	97.851	17,1
Sitka spruce (*Picea sitchensis*)	34.926	6,1
Nordmann fir (*Abies nordmanniana*)	25.689	4,5
Noble fir (*Abies nobilis*)	11.876	2,1
Other firs	15.767	2,8
Pines (*Pinus silvestris, contorta, mugo* a.o.)	68.249	12,0
Other conifers (including Douglas fir)	39.552	6,9

Table 1: Species distribution in the Danish forests (Nord-Larsen et al. 2009).

The Danish forested area has over the past 20 years increased by approximately 1% on an annual basis, due to afforestation, mainly in relation to urban forests, ground water protection and recreation but also as regular forest. The expected increase in timber supply may to a certain extent be counteracted by the planned reservation of areas for non-intervention forests and forests for other than timber producing purposes.

Forests are the natural vegetation form almost all over in Denmark. Since the forest over the past millennia has been pushed heavily back and around the year 1820 represented only 2 to 3% of the land, the biodiversity associated with forest was seriously threatened. Hence, the Danish forests have a special significance for securing biological diversity, the diversity which in general is threatened by climate change.

With an annual harvest of around 2 million m^3, the Danish forests provide at present significantly around 30% of the Danish wood consumption. Beside the wood production the forests provide Christmas trees, greenery and hunting - which in economic terms more than equals the value of the harvest. The forests also have a number of ecosystem services of great national importance are the contribution to ground water protection, carbon sequestrations and storage and the major scenic, biological, and recreational values that forests add to the landscape. Hence, the total economic value of the Danish forests is much larger than the forest area and the annual harvest imply.

Climate change and forests

As long living organisms trees are especially sensitive to changes in growing conditions. The trees we plant today must be able to cope with the climate 50 to 100 years ahead. Therefore, forestry has a special commitment in safeguarding long-term adaptability to climate change. Hence, this problem was addressed in relation to forestry in Denmark soon after the first convincing reports of possible greenhouse effects were published (Larsen 1990).

A "natural" forest ecosystem, its structure, dynamics and species composition is largely a result of the prevailing growing conditions, i.e. soil and climate in particular. When climate changes, there will correspondingly be changes in forest structure and functions. Thus, the Danish forests have undergone dramatic changes since the last ice age: from birch-pine forest and oak-lime woods to contemporary beech-dominated forests. The last 200 years, man has further affected the forest through the introduction of a variety of "exotic" tree species, so that the forests today are far from reflecting the prevailing climatic conditions. The question is: What happens - not only with our native tree species but also with the introduced species when climate change really takes hold?

I. Impacts

Climate change will have a profound impact on forest management in Denmark. In fact, it already has: The use of Norway spruce has decreased noticeably 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.

I.1. Observed impacts

The main sensitivities of forest trees in Denmark are mainly related to weather extremes such as frost, drought and high wind speeds. Damage caused by biotic factors (insects, fungi) occurs frequently but to a lesser extent.

Late spring frosts especially limit the regeneration of several species including beech and most fir species including Douglas fir. There seems to be a special problem with Norway spruce in relation to warm winters. After the extreme mild winters of 1989 and 1990 Norway spruce experienced a period of pronounced decline symptoms characterised by discoloration, needle cast and wide spread mortality (Saxe, 1993). Norway spruce in Denmark seems to be at its limits regarding summer precipitation and lack of dormancy due to frequent mild winters (Larsen et al., 1993).

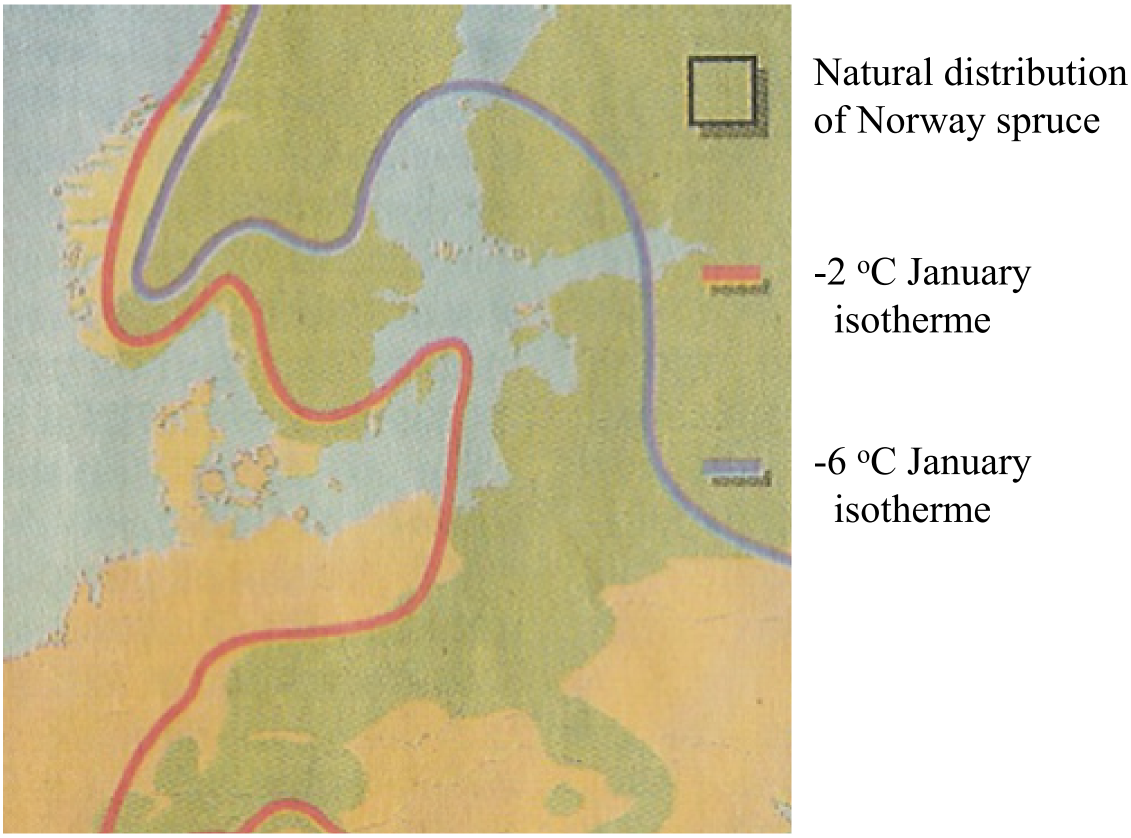

Figure 1: Norway spruce and climate change.
The natural distribution of Norway spruce as well as the -2^{O} C and the -6^{O} C January isotherm. There is a striking concurrence between the western limit of the species and winter temperature, indicating that Norway spruce omits mild winter climates. With a 4^{O} C increase in winter temperature the future -2^{O} C isotherm will move to present days -6^{O} C isotherm, consequently Norway spruce in Denmark will “move” further away from “home” than it is the case to day (from Larsen and Saxe, 2001).

There is a striking concurrence between the natural distribution of Norway spruce and the –2^{O}C January-isotherm (Fig 1). These findings are alarming, since Norway spruce is the most common tree in the Danish forests, and the most likely climate change scenario includes up to 4^{O}C warmer winters. In this case the "natural" range of Norway spruce around year 2100 will be even further away from Denmark than is the case today. Bioclimatic simulation models correspondingly predict a rapid northward contraction of Norway spruce in Scandinavia (Bradshaw et al., 2001). However, the physiological control mechanisms involved in the natural distribution of our forest trees – including Norway spruce, is widely discussed but little understood (Sykes et al., 1996).

With intervals of 15 to 20 years Denmark experiences devastating storms, which cause heavy damage to conifer stands with heights above 15 to 18 m, and in rare cases also to broadleaves. Although it is debated, whether the frequency and the severity of storms have increased during the 20th century, the effects on forests has certainly increased during the same period. During the last 40 years, in 5 storms (1967, 1981, 1999 and 2005) a total of 11 million m^3 were blown down, whereas "only" 1 mill. m^3 were blown down during the first 60 years of the past century (Holmsgaard, 1982). A major reason for the increasing impact of storms on the Danish forests is the increasing use of storm sensitive conifer species during the last century.

Limitations in water supply and especially lack of rainfall during the growing season limit growth of all forest trees in Denmark. In rare cases drought leads to direct tree decline, and the inverse correlation between summer precipitation and tree vitality, measured as defoliation scores, has been shown, most clearly for beech but also for oak and Norway spruce. In addition, warm and dry summers create a vicious combination of population growth of bark beetles and vitality loss of especially Norway spruce and Sitka spruce. In dry summers beech suffers especially on clayish soils with limited drainage, leading to early leaf shedding and wood discoloration (freckles), and shedding of whole shoot systems by oak has been observed after prolonged summer drought.

I.2. Expected impacts

When predicting the expected impact of climate change, we are in essence dealing with different kind of uncertainties.

The main uncertainties are founded in the limitations in the predictions of regional precipitation and storm patterns. Since Denmark is situated close to the limits of tree growth in respect to water, small deviations in rainfall during the growing season, including the occurrence of extremes, might cause pronounced effects on tree growth and eventually initiate dramatic shifts in vegetation. Further, rather small increases in the magnitude and frequency of storms over Denmark might lead to a total abolition of the storm sensitive conifers.

However, no mean climate value has ever killed a tree! What interests is the excessive event: the extreme drought or temperature, the particular mild winter, the extreme storm. Forecasting extremes is even more uncertain than the actual projection of mean values.

Other uncertainties are related to the lack of knowledge about species and provenance specific reactions to climate change, including their ability, physiologically, to buffer such changes. Further, the potential for breeding for physiological and evolutionary adaptability is limited (Larsen 1991). Though much is known about the profound effects on forest trees, stands and ecosystems caused by elevated CO^2 (Saxe et al., 1998) and temperature (Saxe et al., 2001) alone, only little is known about the degree of interactions between these and with other natural factors (pest, diseases) and anthropogenic stresses (air pollution etc).

With these uncertainties in mind the expected impacts on Danish forest tree species are discussed under the headings: temperature rise, precipitation change, storm frequency, and pests. In Table 2 the findings are listed and complied.

Temperature increase.

The expected moderate increase in temperature is likely to promote tree growth in general. Since most of our native tree species in Denmark (beech, oak, ash, sycamore maple, Norway maple, hornbeam, lime and others) are close to their northern distribution limit and this limit is mainly due to low temperatures, these will be relatively robust to temperature increases between 2 to 4 degrees. Some species are expected to benefit directly from small increases in average temperature (lime, hornbeam, oak). Scotch pine, our only native conifer, will also be robust. Regarding the most used introduced tree species, Sitka spruce, larch and Douglas fir are also able to adapt to smaller temperature increases. Red alder is expected to react slightly negatively on rising temperature judged from rather bad experiences with more southerly provenances: this species seems to be especially sensitive to transfer of seed sources. The only species, which is expected to react negatively, especially to warmer winters, is Norway spruce, unfortunately the most commonly planted tree species in Denmark. Norway spruce showed marked decline after the extremely mild winters 1988/89 and 1989/90 (Saxe and Larsen 1992).

Precipitation.

With rainfall below 400 mm during the growing season, water is generally a minimum factor for tree growth in most places in Denmark, especially in regions with sandy soils with low water holding capacity. Thus, the predictions for Denmark of increasing yearly rainfall are overruled by the expected decrease in summer rainfall and especially the likelihood of prolonged periods of drought. This will generally weaken all tree species. However, it is mainly conifers and here especially those with relatively shallow root systems that will be most sensitive (Norway spruce, Sitka spruce), while larch, Scots pine and Douglas fir are expected more robust. Beech, maple and ash could also have problems, whereas oak will be relatively robust.

Storm Frequency.

The risk of an increase in storm frequency and storm intensity must be taken very seriously in relation to the forestry strategy on climate adaptation. The last 40 years has offered 5 severe storms with disastrous consequences for forestry (1967 (twice), 1981, 1999 and 2005). Since most storms occur in winter when deciduous trees (and larch) have shed their leaves, it is especially conifers which are at risk. This is particularly true for Norway spruce, Sitka spruce and grand fir, while larch, Douglas fir and Scots pine are more robust against storms (see Fig. 2).

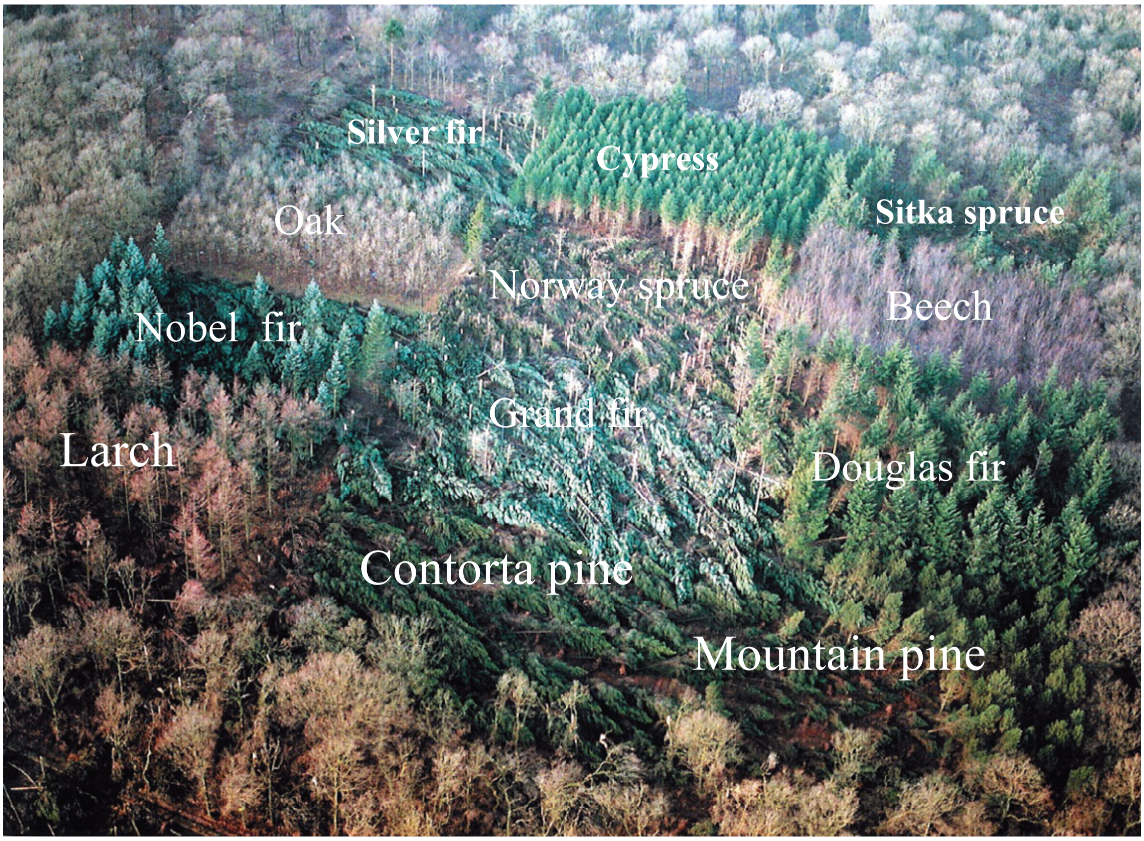

Figure 2: Forest tree species and wind stability.
The species trial at Lindet forest District in southern Jutland shortly after the gale of December 3, 1999. There are strikingly differences in the ability to withstand storm among species. The “leaf shedding” species beech, oak and larch are almost undamaged, whereas most conifers (spruce, firs, and pines) are almost completely destroyed. Interesting exceptions are cypress and Douglas fir (from Larsen and Saxe 2001 – photo: B.B. Jørgensen).

Pests

When trees are weakened physiologically because of climatic stress, they will generally be less resistant to pests. Further, changing climatic conditions might influence the relationship between pests and their hosts (trees): Therefore, in some cases increased problems with known pests are expected.

Increase in seasonal thermal sums will in general improve development conditions for insects. For some species this will allow more generations per year or higher breeding success, thus reinforcing already existing problems. As an example the well-known problems with the spruce bark beetle (*Ips typographus*) are expected to be more frequent with dryer summers and higher average temperatures and more frequent heavy winds.

Mild winters cause early springs, which will favour the green spruce aphid (*Elatobium abietinum*). The great spruce bark beetle (*Dendroctonus micans*) is depending on sunny and dry summers for successful development. Both species attacks Sitka spruce and will endanger the stability of this tree species under Danish conditions if the predicted climate changes come true

Increasing temperatures can also lead to the occurrence of insects which to date for climatic reasons do not exist in Denmark, facing forestry with problems so far only occurring in countries further south. Examples are oak processionary moth (*Thaumetopoea processionaria*) and gypsy moth (*Lymantria dispar*). However, the importance of pest species expanding their natural range of distribution usually will be insignificant for forestry as such – at least at an early stage.

Diseases

Few fungal diseases are dependent on temperature and other climatic factors to the same degree as insects. However, one of the most devastating rot roots in Europe, *Heterobasidion annosum*, requires temperatures above 5ºc to become established on stumps, from where it spreads to standing trees. Stump treatment can prevent this disease, but in the other Nordic countries winter felling is considered another option. With milder winters due to climate change, the season and thus cost of preventive stump tretment will expand, or if no action is taken the frequency and severity of *H. annosum* root rot will probably increase.

Other fungi may benefit from reduced vitality in trees that are weakened physiologically because of climatic stress, but this is not an effect which will threaten tree species, but rather single trees.

The most sensitive areas

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 introduced tree species in monocultures (Saxe and Larsen, 2001). These systems have a very low resistance and resilience, thus being very susceptible to environmental perturbations (Larsen, 1995). Other regions of potentially low robustness in relation to climatic changes are the ground water influenced young moraine soils of central and eastern Zealand, which have very high clay content and poor drainage.

Species	Temperature	Precipitation	Storm	Pests	Overall assessment
Beech		-	-	-	---
Oak	+	-	-	-	--
Ash		-	-	-	---
Sycamore		-	-	-	---
Lime	+	-	-	-	--
Wild cherry		-	-	-	---
Hornbeam	+	-	-	-	--
Norway maple		-	-	-	---
Alder	-	--	-	-	-----
Birch		-	-	-	---
Norway spruce	---	---	---	--	-----------
Sitka spruce		---	---	--	--------
Douglas fir		-	--	-	----
Silver fir		--	--	-	-----
Grand fir		-	---	-	-----
Noble fir		--	--	-	----
Larch		-	-	-	---
Scots pine		-	-	-	---

Table 2: Summary of tree species sensitivity to the expected climate change.
Legend: (---) = strongly negative, (--) = negative, (-) = slightly negative, ( ) = neutral, (+) = slightly positive. The last column sums up the expected effects.

As shown in the Table 2, all tree species used in Danish forests are expected to be negatively affected by the anticipated climate change - but to varying degrees. The species can be divided into the following groups:

1. Generally robust species: oak, sycamore maple, beech, ash, lime, hornbeam, wild cherry, Norway maple, birch, Scots pine, larch.

2. Sensitive species: Douglas fir, silver fir noble fir, grand fir, red alder

3. Very sensitive species: Sitka spruce and especially Norway spruce

I.3. Impact monitoring

The systematic monitoring of climate change impact is conducted through the National Forest Inventory. Forest health monitoring started in 1986 and in 2002, a new sample-based National Forest Inventory (NFI) was initiated including forest health.

The forest definition adopted in the NFI is identical to the FAO definition (FAO, 2005). Compared to the National Forest Census, this forest definition is more specific and includes a larger variety of areas. It includes "wooded areas larger than 0.5 ha, that are able to form a forest with a height of at least 5 m and crown cover of at least 10%. The minimum width is 20 m." Temporarily non wooded areas, fire breaks, and other small open areas, that are an integrated part of the forest, are also included.

The NFI is a continuous sample-based inventory with partial replacement of sample plots based on a 2 x 2 km grid covering the Danish land surface. At each grid intersection, a cluster of four circular plots (primary sampling unit, PSU) for measuring forest factors (e.g. wood volume) are placed in a 200 x 200 m grid. Each circular plot (secondary sampling unit, SSU) has a radius of 15 meters. When plots are intersected by different land-use classes or different forest stands, the individual plot is divided into tertiary sampling units (TSU).

About one third of the plots are assigned as permanent and will be re-measured in subsequent inventories every five years. Two thirds are temporary and are moved randomly within the particular 2x2 km grid cell in subsequent inventories. The sample of permanent and temporary field plots has been systematically divided into five non-overlapping, interpenetrating panels that are each measured in one year and constitute a systematic sample of the entire country. Hence all the plots are measured in a 5-year cycle.

Based on analysis of aerial photos, each sample plot (SSU) is allocated to one of three basic categories, reflecting the likelihood of forest or other wooded land (OWL) cover in the plot: (0) Unlikely to contain forest or other wooded land cover, (1) Likely to contain forest, and (2) Likely to contain other wooded land. All plots in the last two categories are inventoried in the field.

In the first years of the NFI (2002-2008) the average number of clusters (PSU) and sample plots (SSU) are 2,196 and 8,604, respectively. On average 1,627 plots (SSU) were identified as having forest or other wooded land cover based on the aerial photos and were thus selected for inventory.

On every sample plot a random sample of 2-6 trees are further measured for total height, crown height, age and diameter at stump height are made and the presence of defoliation, discoloration, mast, mosses and lichens is recorded. On plot level impacts of biotic and abiotic damages are recorded.

Further more - observations of growth, defoliation and discoloration are recorded on a number of field experiments annually. These experiments both include experiments on species, forest management and provenances. In addition, a number of intensive forest ecosystem monitoring plots and plots for monitoring of forest health are annually monitored for impacts of climate change.

The monitoring contributes to both the national monitoring of forest health, impacts of climate change and the international reporting to EU, UN and MCPFE. The issues related to climate change include defoliation, discoloration, phenology, carbon sequestration and carbon stocks.

I.4. Impact management

The Ministry of Energy and Climate have initiated a process to follow impacts of climate change. So far it is based on already existing monitoring. The goal is to obtain early warnings of climate change impacts that will need actively management.

In relation to forests specifically there is general climate change impact management. However - a number of instruments can be seen as useful tools for impact management.

Nationally the Danish Plant Directorate continuously monitor imported plants and plant material. This is specifically as precaution against introduction of new pests and diseases that could negatively affect the health and productivity of the forests. This leads occasionally to specific monitoring for e.g. bark beetles that may be introduced along with other goods.

In relation to the Elm disease a general instruction was given in relation to how to reduce the impact and to constrain the spread of the disease. The instructions lead to systematic removal of all infected wood and neighbouring trees - thereby reducing the effect of the disease. Similar approaches can be used for management of other pest or infection diseases. Currently Denmark is experiencing an ash dieback, but so far the knowledge on the disease and the spread of it is not sufficient to provide instructions on how to manage the impact.

II. Adaptation

II.1. Vulnerability of forests and forestry

During the last century the productivity of the Danish forests has increased considerably, mainly caused by more intensive management, the use of faster growing conifer species and better provenances, nitrogen deposition and probably the already realised increase in CO_2. With adequate silvicultural measures to counteract the present climate change scenario wood production in Denmark tends to increase further but might certainly change towards more hardwoods. In the longer perspective (beyond 2050) a drop in softwood harvesting might be encountered. Within this time scale the wood industry is supposed to be able to adapt.

Since management practices of Danish forests are expected to control or even take advantage of most effects caused by climate change, no dramatic change in the forest cover is being expected. Consequently, the implications for other sectors are small to insignificant. Conversely, the necessary change in management practices in order to cope with the expected climate change (see II.2 and II.3) might have positive side effects on other forests functions, such as carbon storage, recreational values, ground water protection, biodiversity conservation etc.

II.2. General adaptation strategy or policy

In 2002, the Danish Ministry of Environment decided on a new national forest program (Danish Forest and Nature Agency, 2002). In this program, nature-based forest management is promoted as an efficient and economically attractive tool for sustainable forest management and as a mean to cope with climate change.

The close-to-nature forest management combined with an increased use of climate robust deciduous and coniferous species and the reduction of climate change intolerant conifers (i.e. Norway spruce and Sitka spruce) are here identified as the overarching principles to prevent the negative effects of climate change.

Close-to-Nature forestry, in combination with other incentives, will be used as a rehabilitation tool for changing our forests fundamentally from monoculture plantations, largely based on non-native species, to sustainable forest ecosystems with more site-adapted, often native broadleaved species. The goal is a gradual readjustment of all public forests (133,000 ha) plus additional voluntary conversion in private forests.

Consequently, The Forest Act from 2004 supports the 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 structural differentiation. The Forest Act also grant schemes targeted at the private forestry, which include the use of mixed stands and of more climate robust deciduous trees species. Currently the grant scheme only focuses on afforestation?

II.3. Forest adaptation measures

Basic measure: Close-to-nature silviculture

As mentioned above, the overarching silvicultural measures that best ensures the forest against potential and unforeseen climate change is largely identical with the principles of the so-called "close-to-nature forest management". This silvicultural “tool-box” aims in particular at: 1) maintaining a permanent forest climate by refraining from clear-felling, 2) stability improvement and risk diversification through the creation of uneven aged mixed forest stands of site-adapted tree species, 3) active stand improvement through frequent and weak thinnings and 4) protection of natural equilibriums among forest organisms, including pests with the aim to promote biodiversity and avoid pesticide use.

To facilitate the transition from classical even-aged plantation forestry to close-to-nature silviculture 19 Forest Development Types (see Fig. 3) and different conversion models have been developed in a participatory process with forest practitioners and other stakeholders (Danish Forest and Nature Agency 2005, Larsen and Nielsen 2007).

Specific measures:

1. Promoting continuous forest cover.

The main reason for promoting continuous forest cover or at least refraining from larger clear cuts is the obvious importance to maintain the forest climate. An intact forest climate levels climatic extremes and supports natural regeneration and seedling survival. These functions are of basic importance for silviculture but are going to be even more important when the climate gets more extreme.

2. Promoting site adapted and climate tolerant species.

As shown in Table 2, our tree species have different ecological requirements and possess unequal abilities to adapt to the expected changes in the climatic conditions. This implies increasing the proportion of storm resistant – mainly broad leaved species, and decreasing the forest area with monocultures of the most climate and storm susceptible tree species such as Norway spruce and Sitka spruce. Species selection is about “what is adapted in the future” and not merely “what has been historical natural in the past”. Therefore, future species selection will also include exotic species to enrich our forests with elements, which could further increase their adaptability (larch species, Douglas fir and other mainly North American species).

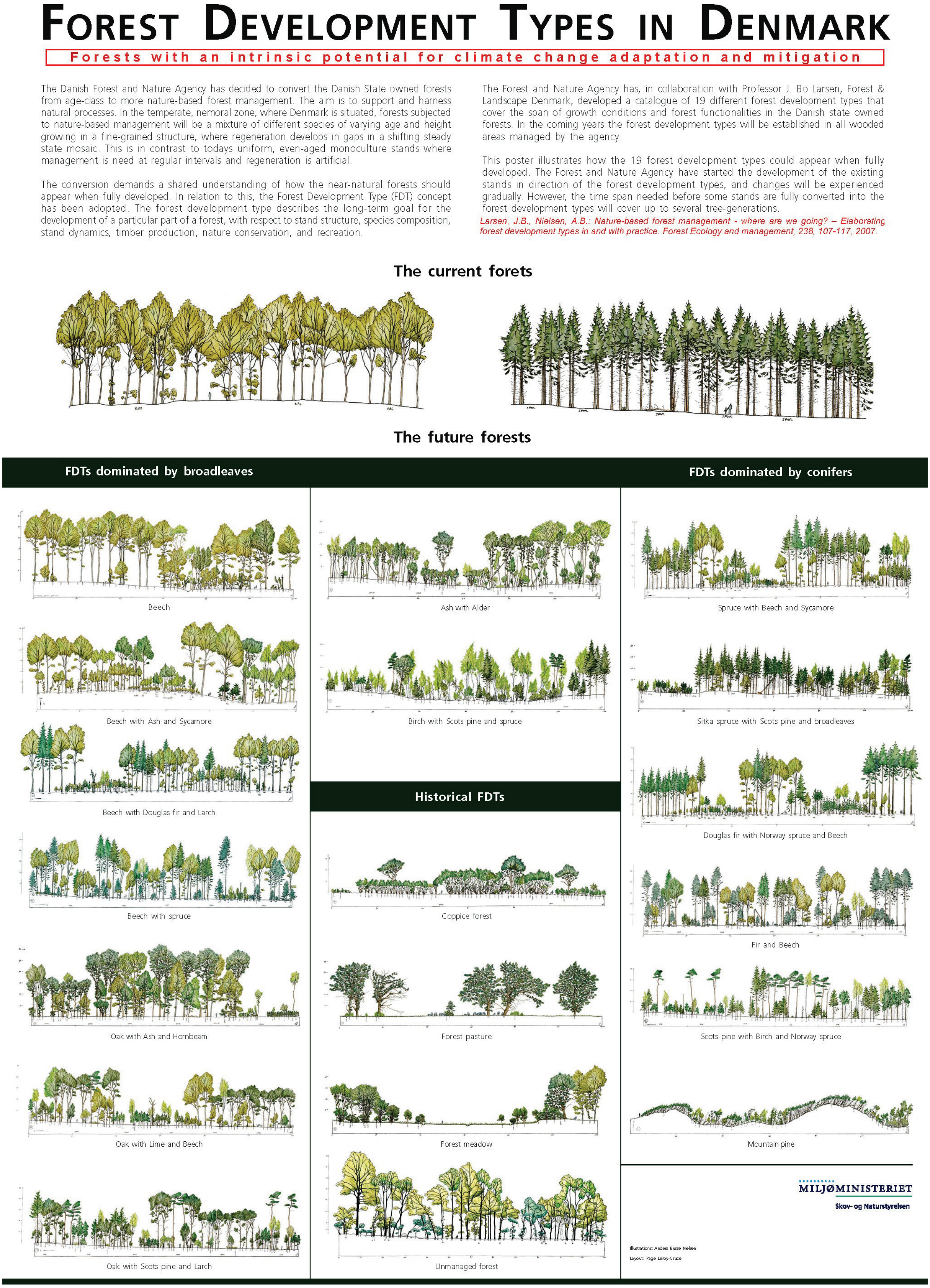

Figure 3: The Danish Forest development Types (Larsen and Nielsen 2007)

3. Promoting mixed stands

Cultivation of tree species in mixture is a highly effective way to increase the adaptability of a forest to climate change. Hence, a forest stand consisting of two or more species characterized by differences in ecological requirements and ability to adapt to projected changes in temperature, rainfall, storm frequency and pests will involve opportunity for continuous adjustment of the operating target in accordance with the development of the climate. A mixture of beech and spruce, for instance, could end up in a more or less pure beech stand, if the climate would evolve against the spruce, where a pure spruce stand would be lost. In essence, mixed stands give future generation options to select the best climate adapted species at the time when climate change has become apparent.

However, not all mixtures are suitable to manage. In order to help management to develop manageable and site adapted mixtures a catalogue of 19 different Forest Development Types (Fig. 3) – all representing appropriate mixtures – have been developed to be used in Danish close-to-nature management (Larsen 2006, Larsen and Nielsen 2007).

4. Promoting natural regeneration and enrichment planting of robust species.

Natural regeneration mostly leads to high numbers of trees in the initiation phase, thereby maintaining genetic variation and a high potential for natural and man made selection. In order to further increase the adaptive potential, supplementary (enrichment) planting of robust species is recommended. Natural regeneration further promotes most favorable root development, thereby supporting future storm stability.

Promoting the use of the best genetic material (provenances, reproductive material from tested seed orchards) when planting/sowing and promoting the use of plug plants instead of bare root planting stock.

5. Promoting stand structure through active thinning and single tree selection

Assuming that our forests continue to be exposed to an increasing stress of climatic nature, forest management must try to minimize the other (internal) stressors. This includes the need for more active stem reduction methods characterized by frequent interventions, thereby reducing the inter- and intra-specific competition and reinforcing the individual tree vitality. Active thinning to promote deep and vital crowns (especially in conifers)

Thinning should further promote species mixtures and uneven-aged stand structure. Uneven-aged stands will be less exposed to hazards, since many biotic and abiotic stressors are often linked to specific developmental stages (small trees are seldom storm felled and attacked by bark beetles, young trees are more exposed to drought than older trees with deeper root systems).

6. Promoting site classification and projections for future climate as decision support to select appropriate Forest Development Types

II.4. Research studies of forest adaptation

Results from Danish experimental field- and chamber studies indicate that the predicted climate changes will most likely result in improved forest growth and production, particularly with prudent management based on the most suitable species and genotypes and an optimal forest structure (Bruhn et al. 2000, Saxe et al, 2001).

III. Mitigation

Until now, mitigation strategy has mainly derived from the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. However, some instruments can be decided in other frameworks and the energy crisis adds new views and opportunities.

III.1. Carbon accounts

Carbon accounts constitute a major instrument to assess the current situation relative to mitigation of greenhouse effect and climate change and to plan future measures. They are officially declared in the frame of UNFCCC and they are just reminded here. They can be downloaded from the Unfccc website http://www.unfccc.int (GHG data, GHD data UNFCCCC, flexible queries) for forests, have they been forests or not in a recent past. A standard table could be proposed here for each country and filled either by the country representative or by Echoes secretariat.

(We would like to contribute to this table - as the Danish data for the periode have been updated given the new knowledge based on the NFI and new remote sensing land use mapping - see Johannsen et al., 2009)

III.2. Forestry as a source of bioenergy

The Directive on electricity from renewable energy sources for electricity production requires that Denmark by 2020 have 30 % renewable energy. Biomass from forests already plays a large role in the Danish electricity production and with this directive this will also be the case in the future.

For the general energy production biomass plays a large role, with a substantial part of the energy for the combined heath and power plants being provided by woody biomass from forests. In supplement to this, fire wood remains an important energy source in many private households.

There are currently no specific policies on the forests role in the mitigation strategy in Denmark, but initial analyses are being performed, looking at the sustainable level of biomass supply from forests.

The forests are expected also in the future to play a pivotal role in the provision on bioenergy, with a significant increase in the utilisation of woody biomass for energy (DIRECTIVE 2001/77/EC. The main research and management challenge is to ensure a sustainable biomasse production - in forests and in the landscape in general, where biomass from agriculture also will contribute.

III.3. Strategies, processes and instruments

Denmark have in addition to article 3.3 of the Kyoto Protocol also elected article 3.4. A specific monitoring and accounting programme have been set up, building upon the already existing National Forest Inventory, to provide accurate accounts of carbon stocks in forests and agricultural land and the changes therein. Currently it is mainly a monitoring programme with no accompanying instruments for influencing the development of carbon stocks. For forests some preliminary results are already published and will bee used for the GHG reporting in 2010 (Johannsen et al. 2009).

The Ministry of Energy and Climate are having several processes starting to focus on bioenergy production from other sources than forests - e.g. biogass production from animal manure through the Green Growth Strategy. Further, Denmark have to some extent been involved in CDM and JI projects, but only in a minor scale.

Another issue of the mitigation is afforestation, where the goal of doubling the Danish forest area contributes to establishment of new forests over the next 80 years. However - the grants for new forest have declined over the recent years, and the restrictions on intensity of the new forests (e.g. low stem numbers and species selection) may lead to less carbon capture in the new forests and on the long term, a lower biomass production potential than the area it self could indicate.

III.4. Research studies on mitigation

In Denmark a number of research studies deals with the improved utilisation of forest biomass for bioenergy. This involves a number of projects on improved handling and usage of fire wood and on higher energy efficiency of wood burning. During a number of years studies have been performed on the production of wood chips as a product directly from the forest. Recently new research studies have started looking at options for utilizing forest biomass for biofuels, but so far on a minor scale.

Denmark has also been involved in research projects on the standardisation of wood based bioenergy, such as the BioNorm projects.

Through a number of field experiments, the sustainability of bioenergy production from forests has been analysed. This have involved analyses of soil, effects of fertilisers, distribution of forest ashes, effects on remaining forest stand in terms of growth and health.

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