GENE FLOW, GENETIC STRUCTURE AND CONSERVATION GENETICS OF *FAGUS CRENATA*

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General Introduction

By using parentage assignment and phylogeographic analysis with DNA markers, it is possible to determine the gene flow and genetic structure in natural forests. This is a review of our recent studies of the molecular ecology of *Fagus crenata*.

1) In a primary beech forest, current-year seedlings and adult trees of *F. crenata* were sampled for microsatellite analysis, and the spatial patterns of seed and pollen dispersal were investigated based on parentage assignment analysis.
2) To evaluate the effects of forest fragmentation on pollen flow, the seed set and genetic diversity of the resulting seeds were compared among *F. crenata* trees located within various local pollen donor densities.
3) The variation in chloroplast DNA and nuclear microsatellites was investigated for natural and planted populations of *F. crenata* in Miyagi prefecture, northern Japan. Furthermore, cpDNA haplotypes and growth performance were investigated in a planted population of the species to demonstrate the fitness advantages of local genotypes.

1. Seed and pollen dispersal in **Fagus crenata** *revealed by parentage assignment analysis with pericarp and cotyledon DNA*

Introduction

The availability of hypervariable microsatellite markers has greatly extended the possibility of parentage assignment analysis in natural forests. However, maternity and paternity assignment based on DNA from biparental tissues is often difficult when both parents are unknown and many candidates are available. We used an effective approach for the identification of parental trees based on the microsatellite analysis of maternal and biparental tissues from seedlings.

Materials and Methods

DNA from the woody pericarp, a tissue of maternal origin that is usually attached to emerged seedlings, was used to identify the maternal trees of current-year seedlings of *F. crenata* in a primary beech forest in northern Japan. In the 90 × 90 m study plot, 10,710 current-year seedlings of *F. crenata* that emerged in 324 quadrats (1 × 1 m) were tagged for the demographic study, and their pericarp samples (maternal tissues) were collected. DNA was extracted from 1387 pericarp samples (representing 10% of the emerged seedlings) and 287 leaf samples from all adult trees in the plot, including a buffer area (170 × 170 m). By comparing the pericarp genotypes at four microsatellite loci with the genotypes of all of the adult trees, the maternal trees of the seedlings were identified. The demography of the seedlings was also recorded. The paternal trees of 692 current-year seedlings were surveyed based on paternity assignment analysis of their cotyledon DNA using 10 microsatellite markers.

Results and Discussion

Maternal trees of 1377 (99.3 %) seedlings and paternal trees of 434 (63.6 %) seedlings were identified based on maternity (perfect matching of genotypes) and paternity assignment analysis (simple exclusion method), respectively. Seeds were dispersed near their maternal trees (average distance: 11 m), but the average pollen dispersal distance was greater than the seed dispersal distance (> 33 m). Larger trees tended to produce more seedlings as both maternal and paternal parents. Our analysis revealed not only the basic pattern of gene flow at the local scale, but also the relative fertility of individual trees and the temporal changes in spatial genetic structure in the forest.

***2. Effects of local pollen donor density on pollen pool diversity in* Fagus crenata**

Introduction

Forest fragmentation can cause reduced seed production and genetic erosion in future generations. To evaluate the effect of forest fragmentation on pollen flow, the seed set and genetic diversity of the resulting seeds were compared among trees within various pollen donor densities.

Materials and Methods

A total of 9453 seeds were collected from nine trees of *F. crenata* located within various local pollen donor densities (1–34 adult conspecific trees ha^{-1}) in a deciduous broadleaf forest in northern Japan. We counted the numbers of mature, immature, and insect-attacked seeds in the collected samples. The DNA was extracted from 96 mature seeds per tree. The pollen pool diversity was investigated based on the genotypes of the seeds using seven microsatellite markers. The paternal trees of the seeds were surveyed from 1531 adult trees within an approximately 500 ha area in the forest using paternity assignment analysis.

Results and Discussion

As expected, the proportion of immature seeds was significantly negatively correlated with the local pollen donor density. However, allelic richness in the pollen pool was high at low pollen donor density. The paternity assignment analysis showed a relatively large number of pollen donors and long-distance pollen dispersal at low pollen donor density. In addition, the outcrossing rate was high (95–100%), even for low-density trees. Although pollen limitation was suggested by the seed set data, pollen flow over a long distance was effective in the low-pollen donor density populations of *F. crenata* in the study plot. The results draw attention to the potential reproductive ability of fragmented or low-density population remnant forests as core populations for future generations.

***3. Conservation units and home-site advantage in* Fagus crenata**

Introduction

Reforestation with non-local seed sources may result in genetic disturbance and maladaptation to local environments. Therefore, it is important to use a local seed source within a seed transfer zone delineated by the phylogeography of the species being reforested. This study can be regarded as a model for the establishment of local seed transfer zones or conservation units for *F. crenata*, a dominant tree species in the cool temperate region of Japan.

Materials and Methods

To determine the local phylogeographic pattern (genetic structure) of *F. crenata*, chloroplast DNA haplotypes based on six single-nucleotide polymorphisms were investigated. A total of 518 trees were sampled, representing 63 natural populations covering the natural distribution of the species in Miyagi prefecture, northern Japan. Nuclear DNA variation in seven microsatellite loci was also investigated for eight main populations in the area. To clarify whether the origins of planted trees were local, cpDNA haplotypes of planted trees were also investigated for 72 individuals from 18 planted populations of the species in the area. In a planted population with mixed origins from local and non-local plants, cpDNA haplotypes and their growth performance (height, diameter, and form) were investigated for all of the planted trees (259 individuals).

Results and Discussion

Two major and three minor cpDNA haplotypes were detected from the natural populations. The main natural populations were divided into at least two genetic clusters based on the allele frequencies of seven microsatellite loci. As a result, at least three seed zones (conservation units) are indicated for *F. crenata* in Miyagi. Furthermore, the cpDNA haplotypes of the planted trees showed that half of the plantations were non-local and that some plantations have a higher risk of genetic disturbance to adjacent natural forests. A fitness advantage of local haplotype plants (home-site advantage) was demonstrated in the planted population with mixed origins by comparing growth performance between local and non-local plants. Our results indicate that the establishment of conservation units is necessary to conserve local genetic resources in this species.

Conclusion

Although gene flow via seed is limited to a small area, long-distance pollen flow could be effective to maintain local genetic diversity, even in a fragmented forest. It is important to conserve remnant forests in each region to promote the fitness of local species while avoiding the transplantation of non-local species that may devastate local populations.

Acknowledgements

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GENETIC VARIATIONS IN SEEDS OF SMALL, ISOLATED BEECH POPULATIONS IN THE NOTO PENINSULA

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Introduction

Woody plant populations persist in their original establishment site throughout their long life spans and the population persistence is attributed to demographic and environmental variance (Holsinger 2000), where spatio-temporal genetic changes are inevitably involved. The natural selection and random genetic drift are major aspects causing genetic change in finite plant populations (Wright 1940). The fewer the number of individuals in the population, the more susceptible it is to genetic drift by stochastic shifts. Therefore, fragmentation leads to shrinkage of the local population and has important implications for the genetic structure of geographically isolated small populations.

Small isolated beech (*Fagus crenata*) populations are found in the lowlands along the Sea of Japan. Among others, remnant beech populations preserved in the Noto Peninsula. These populations are small, fragmented, and isolated. Moreover, some populations are extremely small, consisting of only a very small number of individuals. We will report genetic variation in these remnant populations by analyzing seeds in order to determine the effect of extreme isolation and small population size.

Materials and Methods

Study sites and sample preparation

We identified nine remnant beech populations (all fragmented and isolated) in the Noto Peninsula. Five of these populations (HR, KS, HB, SD, and HD), located at a higher altitude in the mountains, are estimated to have a good number of mature individuals (>500). The other four populations (km, mz, hm, and tb) are located at an extremely low altitude and consist of a very small number of mature trees (<500).

We collected seeds from these nine beech populations in November of the mast fruiting year 2005, and also from lowland beech populations in the Echigo Plains as a control. We measured morphological traits of seeds, then sown them in a plant pot and collected leaves from germinated seeds for microsatellite (SSR) and allozyme analyses.

Results and Discussion

Morphological traits: Measurement of four morphological traits (width, height, weight, and wing width) of seeds are summarized with average values of populations in Echigo Plains (Fig. 1). The seeds tend to be smaller in populations consisting of fewer numbers of mature trees. The size of the seed is associated with inbreeding in small populations (Hensen and Oberprieler 2005), and might

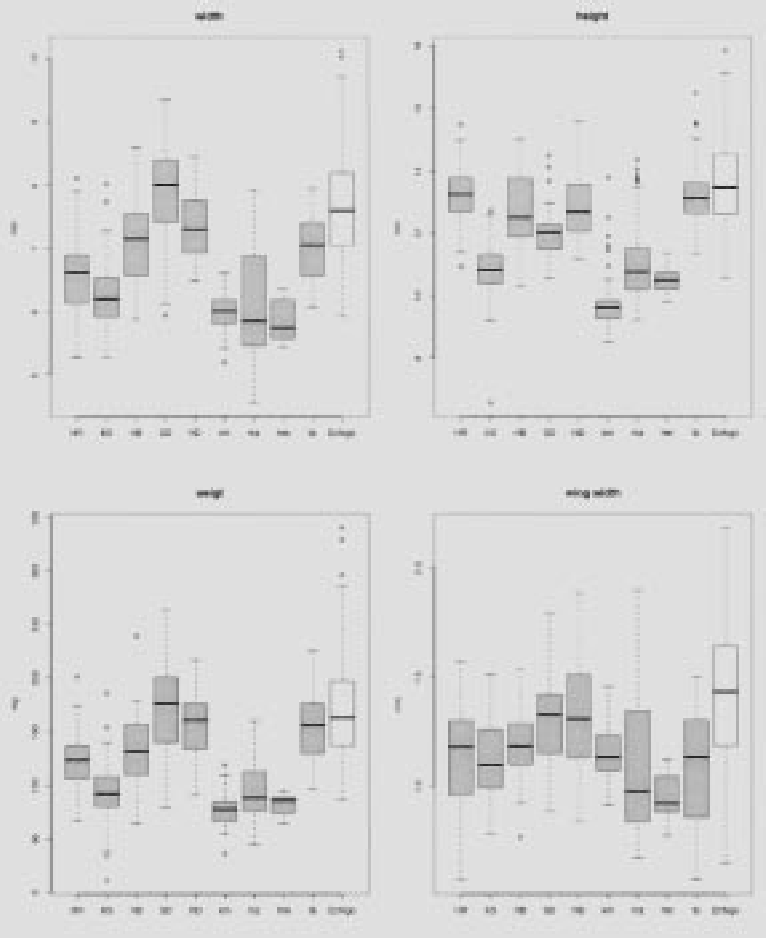

Fig. 1: Four morphological traits of seeds.

directly affect the survival and fitness of the individual. Our field observation also indicated that viable seeds are fewer in small populations. The small seeds indicated strong inbreeding depression due to the limited number of reproductive individuals in the population.

Genetic diversity: Heterozygosity and allelic richness are clearly lower in all four smaller populations (Fig. 2). The average value of Noto Peninsula was lower than that in Echigo Plains. Genetic diversity is an important trait for population persistence under a changing environment. Therefore, our results suggest the genetic feasibility of small populations. Genetic differentiation among populations (*Fst*) in the Noto Peninsula (0.106) was higher than that in Echigo Plains (0.079). This result might be attributable to population fragmentation. In particular, two fragmented and isolated populations were genetically differentiated from the other populations. This could be due to genetic drift, and these two small populations must have been isolated from other beech populations for a relatively long period of time.

Differences of genetic variation between mature trees and seedlings: Heterozygosity tended to decrease in seedling populations, which indicates genetic loss in the reproduction process of small populations. A number of alleles had been lost in the seedlings. On the other hand, there were several alleles observed in seedlings, which were not in mature trees. These are evidently migrant genes, which were brought into the population by long-distance gene flow. This was conspicuous in the extremely fragmented population with only six mature trees. This fact indicated that populations in the Noto Peninsula, however fragmented they may be, are not completely isolated, and even a small number of immigrant genes can drastically increase and recover the genetic diversity of extremely small populations.

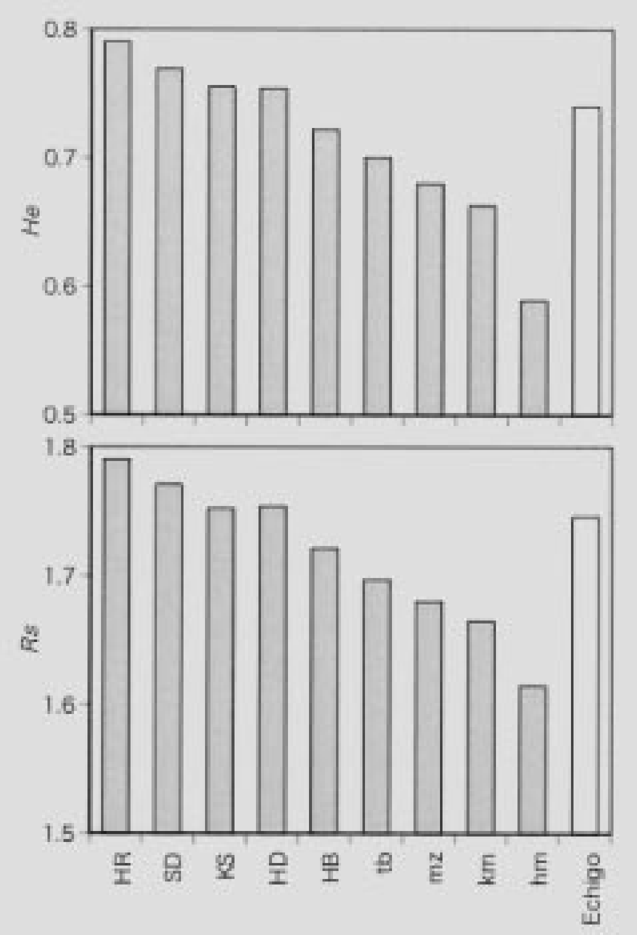

Fig. 2: Two parameters for genetic diversity revealed by SSRs.

Conclusion

The genetic variation reserved in finite populations decreases by generations (Kimura 1955). The reduction process for variation is expected to proceed rapidly in small populations. In addition, genetic fluctuation by genetic drift strongly alters genetic variation in small populations. Therefore, the dominant alleles of loci are not positively identical among populations. If isolation occurred among small populations, the genetic structure of each population inevitably differentiates. Fragmentation also causes genetic changes including loss of genes. Lower genetic variation within populations also reduces the opportunity for adaptation and may result in reduced reproduction or survival and thereby reduce the viability of the population (Madsen et al. 1996, Sherwin and Moritz 2000).

On the whole, small isolated remnant beech populations in the Noto Peninsula have lower genetic diversity, especially for the extremely depauperation. The impact of population fragmentation evidently caused the genetic differentiation among populations. This case study shows that the population size practically affects genetic diversity and dynamics of the plant population, especially for small fragmented populations that are threatened by genetic drift and inbreeding depression, both of which may result in a decrease of genetic variation and a resulting negative impact on plant fitness.

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EFFECT OF PREVAILING MONSOONS ON THE DISTRIBUTION OF BEECHES IN CONTINENTAL EAST ASIA

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Introduction

There are about 7 or 8 beech species in continental East Asia (Chang and Huang, 1988; Peters, 1997). All of them occur in the moist subtropical mountains, south of 34^0NL. Why are the distribution ranges restricted to the mountains of the subtropical area, or why are the beeches absent in the typical temperate of continental parts of East Asia, such as North China?

The factors limiting the beech species to grow outside of their current distribution ranges have been studied (Huang & An 1993, Cao et al. 1995, Guo 1999, Fang & Lechowicz 2006), but, the results are not consistent with each other. There is still no satisfied explanation.

In East Asia, during the winter, prevailing north and northeasterly winds blow from the super-cooled mainland to the relatively warm Pacific Ocean. These winds carry cold and dry air to the area they are invading, producing cold and dry weather. Their impact on plant growth is generally greater in the north than in the south. In summer, prevailing south and southeasterly winds blow and carry warm and humid air from the ocean in the southeast to the mainland. The intensity and timing of the seasonal shift of the above-mentioned two prevailing wind systems differ for different geographic locations, and determine the length of the growing season (Zhao & Zhang 1993). This implies that the oceanic monsoon season arrives earlier and leaves later in the southeast than in the northwest. The northwest has a shorter rainy season and is more influenced by the cold and dry winter winds than the south. So, the summer-green deciduous trees may tolerate less drought stress in the subtropical mountains than in the temperate zone. This is presumed to be the reason why the beeches are absent in the typical temperate zone in continental East Asia.

In this paper, we collected the data about the distribution locations and the altitudes of all beech species in continental East Asia, and analyzed the relations of the distribution characteristics of three widely distributed beech species and the monsoon climate. Additionally we examined what determines the distribution limits for these beeches.

Methods

Distribution data of beeches in continental East Asia were collected along three main ways: field investigation, private communication with local people and article authors, and data directly collected from the literature.

The ranges of annual mean temperature (AMT), mean temperature for the warmest month (MTWM), mean temperature for the coldest month (MTCM), warmth index (WI), coldness index (CI), continentallity index (K), and annual precipitation (AP), relevant for the distribution areas of Chinese beeches are from Fang & Lechowicz (2006). Some data from temporary meteorological stations were used too. The climatic data of the stations within the beeches' distribution ranges are from the Administration of Chinese National Meteorology Office. The temperatures at various altitudes in the mountains was estimated based on a mean lapse rate of temperature (0.6℃/100m). The amounts of rainfall were estimated by regressions based on data from local meteorological stations. Monthly ratios of precipitation to mean temperature during the growing season of the summer-green deciduous trees (RPT) were calculated based on the formula RPT=Pm/Tm. Here Tm refers to the monthly mean temperature of the months when the Tm>5℃; and Pm refers to the monthly precipitation during the same period.

The timing of beech flushing at each locality was estimated, based on the local climate. The timing of the monsoon rainy season at each locality was estimated, based on the general isopleths of the monsoon front in East Asia.

Results and Discussion

In continental East Asia, beeches occur scattered on some mountain ranges in the moist subtropics, between about 34° and 22° northern latitude. Among the 7 or 8 beech species in continental East Asia, *Fagus longipetiolata*, *F. lucida* and *F. engleriana* are the three species that have broad distribution ranges. *F. hayata* (and its varieties, subsp. *pashanica*) occurs at several locations, such as the Dabashan at the borders of Sichuan, Shaanxi, Chongqing and Hubei provinces, and the Tianmushan in the north of Zhejiang province. Other species, such as *F. brevipetiolata*, *F. bijiensis* and *F. tientaiensis*, occur sporadically at different locations and have very narrow distribution ranges. *F. chienii,* that was collected in the west of the Dabashan, is probably extinct. The beeches are absent in the typical temperate zone, north of the Qinling mountains, where the typical vegetation is considered to be deciduous broad-leaved forest. Compared to beech distribution ranges in Europe, North America and Japan, the distribution ranges of the Chinese beeches are only subtropical, i.e. far from the boreal zone, although in North America one species of beech also occurs in a few mountains in Mexico.

In the subtropical mountains, the beeches occur at higher altitudes in the more northern and western mountains. This is surprising, and contrary to the normal distribution pattern altitudinal vegetation belts. They usually occur as elements of the evergreen and deciduous broad-leaved mixed forests in most of their distribution ranges in continental East Asia. In the northern parts of their distribution ranges and at higher elevations, they occur as dominants of the deciduous forests.

The climatic variables annual mean temperature (AMT), mean temperature for the warmest month (MTWM), mean temperature for the coldest month (MTCM), warmth index (WI), coldness index (CI), continentallity index (K), annual precipitation (AP) at the growth localities of the beech species and of stations outside their distribution ranges in the moist typical temperate zone were compared. Most of the climatic variables at the stations outside the distribution ranges fall within the ranges that are scored at the localities where the beeches occur, with the exception of AP. However, if we allow for an increasing variation in precipitation with increasing altitude on the mountains, AP also falls within range. Therefore, without considering the pattern of annual rainfall distribution, temperature variables and AP do not seem to be factors that restrict the beeches from spreading northward into the typical temperate zone of continental East Asia.

The combination of monthly mean temperature and precipitation data reflect monthly water availability. These data, for four lower-limits of of the distribution of beech species over an altitudinal range in the subtropical mountains and at three stations in the typical temperate zone where no beeches occur, show that the reduced water availability during the early growth season of the summer-green deciduous trees seems to be the reason why the beeches cannot occur below their lower-limits in the subtropical mountains. There is a remarkable dry interval from the beginning of growth season of the deciduous trees to start of the monsoon rainy season. This long drought interval in the temperate zone and at lower altitudes in the subtropical mountains seems to restrict the occurrences of the beeches.

Conclusions

The conclusions are: 1) in continental East Asia, beeches occur only in the subtropical mountains and are absent in the moist typical temperate zone; 2) surprisingly, the beeches occur at higher altitudes as the mountains are located more to the northwest; 3) the absence of beeches in the temperate zone and their unexpected altitudinal distribution pattern can be properly explained by the prevailing monsoon climate; 4) it is not sufficient to simply reconstruct annual precipitation and annual mean temperature values of a locality from a straight forward comparison of current climatic values within the present distribution range of beeches when reconstructing the historical environment of beech fossils. Projecting future variation in beech distribution ranges requires more factors than annual mean temperature and precipitation when the response of vegetation to climate change is predicted.

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GAP DYNAMICS OF A SEMI-NATURAL BEECH FOREST ON LIMESTONE IN CENTRAL EUROPE

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Introduction

In 1999 the Institute of Silviculture of the University of Freiburg began a long term investigation into the natural dynamics of central European beech (*Fagus sylvatica* L.) forests, including the natural gap dynamics. In recent times it has often been argued that silvicultural systems employing gap cuttings that replicate natural disturbances represent a management model that foresters should aspire to. However, very little is as yet known about the natural gap characteristics of central Europe's beech forests, the single most important natural forest type in the region. In most cases management has precluded the possibility of the creation of natural gaps. Indeed, the dynamics generally of European beech forests still throws up many unanswered questions. It is not so long ago that Remmert (1985) postulated the mosaic cycle concept and its relevance to central European beech forests. The fact that this comparatively new theory is now widely accepted as being flawed (Zukrigl 1991, Ellenberg 1996, Böhmer 1997, Schmidt 1998) highlights the lack of knowledge in relation to seemingly fundamental questions concerning the natural dynamics of European beech forests.

The hypotheses underlying this gaps study were that (i) the gaps created in the canopy of an unmanaged, natural European beech forest are predominantly very small and (ii) that the total gap area is very low.

The objectives of the gaps study were to determine (i) the proportion of the canopy occupied by gaps, (ii) the sizes of the gaps present, (iii) the gap distribution, (iv) the rates of gap creation, (v) the gap shape characteristics and finally (vi) to identify any relationship between gap creation and stand structure.

Materials and Methods

The study was carried out in the Weberstedter Holz, a 300 ha large mixed beech forest in the Hainich National Park in the centre of Germany. The forest is located within a larger forest complex covering almost 13 000 ha. The Weberstedter Holz has effectively remained completely unmanaged since the middle of the last century and has attained a largely natural character similar to the virgin beech forests studied in Eastern Europe by Tabaku (2000), Commarmot et al. (2005) and Drößler (2006) in the intervening period (Butler-Manning 2007).

A raster grid was marked out across an area of almost 30 ha within the Weberstedter Holz and a complete stand inventory made in 1999, with almost 15 000 trees mapped and measured. The gaps in the canopy were recorded across the entire site employing a surveying approach. The recordings took place in 2001, sixteen months later in 2002 and again in 2005, 32 months after the previous recording. Three contrasting gap definitions referred to in the literature (e.g., Brokaw 1982; Runkle 1992) were employed in the survey for purposes of comparison (refer to fig. 1).

Results and Discussion

As can be seen from fig. 2, the results varied considerably with the gap definition used, highlighting the need, if not for a standardisation of the term gap, then for a clear statement of the definition used in any given gap study. The results presented in the following refer to the 'canopy' gaps, as illustrated in figure 1.

(i) Proportion of the canopy occupied by gaps: The overall gap area across the site was low. In 2001 the total gap area was only 2 % of the site, increasing to 4 % in 2005.
(ii) Gap sizes: The mean gap size recorded in the Weberstedter Holz was just over 120 m² in 2005. The mean value varied slightly from year to year, but never exceeded 140 m². The mean size of newly created gaps was 107 m², and the single largest newly created gap was 540 m². The maximum gap size was a little under 800 m², but this single gap had closed to 600 m² within 32 months. The greatest part of the gaps present in the Weberstedter Holz were in the 50-100 m² size class. The gap size distribution followed a negative exponential pattern. Only a very small proportion of the gaps exceeded 200 m². The number of gaps in the larger size classes increased slightly over the 3 recording periods.
(iii) Gap distribution: The average number of gaps per hectare was 2 in each period. These were relatively evenly distributed throughout the stand (see fig. 2). The average distance between gaps was 33 m (CV 46 %). By 2005 there were gaps present throughout most of the site.
(iv) Rates of gap creation: The gap area in the Weberstedter Holz appeared to be increasing, but the increase was not constant. The rise in the gap area in the 16 months between the first and second recording periods (+94 %) was 5 times that observed in the 32 months between the second and third recording periods (+9 %). This was the result not only of the creation of new gaps, but also the expansion of existing gaps. The increase in the gap area was offset to a certain degree by the reduction in size and even closure of other gaps. The mean rate of canopy turnover was 0.5% per annum.
(v) Gap shapes: There was no predominant gap orientation evident in the Weberstedter Holz. The gaps took on a multitude of shapes. The majority were elliptical in shape, but this was not overwhelmingly the case. Many gaps were roughly square, rectangular and circular. The chablis was rare.
(vi) Stand structure and gap creation: A connection between the parameters of the stand and gap creation was observed. Gaps were observed to arise in areas where the stocking density was lower (460 trees ha^{-1}) and the mean tree basal area (0.09 m² tree^{-1}) and the mean tree volume higher (1.5 m³ tree^{-1}).

The surveying approach was deemed to possess a number of advantages over traditional gap study methods, including greater accuracy of the data, the provision of georeferenced data and greater possibilities for data analysis. The variation in the data obtained in each of the recording periods highlighted the importance of long term study, as great changes can occur within short periods, whereas little change may occur over longer periods. What seems almost certain, however, is that the Weberstedter Holz will not undergo the same large scale break up observed in the nearby Heilige Hallen (Knapp and Jeschke 1991).
The gap sizes observed have a number of implications for forest management mimicking natural gap creation. The preliminary findings from the Weberstedter Holz suggest that gaps arise relatively evenly throughout the forest area. The extent of disturbance to the canopy varies, however. Whereas in parts of the stand the proportion of the canopy that is open may be very low, elsewhere roughly 10 % may be open. The study of the stand parameters shortly prior to gap creation also suggested that generally natural gap creation occurs after stand productivity levels have started to decline, meaning the site potential is not fully utilised. The greatest implication of the gaps study findings, however, relates to the species composition of forests managed on the basis of a silvicultural system replicating natural gaps. Given the prevalence of small gaps, it would seem likely that light demanding species will not be able to establish successfully. Even the largest gaps measured in the Weberstedter Holz may be unsuitable for the regeneration of any species other than beech, and the small and medium sized gaps are such that the quality even of beech is likely to be poor.

Figure 1: Graphic depiction of the three gap definitions used in the Weberstedter Holz gaps study.

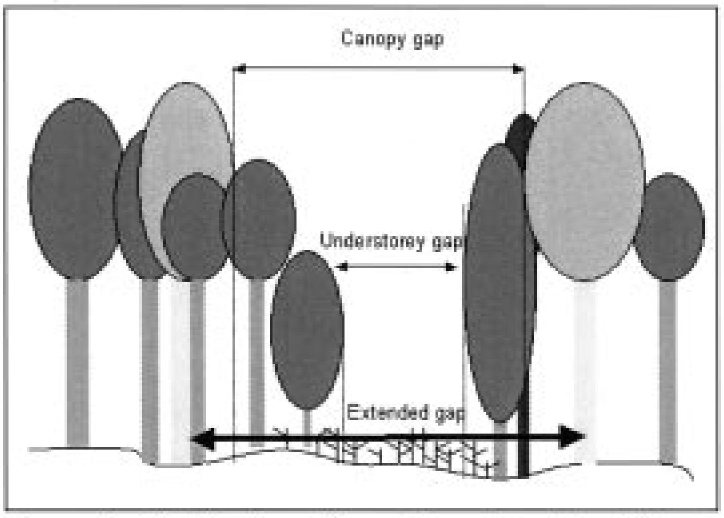
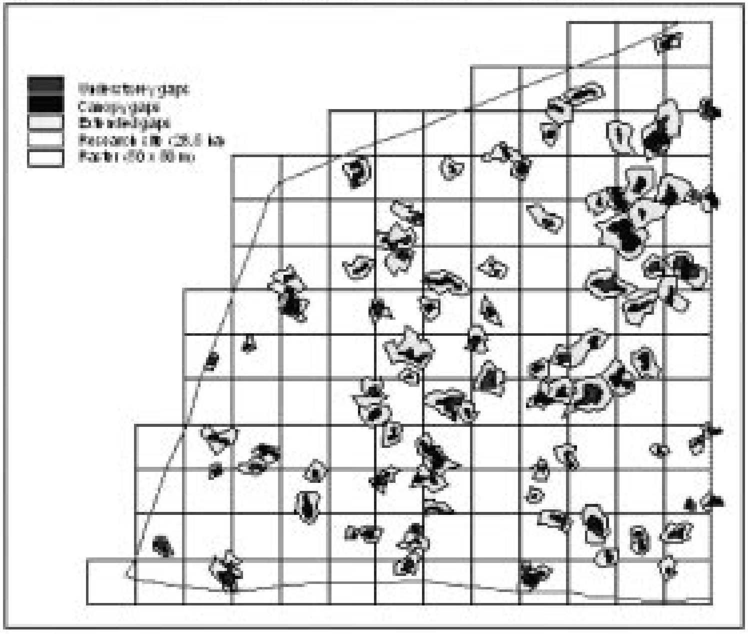


Figure 2: Distribution of gaps throughout the Weberstedter Holz in 2005, depicted for each of the three gap definitions employed in the study.



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PATTERNS OF BEECH NATURAL REGENERATION ALONG AN ALTITUDINAL GRADIENT

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Introduction

Gap formation by death of individual or small groups of canopy trees appears to be the dominant disturbance type in the beech (*Fagus sylvatica* L.) forest ecosystems of Central and Eastern Europe, causing a small-scale differentiation of age and diameter (Korpel 1995, von Oheimb et al. 2005, Nagel 2006). The intensity of disturbances, their specific association and the vegetation conditions are changing with altitude generating specific mortality, growth and regeneration patterns.

Natural regeneration is a key process in the development of beech forest ecosystems. It is shaped by a multitude of factors, out of which light has a known effect on the process. Prior results are somewhat contradictory: some authors found regeneration to be stronger in gaps (Emborg 2000, Szwagrzyk 2001) while others found greater seedlings densities under closed canopy (Nagel 2006). As a shade tolerant species, the beech seedlings can germinate under closed canopy, but they need a gap in order to advance to the canopy (Korpel 1995, Peters 1997). Seed availability also plays a major role in the successful regeneration of beech (Piovesan 2000). These and many other factors (mainly environmental) change with the altitude, changes that lead to different regeneration patterns along the altitudinal gradient (Cuevas 2003).

This study addresses the question whether these differences in the structure and dynamic of the forest (i.e. regeneration stage) are the result of the altitudinal variation of disturbance regime and growth conditions. To what extent do the regeneration patterns of the beech forest differ between these altitudinal levels?

At higher altitudes the proportion of regeneration that takes place in gap conditions is expected to be predominant over the proportion of advance regeneration in closed canopy conditions, while at lower altitudes the situations would be reversed. Regeneration density and seed availability is expected to decrease with the increase in altitude.

Materials and Methods

The research was carried out in the Izvoarele Nerei forest reserve situated in the South-Eastern Carpathians, Romania. The 5.253 ha area is almost completely covered by an undisturbed natural forest, stretching over the full altitudinal range of beech in the Carpathians, from 700 m to 1400 m. Plots were established in different light environments: closed canopy, small gaps (created by the death of 1 or 2 trees) and large gaps (created by the death of at least 3 trees) at three altitudinal levels (900, 1150 and 1350m). Within each plot circular subplots (2 m radius) were established randomly.

In every subplot the number of saplings was counted and their height measured (cm). The number of seedlings was counted in two randomly chosen squares (50 by 50 cm).

The light environment was quantified using fish eye photos taken at the centre of each subplot as well as measuring the size of the gap. Age structure was determined for the 900 m and 1350 m altitudinal levels using a maximum number of 10 saplings from every second plot.

Seed production was quantified by counting the beech nut shells and seedlings in each subplot in a 50 x 50 cm square.

For the analyses the 0.05 level of significance was used. The values corresponding to one replicate (a plot) were obtained by averaging the values of the respective subplots.

Results and Discussion

Total regeneration density is increasing from closed canopy to large gap, but does not differ significantly between the altitudinal levels. Only the plots at 900 m and those from 1150 m differ significantly ($p=0.017$). If the plot types are analyzed separately than the differences are no longer significant. Seedling density differs significantly between altitudes in the case of small and large gaps ($p=0.043$), but not for canopy plots ($p=0.078$). The sapling density does not differ significantly between the altitudinal levels.

The amount of beech nut shells do not differ significantly between altitudes ($p=0.532$) and no significant correlation with the seedling density was observed ($p=0.754$).

Even though the size of the gaps differs significantly between the plot types, it has no significant effect on total regeneration density. Only the correlation between gap size and sapling density is significant ($p<0.001$), but the power of this relation is very low.

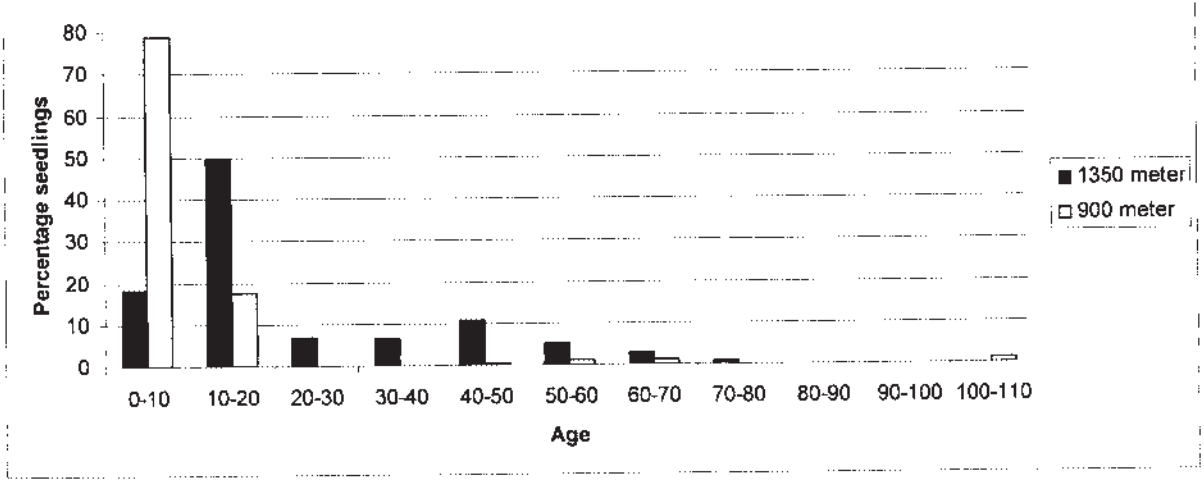
The age structure of saplings for the two altitudes (900 m and 1350 m) is different (Figure 1). In the low part the majority (99%) of saplings is younger than 20 years, while in the upper part the proportion of young saplings is lower (<70%). At the highest altitude the fraction of older saplings is greater.

The results show a different picture from what was expected beforehand. Total regeneration density and seed production does not differ significantly between the altitudinal levels. It was assumed that the regeneration density will decrease in close connection with seed production due to less favorable growing conditions. Instead at 1150m the highest regeneration density and the largest amount of nut shells were found. No correlation between gap size and seedling density was found while the correlation between gap size and sapling density is low.

Contrary to the original assumptions, under canopy, the saplings bank is getting older with the increase in altitude. Probably the competition for light and the drought related stress are lower at these altitudes. Data about the mortality rates of the saplings is needed to clarify this.

At this stage of the research, it appears that the regeneration patterns are less influenced by the altitude and the light regime that it was expected. Further data collection and analyses are needed in order to explain their role in the regeneration process.

Figure 1: Age structure of saplings



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MAPPING THE SPATIAL DISTRIBUTION OF REGENERATION GAPS USING ASTER IMAGERY IN BEECH FORESTS IN NORTH OF IRAN

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Introduction

The structure of forests is a main factor in management of forest ecosystems. Structural characteristics have been used to investigate the regeneration patterns and the gap dynamics (Spies and Franklin, 1989; Runkle, 1991; Buongiorno, *et al.* 1994). Gaps formation and their spatial pattern influence the structural complexity of natural forests and are essential parts in the management regime (Chen and Franklin, 1995). Therefore, monitoring on changing process of forest ecosystems is very important. Because it makes possible to know about current situation and plan for the future with sustainability guarantee as well. Regeneration gaps which were created based on silvicultural interventions can be considered as the attribute of commencement of the development stages.

This information can refine our understanding of natural processes. Also, knowledge about forest dynamics and spatial pattern of gaps can be applied in forest management. In forest plan, determination of gaps position is possible seriously, due to some rough conditions like topography, costly in terms of time and money spent. So, forest researcher often tries to access methods that can provide updated information about forests dynamic characteristics like regeneration gaps and monitoring of their changing process. Therefore, in this study we tried to determine the distribution pattern of regeneration gaps in deciduous forests using of satellite data.

Materials and Methods

The study performed in Kheiroudkenar forest (36° 40′ N, 51° 43′ E), in the North of Iran. It classified as mountain forests with an altitudinal range from about 350-1350m.a.s.l. It has an annual mean temperature and precipitation of 15.8 ° C and 1150 mm respectively. The highest mean monthly temperatures of 29° C occur in June and July and the lowest of 7.1° C in February. Dominant forest types in this area consist of pure and mixed beech (*Fagus orientalis* Lipsky) forests. The soils belong to *Inseptisols* and *Alfisols*.

To map the regeneration gaps Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) sensor of Terra satellite (due to spectral variety; visible, near, middle infrared bands in different spectral ranges, high spatial resolution and low cost) were used. At first digital elevation model of earth was created using counter line of digital maps. Geometrical and radiometric corrections were accomplished with using above mentioned map, selecting 32 ground control points and RMS less than 0.7 pixels up to ortho-rectification. Then spectral transformation such as Band Ratio and NDVI were applied to produce different indices. Basic spectrum accompanied by produced indices were used to study the gaps spectral reflection and finally to classify them. So the position of 1024 gaps was surveyed by means of GPS. All gaps with small area (<100 m^2) were omitted. 120 gaps were used as training area and the rest (420 gaps) as a ground truth. This information which prepared trough field survey was used as data layer using ARCGIS software (Fig.1).

In order to identify suitable gaps, six bands with minimum correlation including 3, 5 main bands, spectral ratio, principal components analysis (PCA_1) and fused band 4 were recognized. Image classification was performed using supervised classification procedures and maximum likelihood classifier (Lille sand et al. 2004). Accuracy of resulted map of classification was compared with the ground truth map. Besides, spectral signature of gaps was studied in different bands and in comparison with closed stands which are around the gaps. The location of regeneration gaps and Aster image of study area was shown in Figure 2.

Figure1. Map of the regeneration gaps in study area.

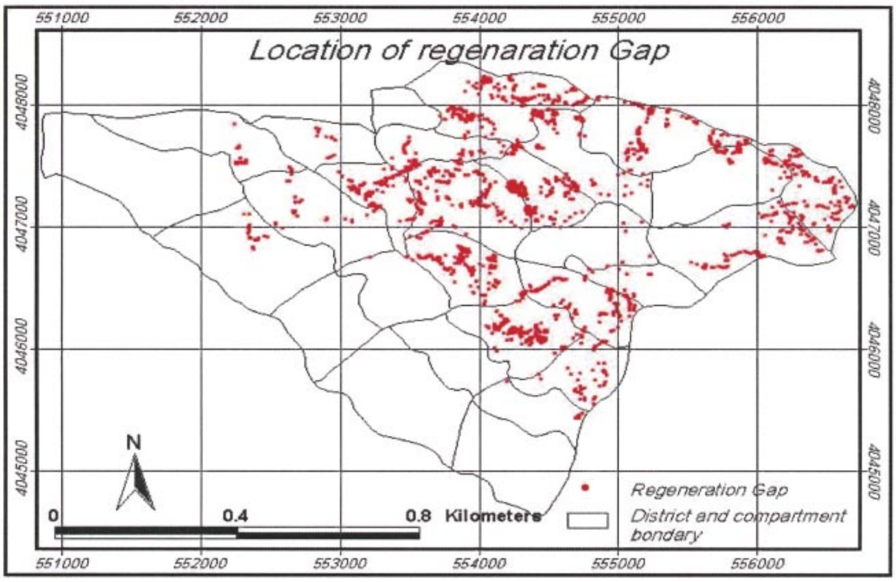
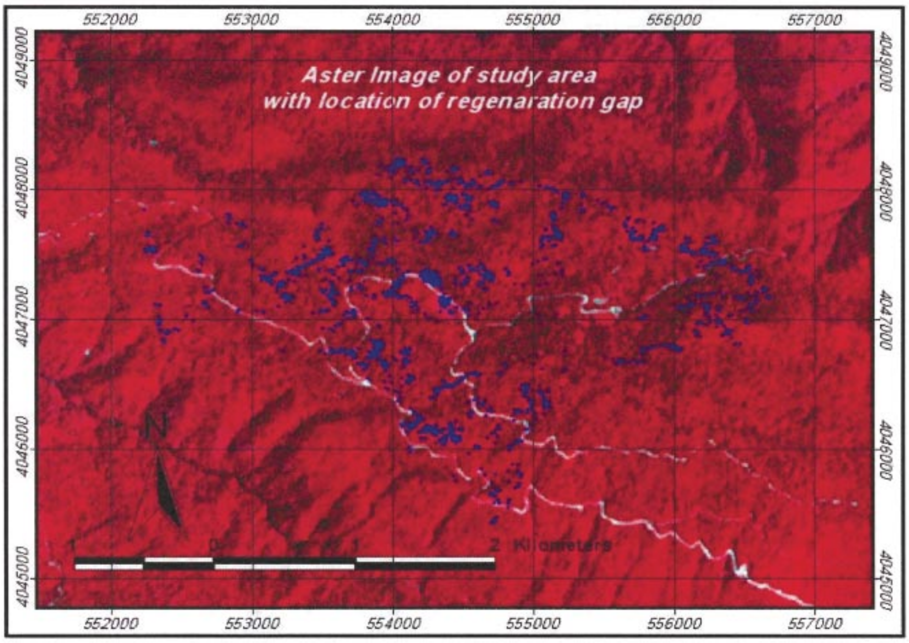


Figure2. Aster image with regeneration gaps location in study area.



Results and Discussion

Aster sensor data has suitable spatial and spectral ability and since Terra satellite was lounged, it has been utilized in different fields of geomatics such as land covers (Jansen, 2000). With considering the spectral variety and high spatial resolution of Aster data, it can be used to identify and determine the distribution pattern of gaps which were created recently and bigger than small size. The accuracy of gaps identification is more than 90 percent. It certainly can not be possible to study of gaps with small size and total accuracy will be low.

In order to identify of gaps, geometrical and radiometric corrections is necessary up to ortho-rectification. Also, using NDVI index, spectral ratio (NIR/R) and PCA_1 are very useful and can increase accuracy in comparison with main bands. The highest Difference between average of spectral reflection in regeneration gaps and around area which covered by trees (closed stands) was occurred in band 3 (near infra red band).

Study of spectral reflection of pixels in different bands in the scope of gaps with larger size in comparison with closed stands around the gaps showed the existence of difference in DN value which has been the highest value in NIR band and NDVI index. It seems that the difference in younger (low-aged) gaps that enjoy low phytomass, is more. Taking this subject in to consideration, the identification of gaps, during their early formation stages is possible at a higher level of accuracy. The accuracy decline in gaps identification is due to spatial resolution of data. This spatial resolution causes the identification of gaps with small size to be practically impossible. The correctly identified gaps area is dependent upon spatial resolution of data (Franklin and Raton, 2001; Ustin, 2004)

Regarding the spectral similarity of main bands in these area (gaps and closed stands around them) using fusion and spectral transformations of the virtual bands beside the main bands is essential. This subject increases the accuracy of identification and has been proved in different researches.

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THIRTY YEARS OF CHANGE IN BEECH (*FAGUS CRENATA*) SEEDLING BANK AFTER SIMULTANEOUS DEATH OF DWARF BAMBOO

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Dwarf bamboo strongly inhibits beech regeneration, which occasionally dominates the forest floor of Japanese beech forests. To know how the effect of life history of this monocarpic plants on beech seedling bank, I have monitored emergence and survival of beech seedlings since 1977, just after the simultaneous flowering and death of dwarf bamboo (*Sasa kurilensis*) in Togakushi, central Japan. The size and population of dwarf bamboo almost recovered in 20-30 years, depending on the light condition. Beech seedling banks were established densely during the first 15-20 years, though they diminished later, according to the recovery of dwarf bamboo. These observations suggest that successful beech regeneration is very limited, only when some canopy gaps were created during the first 15-20 years after dwarf bamboo dieback. It may cause episodic regeneration of Japanese beech forests.

GROWTH CHARACTERISTICS EXPLAIN PREDOMINANCE OF *FAGUS CRENATA* IN JAPANESE COOL-TEMPERATE FORESTS

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Introduction

Japanese beech (*Fagus crenata*) dominates cool-temperate forests at their climax stage in the Japanese archipelago. It often forms almost pure stands, and this phenomenon has interested many researchers. A majority of previous studies have suggested that the high shade tolerance of beech seedlings (e.g., Maruyama 1991) and the formation of a persistent seedling bank on the forest floor (Nakashizuka 1988) contribute to the predominance of Japanese beech, while others have considered the mechanical strength of the species against snow pressure as the cause (Maeda 1988, Homma 1997).

In this paper, I discuss the predominance of Japanese beech by focusing on its growth characteristics, a feature that has received little attention. The queries set are whether Japanese beech exhibits characteristic growth patterns in comparison with other tree species, and whether these growth characteristics explain its predominance.

Materials and Methods

I analyzed the growth patterns of more than 1500 thick trees from 38 species, including about 70 individuals of Japanese beech, grown in and harvested from old-growth forests in northern Japan. Trees were sampled at Yahaba timber auction market in Iwate Prefecture, where various species of hardwoods and conifers are collected for monthly auction throughout the northern Tohoku region and southern Hokkaido Island. Every month, I randomly sampled three to five butt logs based on their species from 25% of butt logs with large diameters from the auction. Butt logs having heavy burls at the base were excluded.

Annual ring patterns at the bottom end of sampled butt logs were measured. I chose one radius that was average in length and ring pattern for measuring the distance from the core to each annual ring at an interval of every 10 years. The basal area of the tree was assumed to be equal to a circle having the same radius. The increment of each individual was compared with the approximated logistic curve. An individual was identified as being stagnant when the observed increment of basal area was less than 70% of the approximated value for 20 continuous years.

In the present paper, the total number of annual rings at the bottom end of the butt logs was regarded as reachable age (RA), indicating the potential lifespan of canopy trees in old-growth stands.

Major tree species were classified by their growth characteristics. The parameters employed were the ratio of individuals having stagnant growth periods at the juvenile stage averaged basal area increments at around 10, 20, and 30 cm in radius, trunk diameter, and RA, respectively.

Results and Discussion

The tree species studied showed wide interspecific variation in their growth characteristics, such as the growth ratio of juvenile stagnation, growth speed rate at each size class, trunk diameter, and RA. Cluster analysis produced eight species groups based on these parameters. The representative species of each group are as follows:

group 1: *Betula platyphylla, Alnus hirsuta, Fraxinus lanuginose , Swida controversa*
group 2: *Maackia amurensis, Carpinus laxiflora, Phellodendron amurense*
group 3: *Juglans sieboldiana, Castanea crenata*、 *Pinus densiflora*
group 4: *Betula grossa, Fraxinus mandshurica, Pinus parviflora*
group 5: *Magnolia hypoleuca, Betula maximowicziana, Tilia japonica*
group 6: *Betula schmidtii, Ostrya japonica, Taxus cuspidata*
group 7: *Ulmus davidiana, Aesculus turbinata Kalopanax pictus, Quercus mongolica*
group 8: *Acer mono, Thujopsis dolabrata, F. crenata, Cryptomeria japonica.*

Each group seemed to have a specific tendency towards the growth characteristics and status in climax forest communities in northern Japan (c.f., Miyawaki 1987). Groups 1, 2, and 3 comprised disturbance-dependent species that seldom experienced a stagnant growth period at the juvenile stage. However, they are diverse in their growth characteristics: some are considered to be relatively long-lived pioneers and others are slow growing gap species. Group 4 comprised intermediate species both in terms of growth stagnation at the juvenile stage and the growth speed of adult trees. Life spans of these species are likely to be longer than that of Japanese beech, the dominant of cool-temperate forests at climax stage. Species in group 4 seem to favor riparian areas or ridges more than slopes. Group 5 may demand more light than group 4 and behave as pioneer species through the regeneration process. Their life spans are longer than that of Japanese beech. They generally show high constancy in old-growth stands, and often become a major component of secondary stands once Japanese beech dominated climax forests are disturbed. Group 6 consists of slow-growing shade-tolerant species. Generally, they grow on specific sites, such as limestone areas and rocky avalanches, and are long-lived. Species in group 7 show high shade tolerance of juveniles and intermediate or low growth speed of adult trees. They live so long that they often become thick trees. Some of them show high constancy. Moreover, they will be sub-dominants of Japanese beech dominating climax forests. Species in group 8 are highly shade tolerant, and grow fast when they become adult trees. They often are the dominant species.

What distinguishes Japanese beech from other species in terms of growth characteristics is that it performs as a shade tolerant at the juvenile stage but grows as a pioneer at the adult stage. Because of these characteristics, Japanese beech is able to form a seedling bank on the forest floor, and is highly competitive with other tree species when it reaches the adult stage. Therefore, I consider that these growth characteristics will also explain the overwhelming predominance of Japanese beech in cool-temperate forests.

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PRODUCTION OF BEECH NUTS, CLIMATE, AND DIAMETER GROWTH: UNDERSTANDING MASTING BEHAVIOR OF EUROPEAN BEECH IN SOUTHERN SWEDEN

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Introduction

Understanding pattern of acorn production in common beech (*Fagus silvatica* L.) may provide guidance in planning of afforestation activities, which take advantage of natural masting cycles. Across natural distribution range of beech, flowering and nut production were previously shown to be strongly controlled by climatic factors (Piovesan, Adams, 2001). Also, a negative trade-off may exist between production of acorns and diameter growth. Large masting may reduce diameter growth by up to 40% in that year and also lead to decreased increment in the two following years (Holmsgaard, 1955). In this study, we quantify relationship between climatic variation, tree-ring increment, and masting behavior of European beech (*Fagus sylvatica*) in five southern Swedish sites over the periods 1950-1964 and 1974-2006.

Materials and Methods

During the summer of 2007 six plots were established in counties of Skania, Halland and Blekinge. We sampled on a 5 to 10 m wide transect stretching across the plot. The length of transects varied between 20 and 40 m to allow sampling of 20 trees. Chosen trees were cored twice in perpendicular directions at 0.3-0.6 m height from the ground with an increment corer. Standard dendrochronological techniques were used to process and to crossdate cores. Annual rings of prepared samples were measured with accuracy of 0.001 mm using LinTab measuring stage and TSAP 3.0 software (Rinn, 1997). Verification of dating accuracy was done in COFECHA program (Grissino-Mayer et al., 1997). We used superposed epoch analysis, response function analysis, and linear regression techniques to quantify relationships among climate, growth, and masting. Additionally, a simple bioclimatic model was developed to study relation of masting and growth to annual drought indexes.

Preliminary results

There was a significant trade-off between seed production and tree ring increment, big masting years ($> 5*10^6$ nuts * ha^{-1}) typically associated with strong negative growth anomalies. Although a big masting year tended to most closely coincide with increased July temperature one or two years prior to that masting year, other climatic extremes may also function as triggers for increased production of nuts. High degree of across-site synchronicity in masting records suggests that beech masting is a regional phenomenon. Bioclimatic modeling of biomass production appears useful in explaining temporal pattern of diameter growth and acorn production in beech over annual and decadal scales.

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MASTING IN BEECH FOREST (*FAGUS CRENATA* BLUME) BASED ON INDIVIDUAL FLOWERING BEHAVIOR ANALYSIS

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F. crenata shows high year-to-year variation in seed production. However, sometime *F. crenata* has the years of middle flowering. This study focus on whether such middle flowering is derived from stand or individual level. Inflorescence scars on each branch gave us the information on historical record of flowering behaviors of individuals. We gather branches from 75 trees at Yamagata prefecture in 2005 and determined individual flowering records by investigating inflorescence scars on branches. Positive correlations between seed traps data and mean annual inflorescence scars ratio indicating that scars represent flowering traits of individuals. In the study sites 2000 and 2005 were mast year and 2002 was middle mast year. Since, a few individuals flowered in 2002, middle flowering years are realized by a few individuals with frequent times flowering. Furthermore frequent flowering individual tend to be larger size among the population.

EFFECTS OF LIGHT AND SOIL MOISTURE ON A MIXED SPECIES NATURAL REGENERATION OF BEECH, ASH, AND SYCAMORE MAPLE

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Introduction

Traditional and common silvicultural methods from several North-western European countries like Denmark, Sweden and Germany to naturally regenerate Beech (*Fagus sylvatica L.*) include soil preparation shortly before and/or after a good mast crop. Natural regeneration of ash (*Fraxinus excelsior L.*), and sycamore maple (*Acer pseudoplatanus L.*) has also been widely used since these two species often regenerate vigorously due to frequent mast crops and presumably less dependency on forest floor disturbance by e.g. soil preparation. Contrary to the traditional beech regeneration the ash and sycamore maple regenerations are usually based on several mast crops.

Often the three species regenerate naturally to form mixed stands (Petritan et al. 2007). In Denmark there are many examples of sycamore maple regeneration in old beech stands so vigorous that it has been regarded an invasive species by many silviculturists for decades. This attitude has largely changed during the past two decade after many failed attempts to remove sycamore regeneration to favor beech regeneration instead. Additionally, a nature-based (or close-to-nature) approach has gained popularity – starting in Germany decades ago (Thomasius 1996) and now adopted by the Danish national forest service (Hahn et al. 2005), and slightly attracting more attention in Sweden, too. In nature-based silviculture the natural stand dynamics and stand processes are supported by the silviculturist to a greater extent than in the more traditional silviculture. Likewise, mixed species and even multilayered structures are accepted or favored rather than uniform single species stands.

An important challenge for silvicultural practice regardless of the silvicultural approach is to adequately control stand structures and species composition with respect to site conditions and management goals. For example – some beech forest habitats located in EU member states are designated Natura 2000 Sites of Community Importance according to a Habitats Directive launched by the EU. Such forests are supposed to remain beech dominated, to be managed according to the nature-based approach, and not to develop into sycamore maple stands due to vigorous natural regeneration. Consequently, there is clearly a need to gain more knowledge about how to control the species composition in mixed species regenerations of beech, ash, and sycamore maple in the context of nature based forest management (Petritan et al. 2007).

Particularly German forestry has compiled experience with mixtures of beech, ash and sycamore maple (Wagner 1999). This experiences is, however, rooted in silvicultural practices that involve relatively long rotations – e.g. more than 150 years – which also involve long regeneration phases (e.g. 30-40 years). Beech is usually regarded a very shade-tolerant species, whereas ash and sycamore maple often are described as "gap-specialists". They are not regarded as shade-tolerant as beech but grows faster in the regeneration phase once the canopy of the old stand is opened (Schmidt 1996, Emborg 1998). Long rotations and regeneration phases allows for utilizing the shade tolerance of beech to support this species in the competition with ash and sycamore maple by opening the canopy very slowly in the regeneration phase. However, there is a need for knowledge about how to control the species composition and to regenerate beech mixed with ash and sycamore maple in silvicultural regimes with both shorter rotations and regeneration phases than described from Germany.

Previous studies of light, soil moisture, nutrient supply, and competition effects on beech regeneration in Denmark had been carried out to support optimisation of silvicultural methods (Madsen 1994, Madsen 1995) when we established the present study. The earlier studies showed strong interactions mainly between light and soil moisture and we intended by the present study and others (Madsen & Larsen 1997; Hahn et al. 2007; Madsen and Hahn 2008, Ammer et al. 2008) to obtain more knowledge about how light and soil moisture influence the survival and growth as well as the competition between beech, ash, and sycamore maple. These experiments were conducted at several sites in Denmark. In this paper we describe the results from a shelterwood-cutting experiment in the forest Hestehave Skov.

Materials and Methods

We installed an experiment in spring 1995 including three experimental stands (each 0.28 to 0.6 ha) of beech dominated broadleaved forest in Denmark. For at detailed description of the experimental design please consult Olesen and Madsen (2008). In the present paper we focus on the survival and growth of natural regeneration of beech, ash and sycamore maple established inside permanently fenced subplots (70-100 m long, 20 m wide) in a mineral soil seedbed established by soil preparation shortly before the beech seedfall in the autumn of 1995. A shelterwood gradient was established by systematically cutting 0%, 25% and 50% of the overstory basal area of each experimental stand during the winter of 1995-96.

The regeneration density and growth was inventoried in 23-24 small circular (48 cm diameter) plots in the mineral soil seedbed of each experimental stand. These observation plots were established at 3-4 m intervals. In all the small plots we measured the leaf area index (LAI) of the shelterwood canopy and the volumetric soil moisture content.

Results and Discussion

As expected the regeneration strongly and significantly responded on increased light by increased regeneration density and height growth with the exception of the ash regeneration density that did not respond to light. Surprisingly, the soil moisture effects were absent. Under the most open parts of the shelterwood gradients ash and sycamore maple reached heights typically two to three times taller than the beech. It was not possible to identify a range of canopy openness or relative light intensity where beech showed a superior growth relative to ash and sycamore maple. The two "gap-specialists" showed superior height growth compared with beech within the timeframe (8 years) of this study, which is in accordance with several other similar studies initiated in Denmark in the mid-1990's. A more thorough discussion of these results in the light of the scientific literature and a more detailed discussion will be included in the presentation. It is, however, concluded that for timeframes shorter than approximately 10 years it has not been possible to identify optimal levels of e.g. light and/or soil moisture where natural beech regeneration show superior establishment relative to natural regeneration of ash and sycamore maple under Danish conditions. Whether, such optimal light levels can be identified under other site conditions, over longer study and observation periods, or e.g. under various levels of deer browse has yet to be revealed.

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ADVANCE *FAGUS SYLVATICA* AND *ACER PSEUDOPLATANUS* SEEDLINGS DOMINATE TREE REGENERATION IN A MIXED BROADLEAVED FORMER COPPICE-WITH-STANDARDS FOREST

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Introduction

In the last decades, important paradigm shifts in forest management practice led to the development of silvicultural scenarios that aim at preserving or promoting species diversity. In these scenarios, the main difficulty usually lies in the maintenance of the initially high species diversity throughout the regeneration phase. Gap dynamics theory predicts that gap formation enables species coexistence by producing the necessary abiotic and biotic heterogeneity. The importance of the gradients in environmental factors induced by gaps varies with their size, their shape and their distribution within the stand. By opening gaps with different structures, foresters may create a wide range of environmental conditions that will favor species coexistence and maintain high species diversity.

The limestone plateaux of northeastern France are dominated by broadleaved stands that were historically managed according to the coppice-with-standards (CWS) system and began to be converted into high forests some decades ago. These stands are distinguished by a high broadleaved tree species diversity, with many economically valuable species. Most of these stands, which are presently reaching maturity, will be regenerated in the next decades, and the main objective is to ensure full site stocking with valuable broadleaves while maintaining the existing species diversity.

The general objective of the present study is to assess whether the creation of gaps of different sizes will produce the necessary diversity of environmental conditions to successfully regenerate the various species present in the mature stand of a typical former CWS stand. Two study designs were set up:

- in a stand where gaps of a wide range of sizes had been created by a storm in 1990, an analysis of the regeneration under various canopy closure conditions was made in 2003 (13 years after the storm), in order to: (1) assess whether the existing gradient of canopy closure conditions allows the different species to regenerate; and (2) determine which species dominate along the gradient of canopy closure conditions.
- in the same stand, gaps were created in 2004 above plots containing mixed-species advance regeneration, and seedling survival and growth was monitored during three years, in order to: (3) analyse the immediate response of advance regeneration to canopy opening, and (4) assess whether the immediate response filters against some species.

Study 1: Materials and Methods

The study site was located in the Graoully forest (49°04'N, 06°01'E) in the Lorraine region (northeastern France), on a limestone plateau, 300 masl. The stand was a former CWS broadleaved stand that was managed for timber and firewood production. The last coppice cuts were performed in the 1960's. The stand was subsequently converted into a mixed-species even-aged forest, and coppice cuts were no longer performed.

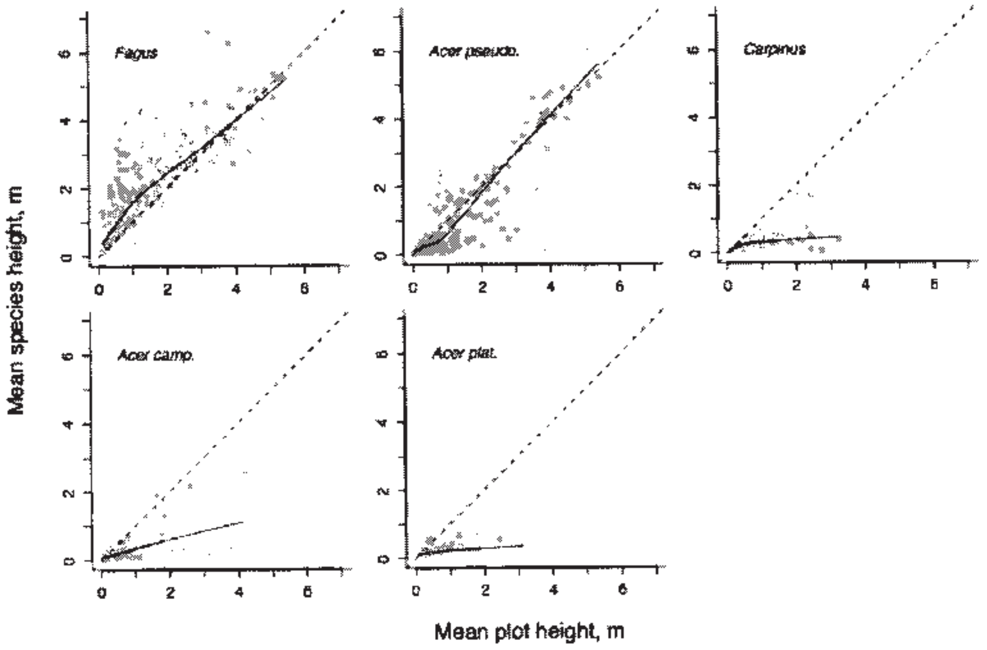
Two plots containing a wide range of canopy conditions (closed canopy, small and large gaps) on a small surface area were selected in 2003. The plots contained small gaps (less than 200 m^2) in a matrix of undisturbed closed stand, and the northern edge of a large gap (0.5 ha). The total basal area in the study plots (including the gaps) was 25.6 m^2 ha^{-1}. Dominant trees (former standards) were mainly beech (*Fagus sylvatica L.*), oak (*Quercus petraea (Mattus.) Liebl.* and *Quercus robur L.*), sycamore (*Acer pseudoplatanus L.*), Norway maple (*Acer platanoides L.*) and some scattered wild service trees (*Sorbus torminalis (L.) Crantz.*). Coppice was mainly composed of hornbeams (*Carpinus betulus L.*) and some field maples (*Acer campestre L.*), limes (*Tilia cordata Mill.* and *Tilia platyphyllos Scop.*) and white beams (*Sorbus aria (L.) Crantz.*).

A regeneration inventory was performed on 339 2 x 2 m quadrat plots, established along transects across several gaps or according to a grid in the whole stand. Understory light conditions prevailing above each quadrat were estimated using a light transmission model supplied with data measured in 2003 in the stand. The model provided an estimation of the Percentage of Above Canopy Light (PACL, defined as the proportion of photosynthetically active radiation reaching the top of the canopy that is transmitted by the canopy), calculated 3 m above the ground for each of the various sampling points.

Study 1: Results

In 1990, just before the storm, the stand had a large basal area with a closed canopy. It was dominated by *Fagus*, *Quercus* and *Carpinus*, and contained a large number of other broadleaved species. Thirteen years after the storm, the regeneration was abundant in the gaps

Figure 1: Mean species height (mean height of all seedlings of the species in the quadrat) as a function of mean plot height (mean height of all seedlings in the quadrat), for the five main species encountered in the inventory quadrats (*Fagus*, *Acer pseudoplatanus*, *Carpinus*, *Acer campestre* and *Acer platanoïdes*).



and under the closed canopy and was largely dominated by advance *Fagus* and *Acer pseudoplatanus* seedlings (Figure 1). No clear relationships were found between regeneration characteristics (species composition, seedling density, seedling basal area, maximum seedling height) and PACL availability. Most light demanding species were absent from the regeneration, even in the gaps.

Study 2: Materials and Methods

In June 2004, two plots containing a mixed advance regeneration of *Fagus*, *Acer pseudoplatanus*, *Acer campestre* and *Acer platanoides* were selected in the same site. Each plot was split into two subplots and a felling was carried out in January 2005 above one subplot of each plot resulting in increased irradiance (gap treatment: G), while the full canopy was maintained in the other subplot (canopy treatment: C). In each of the four subplots (in gaps or under canopy), a regeneration patch with clumped seedlings was delimited. In each regeneration patch, all seedlings of the four studied species were labeled and mapped. In March 2005, and in December 2005, 2006 and 2007, total height and basal diameter were measured for each seedling in the regeneration patches. Hemispherical photographs were taken on 2x2m grids in the regeneration patches, to estimate PACL. The PACL value above each seedling in the regeneration patches was then calculated by linear interpolation between the PACL measurement points.

Study 2: Results

All four species showed rapid reaction after canopy opening. As it has been previously shown on *Fagus* and on other species, the response of *Fagus* and the three *Acer* species to sudden canopy opening involved an immediate increase of active diameter growth and a slightly delayed increase of height growth. Initial seedling size was a major determinant of seedling growth after gap creation, for each of the four species.

Conclusion

The dominance by advance *Fagus* and *Acer pseudoplatanus* seedlings 13 years after canopy opening was ascribed to a regime of periodic natural or anthropic disturbance of intermediate intensity, where small gaps are regularly created in the canopy. This regime results in a succession of short, open and closed canopy episodes that eventually promote shade-tolerant species. During this regime, the shade-tolerant species are able to build a strong advance regeneration that is ready to outgrow the other species when gaps are created.

The first study shows that regeneration methods based on the creation of gaps of different sizes and shapes do not allow to maintain species diversity, and suggest that additional silvicultural treatments would be needed to obtain a more diverse regeneration. Otherwise the high diversity existing in the mature stand might be lost in a single generation. The second study shows that the period of acclimation to sudden exposure to open canopy conditions was not a limiting stage in the recruitment process. It implies that silvicultural treatments using progressive canopy opening in order to attenuate the shock due to gap creation would not be adequate in this type of stand. On the contrary, all four species respond positively to canopy opening and subsequent competition with other tree species is most probably the process limiting the recruitment of *Acer platanoides* and *Acer campestre* seedlings, suggesting that silvicultural treatments controlling the development of competing advance *Fagus* and *Acer pseudoplatanus* seedlings should be advised.

HOW TO PRESERVE PRECIOUS BROADLEAVED SPECIES IN YOUNG DENSE BEECH STANDS: RESULTS OF A 15 YEAR EXPERIMENT

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Introduction

With 1.3 10^6 ha, beech (*Fagus sylvatica*) is the third most represented species in France (Sardin et al. 2007). Because of its natural acute vitality, one of the major difficulties in its silviculture lies in preserving secondary objective-species mixed in stands (Armand et al. 2001). Actually, although precious broadleaved species such as Wild cherry (*Prunus avium*) should naturally grow scattered in young natural beech stands set on rich soils, beech is often almost the only species in older regular stands, because of a lack of suitable silviculture to these mixed species. Indeed the qualification phase (height between 3 and 12 meters) seems to be the key phase for their preservation.

This is certainly a challenge for biodiversity and resilience to global climate changes, which are particularly worrying for the future of the beech in France and West Europe (Badeau et al. 2004). But also for timber production, the forester tries to obtain, at the lowest cost, vigorous and quality stems able to grow fast as soon as the expansion phase starts (Bock et al. 2005).

The objective of the present study was to determine the best treatment for stems of three precious broadleaved species, isolated in young regular beech stand. Four strategies were tested, going from no treatment to intensive targeted thinnings. Fifteen years later, the results show contrasted performances between species, useful for foresters to improve young mixed beech stand silviculture.

Materials and Methods

The experiment was set up in 1992 in the Auberive national forest near Dijon, north-eastern France. The initial stand was a ten-year-old beech stand (height about 3 meters) issued from natural regeneration, with a silvicultural path every 7 meters, with isolated precious broadleaved species mixed. The soil was a brown-calcic soil, with fragmented limestone at a depth of less than 40 cm.

Each stem is an experimental unit. Three species are considered: Wild cherry, Sycamore (*Acer pseudoplatanus*) and Wild service tree (*Sorbus torminalis*).

Four treatments are tested, with graduate intensity (Table 1). They consist of two thinnings at eight-year intervals, defined by (a) a general treatment applied to a 7-meter-wide and 12-meter- long stand unit, centred on the target stem, and (b) a local treatment centred on that stem.

The experiment contains 25 to 30 replicates for each crossing Species/Treatment, except for Cherry tree for which there's no reference treatment, for lack of samples.

Total height, circumference and first live branch insertion height were measured on February 1993, January 2001 and December 2007, from which mean increases were calculated. Analysis of variances are then used to reveal (i) significant differences between species (all treatments considered except reference) and (ii) differences between treatments for each species.

Table 1 : Treatments tested

	1st operation (about 3 meters height) (winter 1992/1993)		2nd operation (about 6 meters height) (winter 2000/2001)	
Silvicultural modalities	(a) general treatment	(b) targeted treatment	(a) general treatment	(b) targeted treatment
Reference (TEM)	Nothing	Cutting of non beech stems to a radius of 3 meters	Nothing	Nothing
Classical (CLA)	Spacing out stems from 1.20 m (8 000 stems ha^{-1})	Idem TEM	Spacing out stems from 1.70 m (4 000 stems ha^{-1})	Nothing
Targeted thinning 2M (2 M)	Idem CLA	Idem TEM + clear cutting to a radius of 2 meters	Idem CLA	Idem TEM + clear cutting to a radius of 2.5 meters
Targeted thinning 3M (3 M)	Idem CLA	Idem TEM + clear cutting to a radius of 3 meters	Idem CLA	Idem TEM + clear cutting to a radius of 3.5 meters

Results and Discussion

- *apical growth.*

(i) Taking into account all treatments except reference (because of lack of Wild cherry) analysis of variance reveals significant differences on apical growth between species ($p<0.0001$). Between 1992 and 2007, apical growth of the Wild cherry is 5 cm per year better than that of the Sycamore, that is already about 10 cm per year better than that of the Wild service tree.

(ii) Compared with more extensive treatments (TEM and CLA), early targeted thinnings seriously penalise (from 5 to 10 cm per year) apical growth of the Wild cherry and Sycamore during the following 8 years ($p<0.0001$). However, when considering the following 15 years, apical growth differences between treatments are no longer significant.

- *radial growth.*

(i) As could be expected, similar results between species are obtained on radial growth.

(ii) But much more surprising are treatment effects. On Wild cherry, compared with classical treatment, targeted thinnings do not give any benefit. And for Sycamore and Wild service tree, whereas radial growth of the reference is obviously lower, this is only since the second targeted thinning, at about 6 meters height, that 3M and 2M treatments have been beneficial compared to classical treatment (Figure 2).

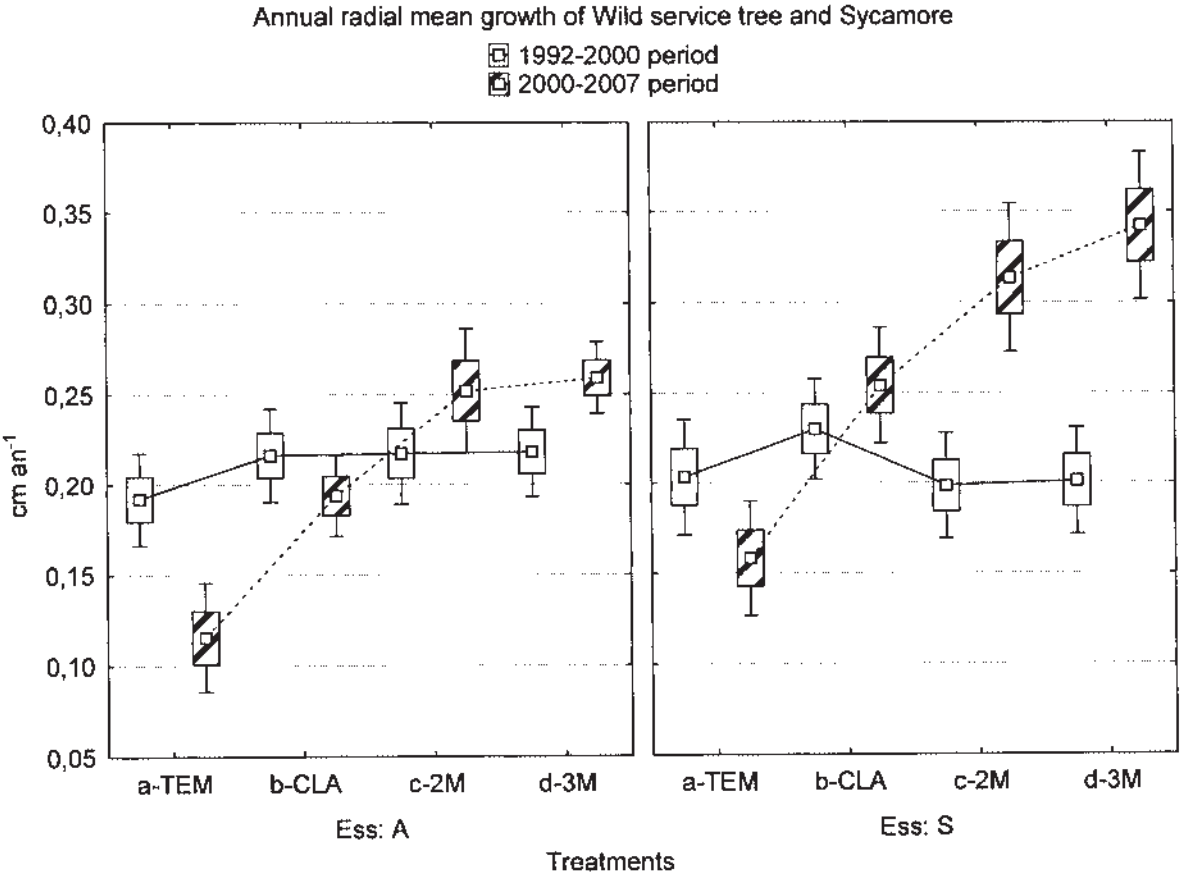
- *natural pruning.*

(i) Natural pruning is obviously the most efficient for Sycamore (40 % of its apical growth). If Wild cherry and Wild service tree seem to prune naturally as fast in absolute terms, considering apical growth performances, Wild cherry tree appears much more efficient (38 % of its apical growth), as well as Sycamore.

(ii) For each species, targeted thinning treatments (2M and 3M) severely penalise natural pruning compared with classical treatment (about 5 cm per year, $p<0.002$). For Wild service tree, the early thinning can be particularly blamed.

Besides the huge growth differences between species this study highlights, it also allows, for each of them, the identification of silvicultural strategies that should be banned, and on the other hand those which should be preferred, given the forestry objective during that development phase (acquisition of vigorous and 6-metre-high naturally pruned trunk stems). 3M treatment (with two intensive targeted thinnings) appears not to be optimal for any of the species. For Cherry tree, whose apical growth is always high and natural pruning deficient, the most suitable silviculture is certainly light, probably much more than the classical treatment applied there. For Sycamore and Wild service tree, suitable treatment seems however to lie between classical and 2M treatments. Other experimental projects are under way in France, in order to define optimal silvicultural rules for these precious species.

Figure 2 : Annual radial mean growth of Wild service tree (A) and Sycamore (S)



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LIMING AS A METHOD TO IMPROVE NATURAL REGENERATION OF BEECH (*FAGUS SYLVATICA* L.) IN SOUTHERN SWEDEN

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Introduction

In Sweden natural regeneration is the common way to regenerate beech forests. During a mast year the ground is scarified and after the seed fall the beech nuts are covered with soil. A heavy thinning leaves a shelter-wood which is removed in steps over a 20 years period (Bjerregaard and Carbonnier 1979). This operation is not always successful, especially not in old beech forests on poor sites with podzol soils and raw humus. A low pH hampers the germination of seeds (Bressem 1998) and decrease the number of organisms in the breaking-down process, creating a thick inactive layer of raw humus (Muys 1989). Seeds germinating at these kind of sites often die due to drought, since the root must penetrate the humus layer before reaching the mineral soil, where the capillary forces brings water. The breaking-down process and the nutrient turnover is hampered, resulting in decreased growth and a longer period of vulnerability when the seedlings are small. These obstacles many times make the landowners unwilling to regenerate their beech forests, resulting in longer regeneration periods, impaired timber quality, and an even worse ground condition. To this comes that The Swedish Forest Act states that a beech stand has to be regenerated with beech (Skogsstyrelsen 2007), and a failure of natural regeneration, forcing the landowner to plant beech seedling, would be costly.

Positive effects of liming or liming combined with fertilization on germination and early growth have been reported from Denmark and Europe (Haun 1958, Müller and Weis 1906). The positive results may be explained by improved ground conditions caused by an increased pH value and a more rapid nutrient turnover, i.e. by earthworms loosening up the soil giving an improved germination environment (Huhta 1979). Ljungström and others (1990) did not show any positive effects of liming on natural regeneration of beech. The same results have been reported from one experiment in southern Sweden, while another showed positive effects of liming (Personal communication. Ulf Johansson, 2004).

The aim of this experiment is to study the effect of liming, soil preparation and fencing on germination and early growth of natural regenerated seedlings of beech, and to develop methods of natural regeneration of beech on poor soils.

Some of the studied hypotheses are:

- liming is positive for both germination and early growth
- best results are obtained if liming is done 10 – 20 years preceding the regeneration
- liming gives the best effect on poor sites with podzol soils and raw humus
- liming influences the ground flora and fauna
- liming gives the best result in combination with scarification
- liming influences the number, size and nutrient content of the beechnuts

Materials and Methods

The field experiment is located in 12 stands in south Sweden representing a wide variation of site fertility (Table 1). Activities to promote regeneration, e.g. scarification and regeneration felling to create a shelter are planned to start between 2005 and 2010. Eleven sites were limed during the winter 1991 – 1992, and one in February 1994. Five tons of grind limestone ha^{-1} was spread on each site. The experiment is of block design with comparison in pairs between limed and unlimed plots of 25*25 meters. One half of each plot will be scarified and some sites will be partly fenced. One stand was regenerated in 1999 and three stands in 2007. Five stands are planned to be regenerated at the next good mast year.

At every mast year the numbers of beechnuts, and the following spring, the numbers of germinates, have been counted, even though no scarification or regeneration felling has been done. Soil samples and samples of beech nuts have been taken for chemical analyses. Earthworm-counting was done in autumn 2000 and 2007. Also dry weight of vegetation has been analysed. After the regeneration felling numbers and height of new seedlings has been recorded and also future development will be registered.

Results and Discussion

15 years after liming the limed plots had an average pH of 4.9 in the humus layer and 4.6 in the mineral soil compared to 4.3 and 4.2 respectively in the control plots (Table 1).

Table 1. Site index and pH value at control and limed plots in the stands 2007.

Stand no		1	2	3	4	5	6	7	8	9	10	11	12
Site index		F 28	F 22	F 20	F 24	F 26	F 24	F 27	F 30	F 26	F 30	F 36	F 26
Control	Humus	4.1	4.5	4.3	4.3	4.1	4.0	4.0	4.5	4.3	4.3	4.9	4.4
Control	Mineral soil	4.4	4	4.2	4.3	4.0	4.0	4.0	4.2	4.3	4.1	4.5	4.4
Limed	Humus	4.5	4.9	4.7	5.3	4.5	4.6	4.8	5.0	4.9	5.3	5.2	5.5
Limed	Mineral soil	4.7	5.6	4.1	5.0	4.4	4.2	4.5	4.9	4.3	4.6	5.1	4.2

No differences in seed crop was found between limed and control plots. It is possible that the plots are too small and that almost all trees have had their roots in both limed and control areas. The seed traps, one in each plot, have been situated as far away as possible from the opposite treatment.

The numbers of new seedlings have been registered after every mast year. Mostly these are relatively few in numbers since no soil preparation or regeneration felling has been done. A clear trend is however shown; after the first years with higher proportions of seedlings on the unlimed plots, an average of about 60 % of the seedlings are found in the limed plots (Fig. 1). The fewer germinates on the limed plots the first years after the liming is explained by Bressem (1988) who claims that pH values above 6.0 and liming in the mast year is unfavourable for the over-wintering of the seeds.

The thickness of the humus layer was measured at eight of the sites in autumn 2006. The humus layer on the limed plots was 80% of the thickness of the humus layer on the control plots, probably due to a more rapid turnover.

Mass and numbers of earth-worms was about 325 and 100 kg ha^{-1} and the numbers 825 000 and 100 000 ha^{-1} on limed and unlimed plots respectively in 2000. Both mass and numbers had increased for both treatments in 2007 but the difference was similar.

Stand 11, regenerated seven years after the liming, is a very fertile site (Table 1). The number of seedlings on limed plots was 685 000 ha^{-1} compared to 558 000 seedlings ha^{-1} on the control plots, but the difference is not significant. No difference in height development was found between the treatments. The explanation is probably the high site index and a rapid turnover enhancing the germination process. The grind limestone also improves the growth of the field vegetation (Bauhus and Bartsch 1996) which may be a severe competitor to the seedlings.

Stand 5, 6 and 10 were regenerated in 2007 resulting in about 25 % of the germinates on the limed plots in stand 5 and 10 had while stand 6 had about 75 %. The influence of the scarification was low. Height growth during the first growing season was better for seedlings on limed plots in stand 5 and 6 while no difference was found in stand 10. In stand 10 a reason might be the high amount of field vegetation on the limed plots, 1 180 kg ha^{-1} compared to 525 on the unlimed plots. This may also partly explain the lower share of germinates on the limed plots. Stand 6 had a low number of germinates, 24 250 ha^{-1} on the limed plots and 8 500 on the unlimed plots, which is much too low to get a good future beech stand.

The results confirm the necessity of further investigations in the stands that are next to be regenerated.

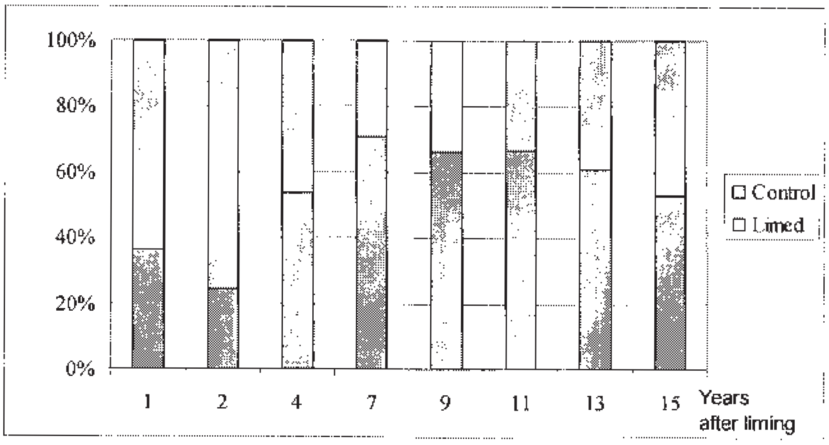

Figure 1. Seedling distribution in limed and control plots in stands where no site preparation or shelter-wood cutting had been done.

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NATURE-BASED SILVICULTURE – HOW CAN WE ACHIEVE THE EQUILIBRIUM STATE IN UNEVEN-AGED ORIENTAL BEECH STANDS?

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Introduction

Oriental beech (*Fagus orientalis* Lipsky) is the common dominant tree, which covers 17.5% of the surface and accounted for 30% of volume in the Caspian broad-leaved forests of northern Iran. Most of the beech stands are uneven-aged that could be managed by group selection system with the background of close to nature silviculture (Sagheb-Talebi and Schütz, 2002; Marvie-Mohadjer, 2005). The application of selection system (Plenterung) is also described in European beech stands (Schütz, 2001). Equilibrium state and estimation of ingrowth, outgrowth, stem number frequency in diameter classes, in particular the first diameter class (N_{10}) and removal rate are the main points for application of this system.

Fully irregular forests are characterized by presence of stems of all sizes and age classes in a relatively limited area. It is not sufficient to remove trees according to certain silvicultural criteria, but the intervention as a whole needs to assure sustainability in the long run. It is essential to know that the structure of a selection forest can only be retained in the long term if enough recruitment is available, which reaches the upper layer to replace the mature trees. For this reason, a close survey of the structure and a continuous control of the growth are absolutely essential (Schütz, 1999). Besides, target diameter, basal area (Schütz and Röhnisch, 2003) and wood quality are also important criteria that should be taken into account. Collete (1951) introduced the diameter class of 70cm as the target diameter for beech in south Belgium, while Roisin (1981) suggested a cumulative basal area of 20 m^2 sufficient for obtaining of equilibrium state.

Equilibrium state could also be assessed by computing of ingrowth and outgrowth rates and the stem number in the diameter classes (Schütz, 1975 and 1999).

The aim of this study was to determine the diameter increment and the frequency of tree number in the first diameter class (N_{10}) as a first step for providing data which is used to achieve the equilibrium state in the oriental beech stands of northern Iran.

Materials and Methods

The frequency distribution of stems should be interpreted as a representative comparable, for instance, to the demography of a whole human population. Thus, it will remain constant or sustainable in time of birth rate exactly compensates mortality, considering life span. Applied to trees, these conditions could be implemented for each diameter class by postulating that, during a given period trees which have been eliminated or grown to next higher diameter class must be replaced by trees moving up from the class below if the systems should be sustainable (Schütz, 1999). Such a postulate of equilibrium has been formulated for a long time (Schütz, 1999 cited from Borel, 1929; Schaeffer et al., 1930; François, 1938; Prodan, 1949). Because the growing stock determines the light conditions in the stand, it also influences the movement of trees from diameter class to diameter class or "tree migration". Equilibrium state is achieved if the standing volume remains constant over time. This means, that the periodic volume increment needs to be removed by the periodic silvicultural interventions (Schütz, 1999).

Schütz (1975 and 1999) has formulated a model for assessing the equilibrium state as following:

[1] $n_{i+1} = n_i * p_i (p_{i+1} + e_{i+1})^{-1}$

Where "p_i" is ingrowth rate (coming from below or migration in class), "e_i" is outgrowth (leaving to next or removal rate) and "n" is the stem number in each diameter class.

In order to study how we can achieve the equilibrium state in irregular stands, six sample plots, each covering one ha (100*100 m) were selected by using of selective sampling method in natural oriental beech stands of northern Iran, Neka-Zalemroud region, Mazandaran province. The studied sample plots were located between 640 and 1540 m.a.s.l., with northwest direction and 15 to 20% of slope gradient. The crown canopy of the plots varied between 75 and 80%. All standing trees with a diameter at breast height (dbh) more than 7.5cm were assessed in each plot. Moreover, marked and felling trees were recorded. For having a better knowledge about the distribution of some quantitative characteristics, four stem sizes were used: small timber (dbh <30cm), medium timber (35<dbh<50cm), large timber (55<dbh<70cm) and extra large timber (dbh>75cm) (Eslami and Sagheb-Talebi, 2006). Determining of diameter increment in the last ten years was done by using of increment borer in different diameter classes (al least three trees per diameter class). Data analysis was carried out by using of SPSS and Excel soft wares.

Results and Discussion

The distribution of stem frequency in diameter classes showed an irregular uneven-aged structure in all six sample plots; however a deficiency in the first class (N_{10}) was obvious. This varied between 7 and 74 stem per hectare, which counted for 0.15% and 1.87% of total basal area of the studied stands. Stem number varied between 126 and 258 $\mathrm{Nha^{-1}}$, basal area between 26 and 42.7 $\mathrm{m^2ha^{-1}}$ and volume between 388 and 509$\mathrm{m^3ha^{-1}}$ (Table 1).

The percentage of the existed and removed trees in each diameter class and the outgrowth rate were calculated and determined. For example in the sample plot three, 93% of stem number was distributed up to the diameter class 90cm. In this diameter class (=90cm) there were only two trees which were both (100%) removed during the silvicultural interventions.

The distribution of stem number and basal area among the timber size classes showed different results. For example in the sample plot four, the percentage of stem number in the small timber size accounted for 63.5%, while the highest percentage of basal area and volume per hectare were determined in the extra large timber size, 50.5% and 54.8%, respectively.

The annual diameter increment varied between 1.6mm and 4.5mm in different diameter classes. The mean annual diameter increment was calculated to 2.7$\mathrm{mm.yr^{-1}}$, which was similar to the diameter increment in the classes of 80 and 85cm. Distribution of mean annual diameter increment in diameter classes showed that the highest rate of mean annual diameter increment (id=3.5 mm $\mathrm{yr^{-1}}$) could be observed between 40 and 55cm dbh classes. Distribution of mean annual diameter increment in cumulative basal area (Gcum) classes showed that it starts with slightly more than 3 mm $\mathrm{yr^{-1}}$ in the cumulative basal area of less than 5 $\mathrm{m^2ha^{-1}}$ and decreases to less than 0.5 mm $\mathrm{yr^{-1}}$ in the cumulative basal area class of 35 $\mathrm{m^2ha^{-1}}$. The mean annual diameter increment (2.7 mm $\mathrm{yr^{-1}}$) has been observed in the Gcum class of 23 $\mathrm{m^2ha^{-1}}$.

Considering all above mentioned criteria, target diameter for the studied irregular oriental beech stands could be introduced more than 60cm (up to 85cm) in stands with a volume of 350 and 400 $\mathrm{m^3ha^{-1}}$ and a cumulative basal area between 21 and 25 $\mathrm{m^2ha^{-1}}$. But, we should take the red rot and stem quality into account as well. The studies show that the risk of red rot in beech could be increased in diameters larger than 60cm (Parsapajouh et al., 1996; Susani, 2001).

Table 1. Some quantitative characteristics of the studied oriental beech stands.

No. sample plot	I	II	III	IV	V	VI
Stem number (N/ha)	126	200	142	189	217	258
N_{10}	11	-	7	63	41	74
Basal area (m^2/ha)	32	37	32	26	29.5	42.7
Basal area of N_{10} (m^2/ha)	0.09	-	0.05	0.49	0.32	0.58
Proportion of basal area N_{10} (%)	0.27	-	0.15	1.87	1.08	1.35
Volume (m^3/ha)	491	491	509	388	442	486

Considering the sustaining of reverse J form of stem number frequency, for improvement of the stand structure and becoming closer to the equilibrium state, a stem number of 120 Nha^{-1} in the first diameter class (N_{10}) could be expected. However, at least two or three period of control method is suggested.

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DEADWOOD ASSESSMENT IN DIFFERENT DEVELOPMENT STAGES OF BEECH (*FAGUS ORIENTALIS* LIPSKY) STANDS IN CASPIAN FORESTS

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Introduction

Deadwood and its biodiversity play a key role for sustaining forest productivity and environmental services such as stabilizing forest and storing carbon. Despite its enormous importance deadwood is now at a critically low level in many countries, mainly due to inappropriate management practices.

Recently, deadwood has become more considered as an indicator in the assessment of the biodiversity and naturalness of forest ecosystems (Larson *et al.*, 2001; Kristensen, 2003; Schuck *et al.*, 2004). The amounts (quantity) of deadwood occurring in natural forests depends on many factors, and its correct estimation must consider forest type (species composition and stand structure), development stages, type and frequency of natural disturbance, type of management, but also soil and climatic characteristics, which together contribute to complete the formation and decomposition cycle of deadwood (Christensen *et al.*, 2003).

How much deadwood should be present in the forests and in different development stages?

Presence of deadwood can be related to the intensity of silvicultural interventions and the way these are carried out (Guby and Dobbertin, 1996; Green and Peterken, 1997). This is why deadwood quantities (woody necromass) in managed forests are considerably lower than in forest left to evolve naturally: it has been estimated that only 2 to 30% of the deadwood found in un-managed forests occurs in managed ones (Lesica *et al.*, 1991; Green and Peterken, 1997; Kirby *et al.* 1998; Jonsson, 2000). Typical managed forests of beech forests contain only small amount of deadwood and without sufficient amount of deadwood the stability of forests will continue to decline due to less attention to stand structure and development stage in managed forests.

Therefore, the aim of this study was to investigate how much deadwood should be present in different development stages in a natural forest as a reference.

Materials and Methods

Materials

The study site is located in the unmanaged 4th district at the experimental forest (Kheiroudkenar) of Tehran University in the west of Mazandaran province, north of Iran (Caspian region) at 51°35' N and 36°35'E. The study area is extended between 750 and 1450m.a.s.l. The climate is temperate, the annual mean temperature is 15.8°C and the annual mean precipitation is 1360mm with maximum rain occurring in late summer and fall. The soils belong to *Inseptisols* and *Alfisols*.

The most important forest associations of the region are *Rusco-Fagetum* and *Carpineto-Fagetum*. Tree species contains beech (*Fagus orientalis* Lipsky), hornbeam (*Carpinus betulus*

L.), maple (*Acer velutinum* Boiss.), alder (*Alnus subcordata* C.A.M.) and other broad leave species.

Methods

Many studies was down in related to determining stand development stages in different forest type in Europe (Leibundgut 1993; Korpel 1995; Emborg *et al.* 2000) and oriental beech forests in north of Iran (Mataji 1999; Sagheb-Talebi *et al.* 2003). But all of them just tried to determine the development stages (three main stages including initial, optimal and decay stages) and do not clarify the amount of deadwood and process of decomposition in each stage. Thus, in this research we study the stand structure and dynamic of development stages with particular reference on deadwood in each stage.

Therefore, in beech communities three sites, each one ha, were established and species, diameter and height of all (living & dead) trees with d.b.h over 7.5 cm were recorded.

Results and Discussion

In the studied forest which beech is dominated species, all three development stages (initial, optimal and decay) would be recognized. Table 1 shows some characteristics like stem number, volume and deadwood value for each stage. The stem number in initial, optimal and decay stages is 462, 319 and 194 per ha, respectively. The range of volume is 411 to 539m^3 ha^{-1} which the highest and lowest volume belong to optimal and initial stages, respectively. In initial stage the highest number of trees is distributed between dbh classes of 10 and 30cm (almost 80% of trees occurred in small size). On the contrary, in decay stage the number of trees in large size (>55 cm) is higher than other stages and the amount of volume is more than initial stage. The maximum value of volume was observed in the optimal stage. Distribution of deadwood by volume and number of stems in different development stages is given in table 1. The greatest volume (54.3 m^3 ha^{-1}) and large number (73 per ha) was occurred in the decay and initial stages, respectively. The results demonstrated the amount and proportion of deadwood volume in beech forests varied between 1.1 and 9.6 percent. When we compare the amount of deadwood in different development stages, it can be seen that the proportion of deadwood to the total volume was increased in the decay stage, which can be considered as a characteristic of old stand in beech forests (Leibundgut, 1993).

Table1. The stem number and volume of living and dead trees in different development stages.

Development Stage	Number of stems				Volume			
	Living trees		Dead trees		Living trees		Dead trees	
	n ha^{-1}	(%)	n ha^{-1}	(%)	m^3 ha^{-1}	(%)	m^3 ha^{-1}	(%)
Initial	462	86.5	72	13.5	411.3	98.9	4.9	1.1
Optimal	319	92.5	26	7.5	539.0	98.7	7.04	1.3
Decay	194	94.7	11	5.3	511.0	90.4	54.3	9.6

How much deadwood should be present in natural forests? Volume of deadwood depends on productivity, natural disturbance regime and human intervention. So, deadwood volume varies between different forest types and management systems. In unmanaged European forest, deadwood eventually rises to anything from 5-30 percent of the total timber, with volume normally from 40 to 200 m^3 ha^{-1} (Mort, 2004). Besides, in beech forests in Europe an average volume of deadwood of 50-200 m^3 ha^{-1}, accounted to 10-35% of total volume can be assumed (Müller-Using and Bartsch, 2004). Therefore, the result of our study in relation to deadwood volume in unmanaged forests is similar to some above mentioned study which was done in beech stands in Europe.

But, in spite of deadwood enormous importance, it is now at a critically low level in many forests due to inappropriate management practices. So, it is necessary to manage deadwood effectively and increase deadwood volume in managed forests. The amount of deadwood within managed forests is open to debate and require detailed knowledge about beech stands in local conditions. For European temperate forests deadwood volume between 20-30 m^3 ha^{-1} or 3 to 8 percent of total volume is suggested as a reference (Mort, 2004). In managed forests of beech in north of Iran deadwood between 10-30 m^3 ha^{-1} or 5-10% of total volume of wood could be considered as a reasonable amount.

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STUDY OF REHABILITATION METHODS IN DEGRADED BEECH REGENERATION AREA IN CASPIAN FOREST REGION OF IRAN

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Intruduction

Oriental Beech (*Fagus orientalis* Lipsky) is the most important tree species in mountainous and mixed Caspian forests of Iran. Today after 40 years experiences we can say that the shelterwood system is not suitable for these forests (Marvie-Mohadjer, 2004). For this reason, disturbed and bare patches are dispersed in some last regeneration areas of Beech forests. Rehabilitation of these degraded stands by means of next to nature methods are seriously considered in Beech forest research programs. Our experiences show that desirable natural regenerations in undisturbed Beech stands occur in small to medium size gaps under shelter of seed trees. Beech seedling in openings bigger than 1000 m^2 are confronted many unwanted competitor plants like *Rubus*, Ferns and other Grasses (Sagheb-Talebi, 2001). In such conditions direct plantation include a high risk and showed Beech sapling mortality up to 70% (Fayaz, 2001). Common artificial regeneration technique is expensive but successful direct seeding offers potentially higher stock densities at lower costs compared to planting (Madsen et al, 2006). This experiment was performed in a protected open area of mixed Beech forests to compare the effect of seeding and nurse species planting *(Acer velutimum* Boiss. and *Alnus subcordata* C.A. M.) on forest rehabilitation.

Materials and Methods

Study site is located on 1400 m.a.s.l, north inclination and 30-40% slope in a 0.5 ha open area surrounded by mixed Beech-hornbeam forest. The mean annual precipitation is about 1500mm, soil pH varies between 5 to 6 in different layers covering with *Matheuccia struthiopteris, Driopteris filix-mas, Driopteris filix-femina* and *Rubus* spp. The layout of the trial is a Randomized Complete Block Design with 4 replications and 7 treatments as follows : a and b: nurse planting of Maple and Alder with a spacing of 2.5× 2.5m, c, d, and e: Row seeding of Alder, Maple and Beech at 1 meter intervals in plot size of 12×12m, f: seed sowing of Beech accompanying with ground covering and g: control. Forest floor cover was eradicated at the first year but weeding was performed every year in late September. Measurements of established seedlings were carried out within each plot (totally 28 plots) at the end of 5th growing season in year 2007.

Results and Discussion

At the end of 2007 growing season ten different forest tree species seedlings were established but Maple(*Acer velutinum*), Hornbeam (*Carpinus betulus*), Alder (*Alnus subcordata*) and Beech with the proportion of 98% were dominants. Number and height of regenerations are presented (Table 1).

Table 1: Mean number and height range of regenerated species in plot counting areas

Species	N/ $25m^{-2}$	%	Height(cm) Min.	Max.
Maple	56	74.5	10	470
Hornbeam	10	13.3	15	275
Alder	5	7	15	350
Beech	3	4	15	160
Others	1	1.2	15	120
Total	75	100	10	470

A density of 75 sapling and seedling per $25m^{-2}$ (irrespective of treatment) is nearly sufficient, but little number of Beech should be increased in the next years. Each of the maple, hornbeam and alder as light demanding species with a range of 2.75-4.70 meter heights will play the important role in shade tolerant beech seedlings reestablishment, because herbaceous competitors under shady conditions are greatly controlled. It is compared with the mean number of seedlings (40) in counting area and height range(40-80cm) at the beginning year of study at 2004 (Gorji et al. 2006).

As expected the regeneration was present in all plots (figure 1).

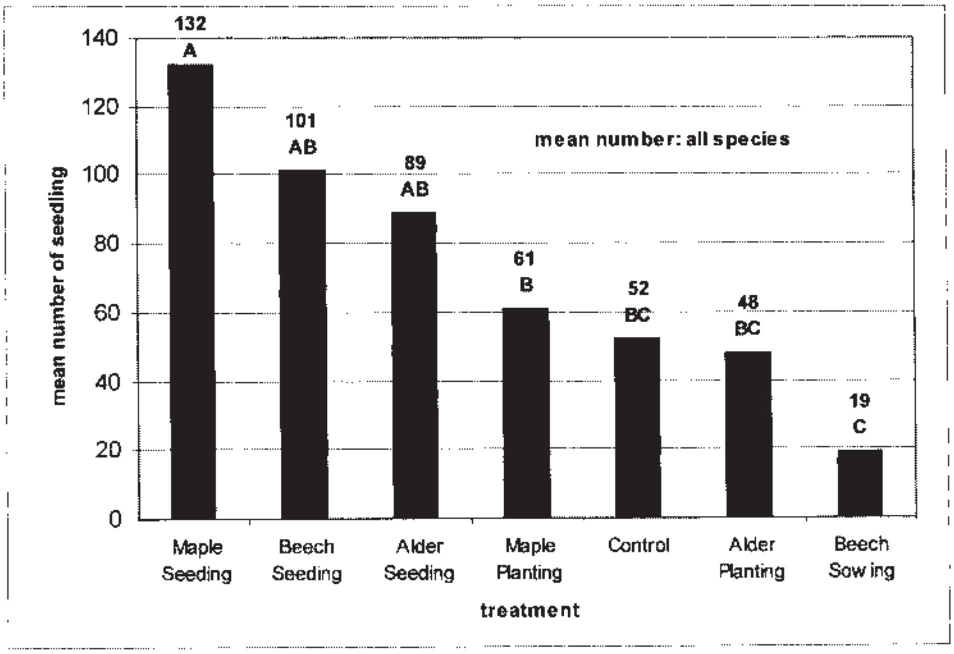

Figure 1: Distribution of mean number of regeneration in treatments. Bars with the same letter are not different($p<0.05$).

Figure 1 gives mean number of established species per plot counting area ($25m^2$) which contains all artificial and spontaneous regenerations in Sep.2007. As figure show the seedlings were established in all treatments but numbers in maple seeding reached 132, and it's difference is significant ($p<0.05$). Beech and Alder seeding, Maple nurse planting, Control and Alder nurse planting have similar effects and their differences are not significant. Beech sowing on herbaceous layer has the least seedlings. It is remembered that direct seeding of beech and alder failed and maple is the main species composition in all treatments (> 75%).

The per cent of Beech seedling is low. We will support and increase the Beech regeneration under shady condition during the next years by means of: 1) to decrease the number of maple in dense groups in order to provide sufficient light for Beech, and 2) seeding and planting of beech under maple storey after soil scarification when necessary. Fortunately, there are a few Maple species in the Caspian forest region(*Acer velutinum* Boiss., *A. cappadocicum* Gled., *A. hyrcanum* F.&M., *A. platanoides* L.) which can play an important nursing role in forest rehabilitation in different ecological conditions. We are going to increase the actual beech mixture percent (3%) to a number of 50% total saplings in study area.

In general, unwanted plant cover is a impediment after seedling reestablishment and involve expense. The control of vegetation is possible only the first 4 years after gap creation where *Rubus fruticosus* dominates the herbaceous layer (Degan et al. 2006). This study also showed that taking care of seedlings is necessary for the first 3 years old, and under this circumstances, they are released and grow up.

There were no regeneration in study area for many years before, but by using site preparation measures and weed control in a protected area, the number of regenerations exceed of 54000 ha^{-1}. These results could be useful for similar beech degraded areas in the Caspian regions.

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GROWTH AND STEM QUALITY OF BEECH (*FAGUS SYLVATICA* L.) IN MIXED STANDS IN RELATION TO NEIGHBORING TREES

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Introduction

Mixed stands may be a suitable way to minimize either biotic or abiotic risks e.g. storm damages, drought etc. and may reduce also economical constraints. Beech (*Fagus sylvatica* L.) is one of the main tree species in Switzerland and would dominate naturally most of the forested areas in altitudes below 1000 m. In the last 150 years beech was replaced mainly by Norway spruce (*Picea abies* (L.) H. Karst.), often in pure stands where the risk of wind damage is high. Spruce has no problem growing as admixed species in mixed stands but this is not true for beech. Beech as an economic species produces either high quality timber or energy wood. To produce high quality timber the appropriate silviculture is necessary. It seems that the neighbouring trees have an influence on the growth and stem quality of beech trees. The aim of this study is to detect how neighbourhood constellations influence this development. On the basis of the results presented by Zingg and Ramp (2007) we define the following hypothesis to test: diameter growth and stem quality of beech is better when the closest neighbours are also beech.

Materials and Methods

We used data from three long-term growth and yield thinning plots in mixed Norway spruce-Scots pine-European beech stands (*Picea abies* (L.) H. Karst., *Pinus sylvestris* L., *Fagus sylvatica* L.) surveyed 14 times from 1907 to 1990 near Murten in the western-central Swiss plains. The plots were treated with three different thinning regimes (Zingg and Ramp 2007). Since 1941 tree positions are known. The neighbouring conditions of each tree were characterised using the Intermingling index of Füldner (1995) describing the mixture and the Dominance index of Hui et al. (1998) describing the diameter relationships, for both indices taking into account the four nearest neighbours.

For each plot diameter growth and stem quality are given for the various intermingling and dominance conditions for beech and spruce.

Correlations for all potential variables for the explaining model were calculated. Then the model to explain diameter growth of the individual trees in relation to their neighbourhood conditions using the variables survey year, diameter, intermingling, dominance was computed by using a stepwise backward procedure of a General Linear Model (GLM). The same was done to explain the stem quality defined from the transformed categorical variable on the basis of the basal area of each tree.

Results and Discussion

Diameter growth: For both beech and spruce there is no clear difference in diameter increment when comparing it with the individual situation of the trees concerning their four closest neighbours (Fig. 1). But the dominance of the neighbouring trees has an influence on

Figure 1: Diameter increment compared to mixture, i.e. the species of the four nearest neighbours.

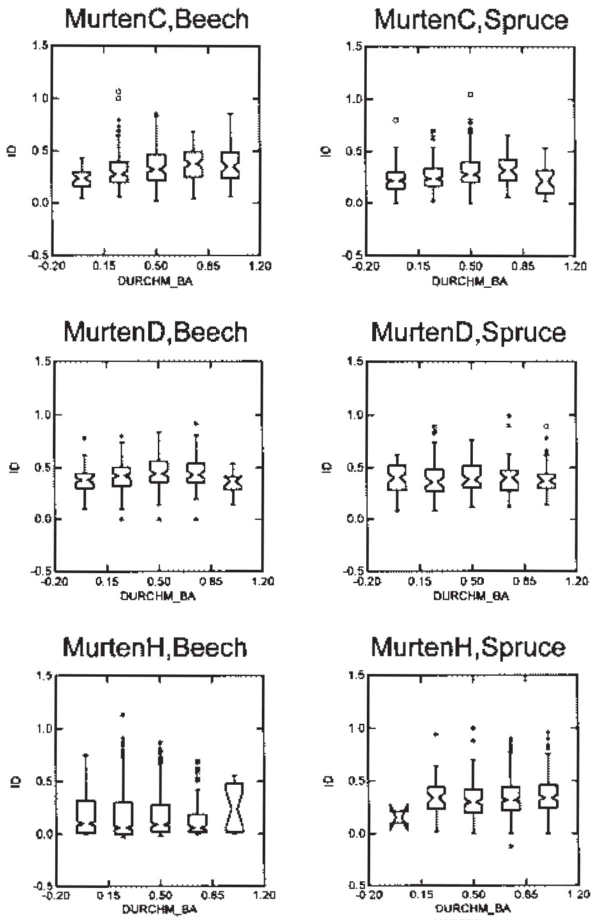
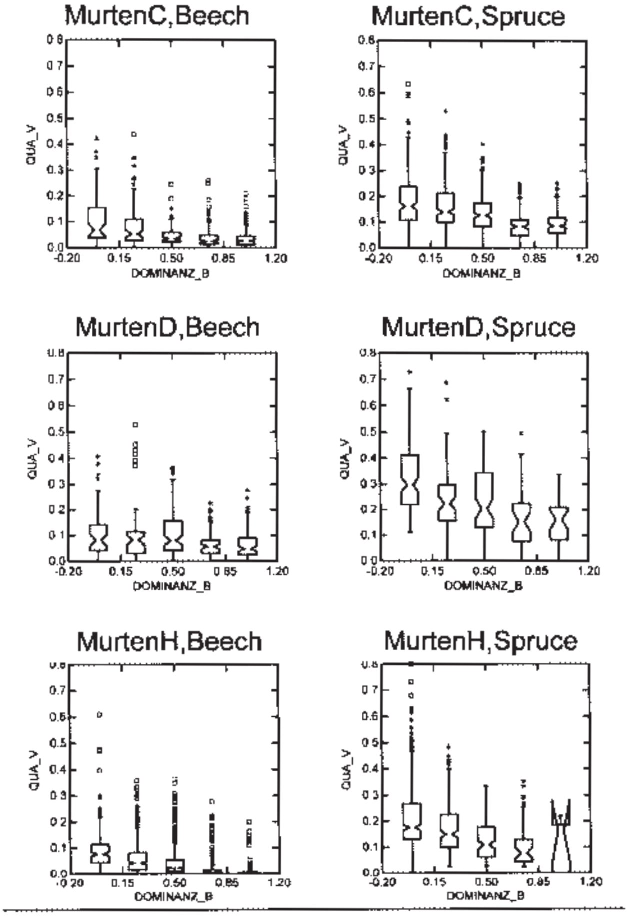


Figure 2: Stem quality compared to the dominance of the four nearest neighbours.



the diameter increment: as more trees have a greater diameter as the reference tree, as smaller is the increment of the reference tree.

Stem quality: Stem quality seems to depend neither for beech nor for spruce from the composition of species in their close neighbourhood, but seems to be influenced by dominance of the four nearest neighbours: as more trees with a diameter greater than the reference tree as less good the stem quality of the reference tree.

Model: The correlations of the used variables are given in Table 1. With the exception of year-dominance all correlations are significant

Table 1: Correlations

	Year	d.b.h.	Tree height	Intermingling	Dominance	Stem quality
Year	1.000					
d.b.h.	0.512	1.000				
Tree height	0.433	0.565	1.000			
Intermingling	0.099	0.274	-0.125	1.000		
Dominance	0.001	-0.575	-0.230	-0.182	1.000	
Stem quality	0.451	0.822	0.432	0.225	-0.497	1.000

The four models which were computed – for beech and for spruce, diameter increment and stem quality – give results presented in Table 2:

Table 2: Regression models to estimate diameter increment for spruce and beech.

	Diameter increment I_d	
	beech	*spruce*
N	2973	1838
Adjusted multiple R^2	0.762	0.418
Constant	6.324 ***	10.051 ***
Year	-0.003 ***	-0.005 ***
d.b.h.	0.018 ***	0.013 ***
Tree height	-0.003 **	-0.330 ***
Intermingling index	0.030 ***	0.033 ***
Dominance index	-0.222 ***	-0.021 .

*** = p<0.001, **=p<0.01, *=p<0.05, .=p<0.1, n.s.= not significant

Diameter increment can be estimated with a good degree of explanation using both indices. But the influence of the mixture expressed with the intermingling index which takes into account the four nearest neighbours seem to be much smaller than what was to expect from the stand data analyses presented earlier (Zingg and Ramp 2007). So the hypothesis can be accepted only partly.

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SILVICULTURE OF YOUNG EUROPEAN BEECH (*FAGUS SYLVATICA* L.) STANDS IN ROMANIA, A COMPROMISE BETWEEN ECOLOGICAL AND ECONOMIC CONSTRAINTS

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Introduction

European beech (*Fagus sylvatica* L.), a tree species dominating the low mountainous and high hilly vegetation zones of Romania, covers over 1.95 million ha, being the most important component of national forest estate (about 30 % of total area).

Beech stands, either pure or mixed, are naturally regenerated by seed following the application of shelterwood systems involving 2 to 4 cuttings. The resulting stands are very dense and, starting very early (thicket stage), face some major ecological and economic constraints such as snow damages (breakage and bending-over), high proportion of forked or cankerous trees, high costs combined with the lack of workforce for early silvicultural interventions (e.g., weeding, cleaning-respacing), lack of local markets for small-diameter trees removed by cleaning-respacing and first thinning, etc.

Under such circumstances and taking into account the official "norms" in use in Romania, mostly ecologically-based and involving low-medium intensity interventions that lead to high densities (200-250 trees/ha) at long rotation ages (100-120 years for sawn logs and 140-150 years for veneer logs) (MAPPM, 2000/1, 2000/2), a research project on early silviculture of young European beech stands was launched back in 1999. It involves silvicultural interventions - weeding, cleaning-respacing, and thinning - of various intensities, usually much higher than those officially recommended in Romanian beech forests.

The objective of the present paper is to analyse the effects of such interventions on individual beech trees and stands and propose alternative scenarios to reduce the impact of above-mentioned constraints on rotation age and quality on wood products.

Materials and Methods

The project comprises seven European beech stands in sapling and thicket stages of development. No interventions or low intensity interventions (weeding or cleaning-respacing) removing only pioneer species or a small part of defective trees (e.g., wounded, forked) have been performed in these stands in the past.

Starting 1999, weeding and cleaning-respacing of various intensities were performed in experimental plots (150 sq.m. in sapling stage, 400 or 500 sq.m. in thicket stage) established in all stands. For all removed trees d.b.h., total height, pruned height, and forking height were measured. Presence of cankers was recorded. For all trees remaining within the plots after interventions d.b.h, total height, pruned height, forking height, crown rays, and spatial coordinates (x, y) were measured.

Yearly after the establishment of plots, measurements of d.b.h., pruned height, total height, crown rays as well as of epicormic branches (e.g., location along the bole, diameter at insertion point, length, if applicable) on remaining trees were performed.

All these data were subsequently analysed focusing especially on stand densities at various ages, effects of stand densities on individual tree stability to snow damages, natural pruning of beech trees, different correlations existing at individual tree level, occurrence and size (diameter and length) of epicormic branches, etc.

Results and Discussion

Stand density: in naturally regenerated European beech stands left untended, initial stand densities in sapling stage can be as high as 120,000-150,000 trees per ha. The density decreased down to 30,000 trees per ha at the beginning of thicket stage and 8-12,000 trees per ha at the end of the same stage. Such decrease is the result of a high (up to 30 %) natural mortality at the beginning of sapling stage followed by a much lower intensity (10-12 %, sometimes even less than that) later on. However, due to these very high densities, the access into stands for performing various future interventions is very difficult and requires the opening of silvicultural (access) racks, even very expensive and time-consuming, as stressed earlier (Nicolescu et al. 2004/1).

Snow damages. The very dense beech young stands, leading to the production of tall and slender trees, with high stability indices (SI = h/d.b.h.) make them prone to snow damages – stem breakage or bending – (Nicolescu et al. 2004/2). These conclusions – do not leave the sapling and thicket stage beech stands too dense and untended; try to remove as many as possible forked trees to avoid their snow breakage or split - have been confirmed in a newly (2006) established experiment. In plots (beginning of thicket stage) with stand densities reduced down to 4,600-8,200 trees per ha (experimental ones) and reaching a maximum of 23,800 trees per ha in the control plot, the proportion of trees damaged (bent-over) by snow varied between 43 % and 58 %. The most affected trees were those forming the lower half of canopy or the thin (slender) trees in the upper canopy. The largest (tall and thick) beech trees, of which the *final crop trees* will be selected in the future, have been barely affected by snow damages.

Natural pruning. The process of natural pruning is quick under the very high stand densities of young beech stands. In the sapling stage the pruned height was as high as 2-3 m and reached 4-5 m at the end of thicket stage. Only in the first half of pole stage (mean diameter 12-15 cm) the pruned height reached 6-7 m (target values for the production of two veneer logs) so the *phase of natural pruning* is completed. It means that until the end of sapling stage-beginning of thicket stage stands should be kept as dense as possible to allow for the formation of straight and naturally pruned trees. Only pioneer and defective beech trees – especially forked or with cankers -, along with those forming too dense groups of individuals, should be targeted during weeding interventions.

Different correlations existing at individual tree level. In all experimental plots, cleaning-respacing interventions leaving the lowest stand density had the most significant influence on d.b.h increment. The thickest beech trees, many of them forked or with cankers and forming the upper canopy classes (Kraft 1 and 2), had showed the largest d.b.h. increment reaching values of 7-10 mm per year (Fig. 1). These thickest beech trees had also the largest crowns and most significant crown diameter increment (Fig. 2). As a part of them (defect-free trees) will form the pool for the *final crop trees* they should be favoured by interventions removing surrounding tall and high-quality competitors. Along with them defective trees (mostly forked and with cankers) remaining after weeding in both upper and lower storeys should also be removed so that cleaning-respacing should be mixed operations (*positive* and *negative* selection, *from above* and *from below*) favouring the best-quality trees, vigorous and as evenly spaced as possible.

These *future crop trees* should be selected at the end of thicket stage (last cleaning-respacing) or during the first half of pole stage (first thinning) as soon as they have reached the targeted pruned height.

Figure 1: Correlation between initial diameter (d.b.h.) (1999) and diameter increment (interval 1999-2007) of European beech trees (204 individuals, sub-compartment 97A)

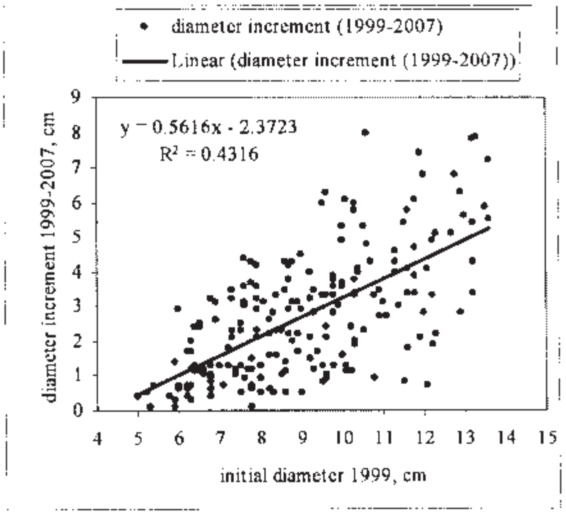
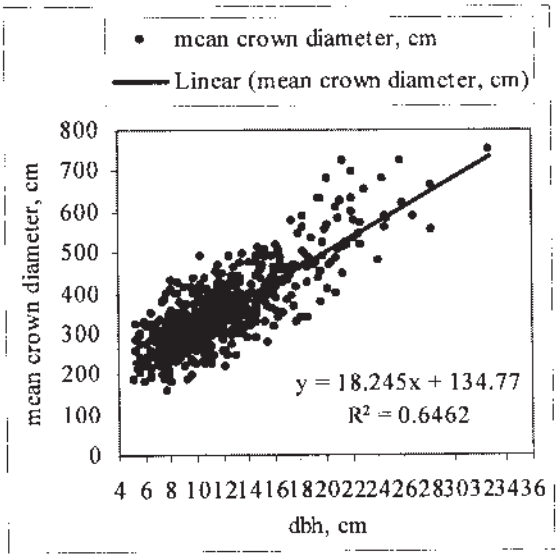


Figure 2: Correlation d.b.h-mean crown diameter in European beech trees (819 individuals, sub-compartments 57A, 59D and 97A)



Since this phase on a complete shift from a *stand-oriented* to *single (crop) tree-oriented* silviculture is desired. This approach involves *positive* selection and interventions *from above* focusing on best beech trees which should be grown free from canopy competition by removing competitors of similar size regardless their quality. Such scenario (*free-growth*) is favoured by the low propensity of European beech trees to produce large amounts of vigorous epicormics after high intensity interventions as recorded in the experimental plots.

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AN INTERNET-BASED DECISION SUPPORT TOOL ON MANAGEMENT OF BROADLEAVED FORESTS: A LINK BETWEEN RESEARCH AND PRACTICE

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Introduction

Forests cover 55 % of the Swedish land area. Most of the forest is dominated by conifers, while noble hardwoods only constitute 1.5% of the growing stock. Nevertheless, temperate broadleaved forest has an important role in the southernmost part of Sweden, with beech (*Fagus sylvatica*) and oak (*Quercus robur*) being the dominant species among the noble hardwoods. These forests, besides having a potential for production of highly valued timber, are very important for biodiversity and recreation.

About 80% of the noble hardwood forest is owned by non-industrial private forest owners. These owners are responsible for the decisions on how to manage the forests in order to fulfil the requirements set up both from their private needs and from the society. Hardwood forestry differs greatly from the more streamlined management of conifer forests. The hardwood forests are often mixtures of several species, each with its own ecological and silvicultural demands. The demands for conservation and recreation are usually much higher than in conifer forests, and there are far more management options. An efficient management requires knowledge, and it is a constant struggle for authorities and scientists to supply the forest owners with sufficient information to raise their competence.

There are several channels to communicate results and guidelines to forest owners. Personal advisory, courses and booklets have been ruling for long, but internet has become a communication channel with increasing importance. In 2007, about 76% of the Swedish forest owners had access to internet, and 53% used internet as a tool in forest decisions (Skogsbarometern, 2007). This project aimed to establish a decision support system for management of broadleaved forests, with the goal to present the most relevant information and guidelines on broadleaved forestry for the private forest owners (Hannerz et al., 2007).

Materials and Methods

The project started in 2004 as a cooperation between the two main forest research organisations in Sweden: SLU and Skogforsk. The project was supported by the Private Forest Association, and it involved 20 researchers, experts and web-designers. The aim was to develop a web-based decision support tool on hardwood forestry. The system was finalized in 2007 and is part of the overall forest decision support system Knowledge Direct, targeted at private forest owners (Hannerz et al., 2005a, 2005b).

The development involved forest owners as advisers and test persons through the build-up of the system. Enquires and visit statistics gives constant feedback to improve the system.

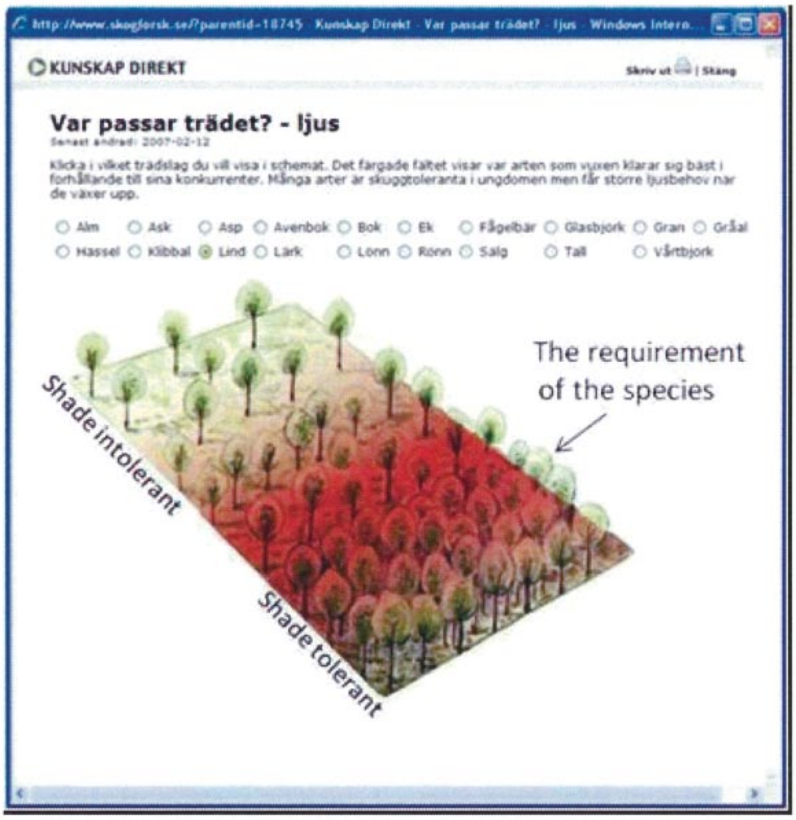
Results and Discussion

Content of the system

The decision support system is focused on the noble hardwoods in Sweden, which includes elms (*Ulmus glabra, U. minor* and *U. laevis*), ash (*Fraxinus excelsior*), hornbeam (*Carpinus* *betulus*), oaks (*Quercus robur* and *Q. petraea*), beech (*Fagus sylvatica*), wild cherry (*Prunus avium*), limes (*Tilia cordata* and *T. platyphylla*) and maple (*Acer platanoides*). It covers:

- Noble hardwoods in Sweden, with information on distribution and growth statistics.
- The hardwood species, with general information for identification and ecology.
- Laws and regulations for management of the hardwood forests.
- Biodiversity concern, with guidelines for conservation purposes.
- Conservation of the cultural heritage
- Management to concern recreation and outdoor life.
- Guide for choice of species with respect to fertility, water, soil and light (Figure 1).
- Guidelines for silviculture, with specific guidelines for each species, divided on regeneration, precommercial thinning, thinning, pruning and final cutting.
- Wood utilization, with species-specific presentation of wood characteristics, product requirements, guidelines for marking for cross-cutting and timber classification.

Figure 1. Example of interactive tool where the different species can be compared along a light gradient. In this case the coloured area shows the main preference for lime.



Var passar trädet? - ljus

Senast ändrad: 2007-02-12

Klicka i vilket trädslag du vill visa i schemat. Det färgade fältet visar var arten som vuxen klarar sig bäst i förhållande till sina konkurrenter. Många arter är skuggtoleranta i ungdomen men får större ljusbehov när de växer upp.

○ Alm ○ Ask ○ Asp ○ Avenbok ○ Bok ○ Ek ○ Fågelbär ○ Glasbjörk ○ Gran ○ Gråal
○ Hassel ○ Klibbal ● Lind ○ Lärk ○ Lönn ○ Rönn ○ Sälg ○ Tall ○ Vårtbjörk

The system contains about 180 web-pages with information, interactive exercises and calculation tools. The user can also validate their knowledge in tests.

Calculation and decision-support tools are important items of the system. Interactive diagrams are developed for calculating site index, thinning and precommercial thinning, and volume calculations (example in Figure 2).

Use of the system

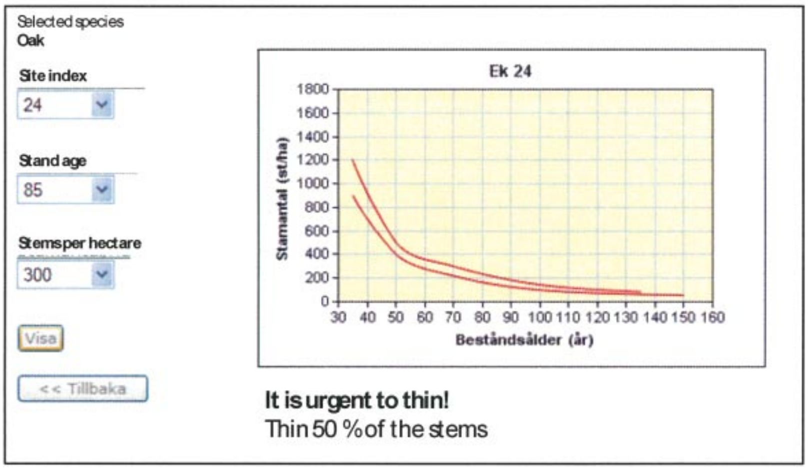
The knowledge system counted 100.000 single visits in 2007, but the use of the system is steadily increasing. It has become a part of a university course in forestry, and it is used by advisors at the Swedish Forest Agency and the Private Forest Association of Sweden.

Conclusions from the development

The process of the project gave some interesting experiences. First, the development of a joint system which involved many researchers from several disciplines was found out to be a very successful way of establishing interdisciplinary cooperation, where all were eager to reach the common goal, to finalize a usable and informative tool. Second, the tight involvement of private foresters gave an understanding among the researchers on the information needs of the end users, and a skill to adapt the scientific results into usable advises. Third, the loading of information gave insights in the knowledge gaps that need to be filled, but still the "best known" advises had to be delivered. Fourth, a tool like this has to be part of a well-established website in order to become known and used.

The knowledge system will be subject to a detailed evaluation among its users in 2008.

Figure 2. An example interactive tools that gives advices on thinning and precommercial thinning in different species. The figure shows the recommended number of stems per hectare in oak forests of various ages, the current situation, and an advice for action.



Selected species
Oak

Site index: 24

Stand age: 85

Stems per hectare: 300

It is urgent to thin!
Thin 50 % of the stems

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PHYSIOLOGICAL AND MORPHOLOGICAL RESPONSE OF YOUNG BEECH TO DIFFERENT LIGHT CONDITIONS (*FAGUS SYLVATICA* L.) IN SLOVENIA

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Introduction

In Slovenia forests cover over 60% of the country; sites of mixed broadleaf species, in particular natural beech forests predominate (Kutnar 2003). Increased risk is predicted in forest management, especially in forest ecosystems (Diaci 2007). In spite of the relatively wide and balanced presence of beech forests, several key questions about the future response of beech (*Fagus sylvatica* L.) to expected changes, such as temperature increase, redistribution of precipitation and increase of atmospheric CO_2 concentration, remain open. The quality of existing and future forests is closely connected with our understanding of tree-response to different light conditions, especially in an environment of reduced intensity under a mature canopy and in younger development stages. In view of the current climate projections (IPCC 1997, 2001) physiological performance, growth and competitive ability of beech may be adversely affected by such changing environmental conditions. The research goal was to define the range of photosynthesis under different canopy conditions (shelter, forest edge and gap) in relation to different light intensities and different concentrations of CO_2. Assimilation responses were further compared among similar light conditions on different plots, in different forest complexes and with limiting values of plagiotropic response in beech seedlings.

Material and methods

Research was performed on five research plots, belonging to two larger forest complexes: Pohorje, in floristic South-eastern Alpine division of the Illyrian province and Kočevje, belonging to Western Dinaric division. Measurements were performed on 10-15 year old beech trees in selected natural forest stands. Light conditions were defined above young beech trees with hemispherical photos and the indirect site factor (ISF) (Wagner and Müller-Using 1997) in percentage. Young beech trees were divided according to light conditions into: stand conditions ($ISF<20$), edge ($20<ISF<25$) and open area conditions, without the sheltering effect of a mature stand ($ISF>25$). In each group, four trees were randomly selected for photosynthesis and leaf nutrient measurements (Leco CNS-2000 analyzer). Light saturation curves were established for different light intensities and constant CO_2, temperature, flow and humidity, as well as A-Ci curves to define the response to different CO_2 concentrations. Photosynthesis was measured with an LI-6400 portable system on at least three sun leaves per plant, located in the upper third of the tree-crown height on every plot. Twelve plants were measured on each plot, four per same canopy light conditions. The parameter for morphological comparisons was the ratio between the length and height of plants (d/h), which increased in case of plagiotropic growth (> 1) (v Lüpke et al. 2004). The limiting value of light was defined after measurements of the ratio in three sequential vegetation periods. In the analysis, the values under similar light-intensity conditions were compared between plots.The limiting value below which plagiotropic growth was observed was defined for each plot separately. Data was fitted within a third-degree polynom. The solution of the derived second degree equation was the limiting value for light on each plot.

Results

The nitrogen content defined per leaf unit (mg/cm^2) was significantly different between light conditions in terms of canopy closure. The maximum assimilation rate (A_{max}) was measured at plots from the Pohorje complex, while the lowest values were measured on plots in Kočevski Rog. Differences between canopy, edge and open area responses were confirmed with high significance on all plots ($_{t\text{-test}}$; $p \leq 0{,}05$; df=22) except in Rajhenav (virgin forest), where there were no differences between edge and open area (gap) conditions. The assimilation response of young beech between the two forest complexes was also significantly different in all light categories ($_{t\text{-test}}$; $p \leq 0.01$; df=46). What was surprising was absence of differences between Pohorje-canopy and Kočevje-edge categories ($_{t=1.421}$; $p \leq 0.162$; df=46), which means that the assimilation rate in young beech is similar under different light conditions and young trees are more shade tolerant in the Kočevje region. The highest response to increased CO_2 concentration was evident on Pohorje plots and lowest in Kočevski Rog. Comparison of the calculated compensation point for CO_2 between light categories showed no significant differences, but differences between forest complexes were evident in all categories ($_{t=3.89}$; $p \leq 0.0037$; df=14). The response of different light categories on the same plot in virgin forest was more homogenous compared to managed forest and differences in response to different light categories were more expressed. In terms of absolute values, assimilation rates were highest in all categories in virgin forests, despite the comparable amount of nitrogen in leaves on the two plots.

Plagiotropic growth

On all plots, plants showed plagiotropic growth if light conditions dropped below 15% ISF. The ratio d/h on plots in the Kočevje complex reached higher values than those from Pohorje, differing on average by 10%. Comparison of clustered data from plots also confirmed the differences between the two complexes. The reaction of plants was better explained with diffuse than with direct light components.

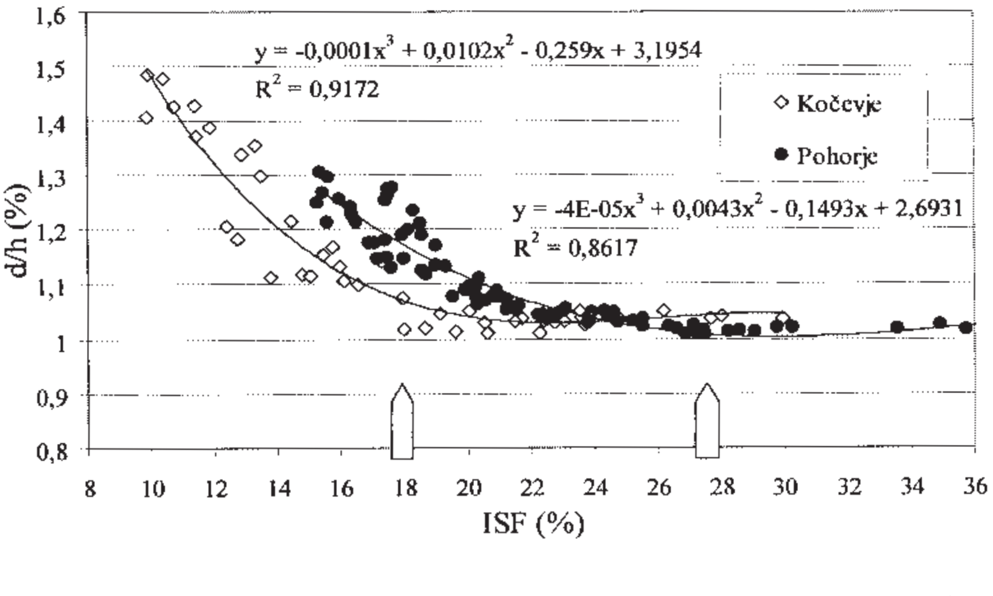

Figure 1: Comparison of ratio between trunk length and tree height in relation to light intensity (ISF) between two forest complexes, fitted by the same type of polynomial curve. Markers on the x-axis are the limiting light values that trigger plagiotropism.

Conclusions

1. Analysis confirmed response differences between beech under shelter, at the forest edge and in the open. The response of young beech to different CO_2 levels was similar to different light intensities, differences between managed and virgin forest were even more pronounced.
2. In spite of comparable light conditions, the highest assimilation rates were measured on the research plots of the Pohorje complex and lowest on plots in Kočevski Rog.
3. Differences in virgin forest between the same light categories were not very pronounced and were thus more homogenous than those observed in the managed forests. The photosynthetic yield in all categories was higher in virgin forest, while the light compensation point was higher on plots of the Pohorje forest complex.

Physiological response of young beech was in accordance with morphological adaptation to light. In Kočevski Rog, young beech is more shade tolerant, the relative response to increased light intensity and different CO_2 concentration is greater than the response of young beech on Pohorje within the same light intensities. Responses in managed and virgin forest are different: young beech trees in virgin forest are more shade-tolerant, and the reaction of different light categories to elevated CO_2 concentration is similar and more homogenous, compared to managed forest where differences between categories are more pronounced.

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