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The structure of natural oriental beech (*Fagus orientalis*) forests in the Caspian region of Iran and potential for the application of the group selection system

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Summary

In the Caspian region of northern Iran, research was carried out into the structure of pure and mixed stands of natural oriental beech (*Fagus orientalis* Lipsky) and the presence of regeneration in natural gaps of differing sizes. Results showed that beech stands usually occurred naturally in small groups of a similar age, whereas the age structure of larger areas (>1 ha) was more uneven. The total volume of stands investigated ranged from 480 m^3 in the pure stand to 600 m^3 in the mixed stand. Only one-third of total trees were classed as large timber (>55 cm diamater at breast height), which in turn accounted for two-thirds of total stand volume. Although beech regeneration within the large gaps (>0.1 ha) showed the best growth characteristics, more well-formed saplings were found within medium-sized gaps (0.02–0.05 ha). From the results, it was concluded that the group selection system, with the removal of two to four main trees, could be a suitable method for managing oriental beech stands.

Introduction

The Caspian region is a humid zone in northern Iran with an annual precipitation of between 600 mm in the east and 2000 mm in the west of the region. The pure and mixed oriental beech forests (*Fagus orientalis* Lipsky) are situated in a belt which lies between 700 and 2000 m a.s.l. Forestry activities in Caspian region are in their infancy and the beech forests have been managed using even-aged silvicultural systems, mostly shelterwood systems, for the last three decades. However, the shelterwood systems have only been partly successful because of regeneration problems.

Another option for management of these forests in a sustainable way would be to use a continuous cover approach by the use of silvicultural selection systems. In order to use the selection system successfully, a close survey of the structure and growth conditions is absolutely essential (Schütz, 1997). This not only applies to the growth potential of the overstorey, but also the dynamics of natural regeneration in gaps, which is so important for achieving an irregular structure. This has certainly been the case with other studies into the beech virgin forests of eastern Europe. For example, Leibundgut (1993), Korpel (1995) and Burger *et al*. (2001) noted that natural regeneration normally occurs in small gaps. They also noted that stand structure at some stages closely resembles the structure of selection forests. This fact has also been recently observed in oriental beech forests in the Caspian region (Eslami, 2000; Shahnavazi, 2001).

The aim of this study was to survey the structure of beech stands and to study the quantitative and qualitative characteristics of beech regeneration in canopy gaps, in order to determine an appropriate gap size for the use of the group selection system.

Materials and methods

Typical examples of pure and mixed oriental beech (*Fagus orientalis* Lipsky) forests were selected in the Mazandaran province of northern Iran. In order to study the structure of beech stands, two main sample plots, each covering 4 ha, were laid out in pure and mixed natural beech stands at each site. These were then divided into two divisions (2 ha), into four subdivisions (1 ha), into eight plots (0.5 ha) and into sixteen subplots (0.25 ha) (Figure 1). All trees with a diameter at breast height (d.b.h.) of >7.5 cm were recorded, and height and canopy measurements were taken to allow the vertical and horizontal profiles of the stands to be studied. The pure beech stand was composed of 91 per cent beech and 9 per cent other broadleaved trees, whereas the mixed stand consisted of 70 per cent beech and 30 per cent other broadleaved species.

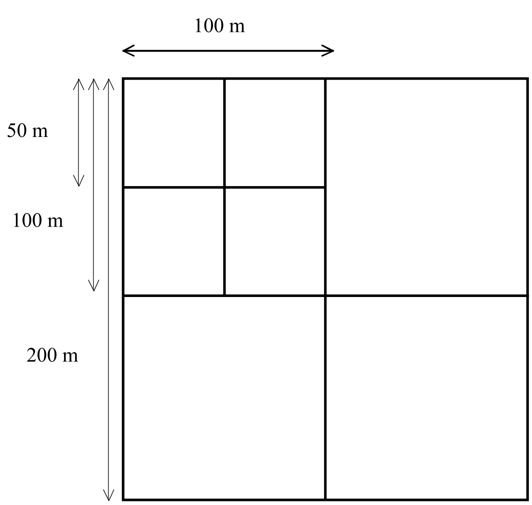

Figure 1. Pattern of the sample plots in the study area.

In order to study the regeneration development within naturally occurring gaps in the stand, four sizes of crown gap were chosen: <0.02 ha, 0.02–0.05 ha, 0.05–0.1 ha and >0.1 ha. One transect, 1 m wide, was established across the widest diameter of each gap. Each transect was divided into plots (1 × 1 m); the number of saplings of different species, stem base diameter, height and mode of branching of all beech saplings were studied in every second plot. The number of assessed plots on the transects was five in 0.02 ha canopy gaps, 11 in 0.02–0.05 ha, 16 in 0.05–0.1 ha and 23 in >0.1 ha gaps.

In order to determine the relative light intensity, four pictures were taken with the aid of a fish-eye lens in four locations in each of the gaps. The pictures were taken in the middle of the gap, external edge of the gap, internal edge of the gap and between the gap centre and gap edge (Figure 2). Using the method of Anderson (1964) and Thormann (2001), the relative light intensity was calculated for each picture.

Analysis of data was by SPSS software using analysis of variance. The Tukey test and the χ^2-test were used to compare treatment means where appropriate.

Results

Stand structure and quantitative characteristics

The results showed that in both stands of the sample 0.25 and 0.5 ha plots, the distribution of stem number per diameter class was heterogeneous but the general view of the curves generally showed an even-aged structure (Figure 3a, b). However, at a larger scale, 1 ha plots and above, an uneven-aged pattern and irregular distribution

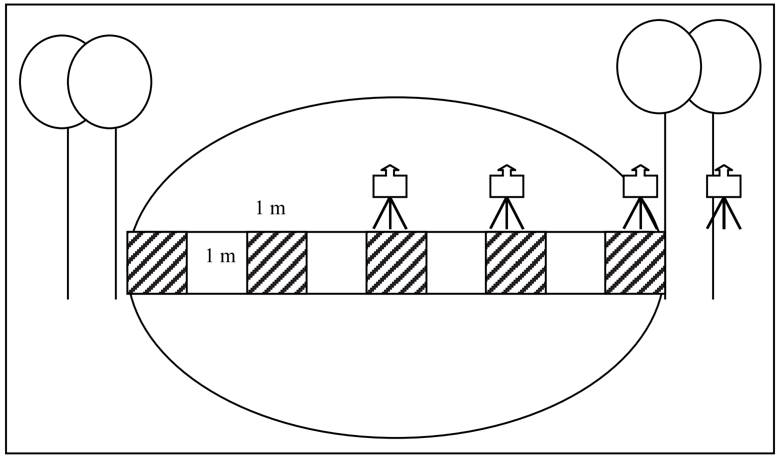

Figure 2. Pattern of the plots on a transect within a gap.

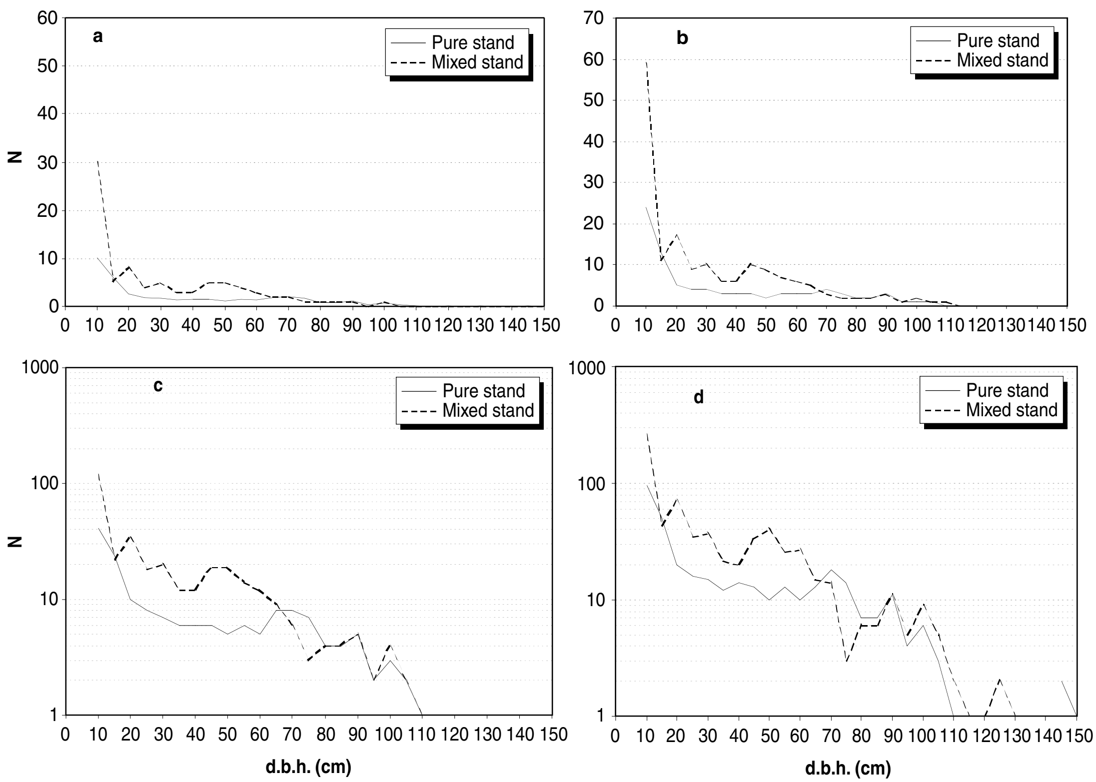

Figure 3. Frequency distribution of stems in (a) 0.25 ha, (b) 0.5 ha, (c) 1 ha and (d) 2 ha in the studied pure and mixed beech stands.

of trees was more apparent (Figure 3c). In the 2 ha sample plots, the frequency distribution of stem numbers displayed a noticeably uneven-aged structure (Figure 3d). This was due to the fact that several even-aged groups of trees existed beside each other. The same trend was observed in the 4 ha sample plots. Figure 4 illustrates the vertical and horizontal profile of the mixed beech stand.

To examine the structure of the stands, data from the 1 ha plots were used. The results showed that the stem number and basal area per hectare, and consequently the volume of the mixed stand were higher than in the pure stand. In the pure stand, the total basal area was 31.8 m^2, while in the mixed stand it was 41 m^2 (Table 1). Beech accounted for more than 80 per cent of basal area and volume of the pure stand, whereas the proportion of basal area and volume of beech in the mixed stand was slightly more than 50 per cent.

The percentage of number of stems and tree volume for different tree sizes is shown in Table 2. The percentage of number of stems per hectare for large timber in the pure and mixed stands was only 32 per cent and 17 per cent, respectively; this accounted for 86.6 per cent and 69.4 per cent of the total volume per hectare (Table 2). In other words, large timber made up more than two-thirds of total volume.

Regeneration characteristics

In small and medium sized gaps, saplings tended to be in the centre (Figure 5a, plots 3 and 4; Figure 5b, plots 4–9), whereas in larger sized gaps there was some evidence that saplings were concentrated at the edges (Figure 5d: plots 1–9 and 15 –23). Only a small number of saplings were recorded at the centre of the large gaps (Figure 5d: plots 11 and 12), and most of these were light-demanding species.

As illustrated in Table 3, the stem base diameter and height of beech saplings increased in line with increasing gap size and relative light intensity. The differences observed in stem base diameter and sapling height between the gaps were statistically significant. The highest proportion of unforked saplings was observed in medium-sized gaps, and this difference was statistically significant compared with small- and large-sized gaps. The percentage of forked and broom-shaped saplings varied in direct proportion (with the exception of small-sized gaps) and increased with

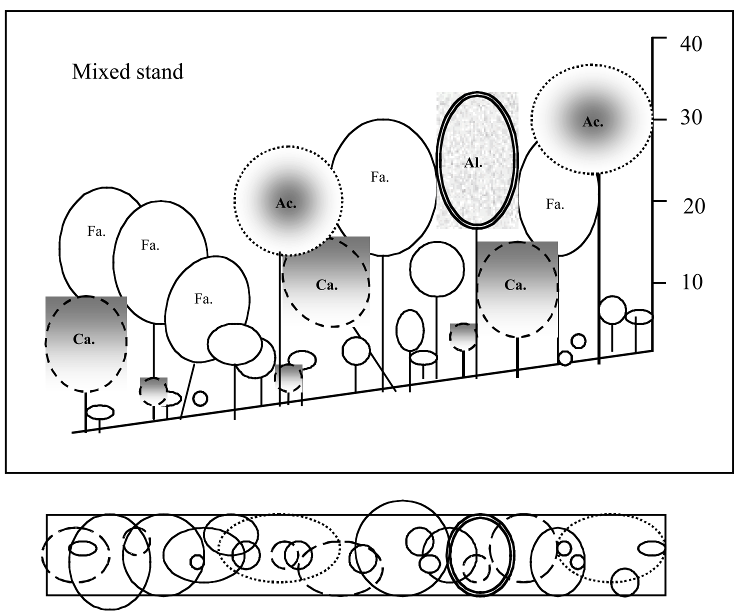

Figure 4. Structure pattern of the studied mixed beech stands (Fa. = beech, Ca. = hornbeam, Ac. = maple, Al. = alder).

Table 1: Quantitative characteristics of studied pure and mixed beech stands (data from 1 ha plot)

		Basal area (m²/ha)					Volume (m³/ha)				
		Beech		Other spp.			Beech		Other spp.		
Stand	N/ha	B.a.*	(%)	B.a.*	(%)	Total	Vol.†	(%)	Vol.†	(%)	Total
Pure	167	26.9	84.6	4.9	15.4	31.8	406.5	84.2	77.1	15.8	483.6
Mixed	336	21.6	52.7	19.4	47.3	41.0	316.6	52.5	286.5	47.5	603.1

* B.a. = basal area.
† Vol. = volume.

Table 2: Frequency of stem number (*n*) and tree volume (m³) for different timber sizes in the studied stands (data from 1 ha plot)

	Timber size (pure stand)				Timber size (mixed stand)			
	Small (<30 cm)	Medium (35–50 cm)	Large (>55 cm)	Total	Small (<30 cm)	Medium (35–50 cm)	Large (>55 cm)	Total
n	89.0	24.0	54.0	167	220.0	59.0	57.0	336
%	53.3	14.4	32.3	100	65.5	17.5	17.0	100
Volume	20.2	44.5	418.9	483.6	59.2	125.3	418.6	603.1
%	4.2	9.2	86.6	100	9.8	20.8	69.4	100

Table 3: Some quantitative and qualitative characteristics of beech saplings in relation to gap size

Gap size (ha)	Relative light intensity (%) Min.	Max.	No. of saplings	S.B.D.† (mm)	Height (cm)	Unforked (%)	Forked and broom-shaped (%)
<0.02	2.0	41.8	89	11.2[b*]	83.5[c*]	64.3[c*]	35.7[a*]
0.02–0.05	3.5	55.8	99	12.6[c]	105.9[b]	82.7[a]	17.3[c]
0.05–0.1	5.5	57.6	71	13.5[b]	105.9[b]	75.9[b]	23.1[b]
>0.1	11.4	63.1	102	14.4[a]	114.8[a]	65.6[c]	34.4[a]

* Different letters indicate significant differences at level of <5%.
† S.B.D. = stem base diameter.

increasing gap size, from 17.3 to 34.4 per cent (Table 3). The reason for this was probably that a high proportion of saplings with horizontal branches (plagiotropic saplings) were in small gaps, which had lower light intensity.

Discussion and conclusion

The plenter structure is rarely found in natural forests; when it does occur, it lasts only for a short period of time, during the so-called 'Plenter stage' and 'Ageing stage' (Korpel, 1995). The genuine plenter system is actually a man-made system; and this can have a longer life span, provided that the appropriate silvicultural operations are continued (Schütz, 1997). The results of this investigation showed that the natural beech stands in the Caspian region illustrate an irregular, heterogeneous and uneven-aged structure at the minimum area of 1 ha, whereas the irregular structure of European mixed fir–spruce–beech

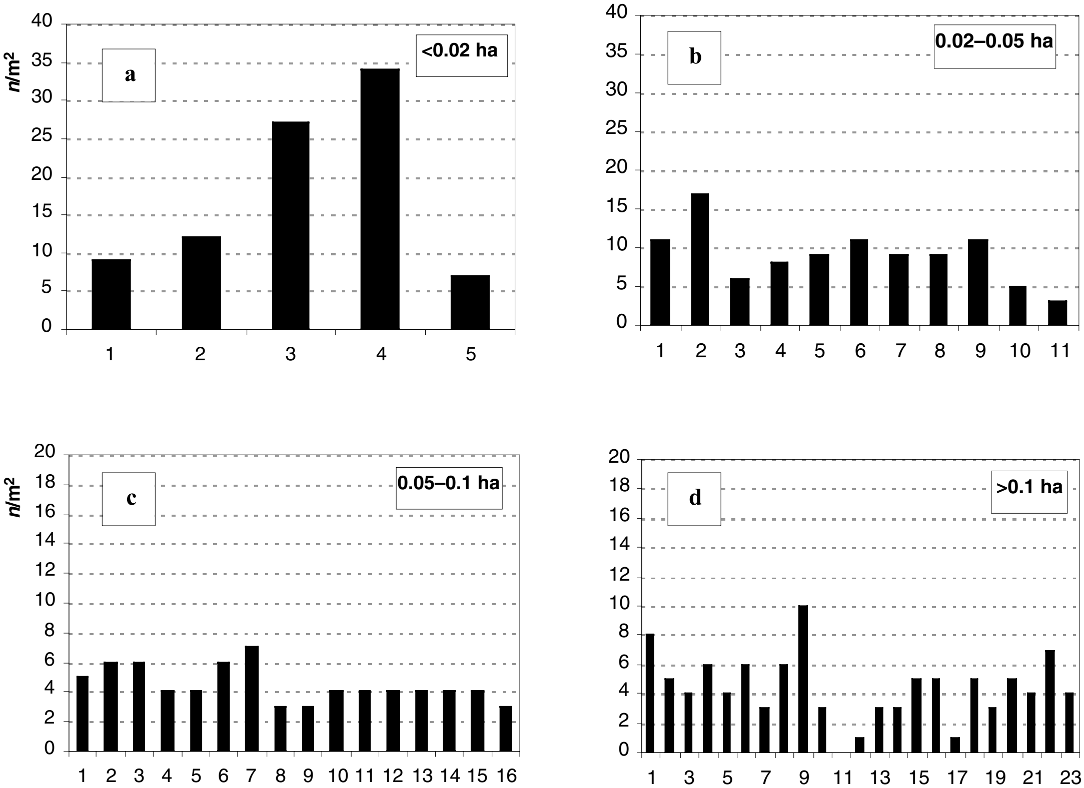

Figure 5. Distribution of saplings according to the position of micro-sample plots of different sized gaps (from one edge – through the centre – to another edge).

stands is distinguishable on much smaller areas (Schütz, 1989).

Moreover, a comparison of volume distribution in d.b.h. classes of the studied stands and some other oriental beech stands with European beech stands (Table 4) showed that all the beech stands in northern Iran are old and contain a higher proportion of large trees. The low proportion of volume in smaller dimensions in Caspian beech stands is obvious from Table 4 and this suggests a possible problem with stem recruitment if the structure of the forests is not changed.

The studied stands regenerate in different sized groups, but different cohorts in the continuous regeneration process can be observed. Korpel (1995) and Mataji (1999) observed similar results in Slovakian virgin beech forests and Caspian natural beech forests, respectively. The presence of regeneration in gaps is very important for achieving an irregular, uneven-aged structure. In the stands described in this study, gaps only occur when an old tree dies and falls down. The gap size depends on the tree crown dimension and on the number of dead trees, which facilitates the regeneration of beech in the gaps. For the regulation of irregular forests, light is more important than lateral competition (Schütz, 1997). On the one hand, excess light in large gaps results in increased diameter and height growth of the saplings, but could negatively affect the form of the saplings. This confirms the results of previous studies (Brown, 1952; Le Tacon, 1983; Roloff, 1986; Sagheb-Talebi, 1995, 1996).

In order to maintain the irregularity and the uneven-aged structure of the stands in the long term and to accelerate the regeneration process, regeneration is best established in groups. Taking into account the stand structure, the high

Table 4: Comparison of volume distribution in d.b.h. classes in the studied and some other oriental beech stands with European beech stands

	Distribution of volume/ha in d.b.h. classes (%)				
Forest stand	<30	35–55	>50	Total	Reference
Pure beech	4	9	87	100	Recent study
Mixed beech	10	21	69	100	Recent study
Mixed beech (in Caspian Region)	9	12	79	100	Fallah (2000)
Mixed beech (in Caspian Region)	6	13	81	100	Sagheb-Talebi*
Beech stand (in Swiss Jura)	15	34	51	100	Schütz (1989)
Beech stand (in Langula, Germany)	36	32	32	100	Schütz (2001)

* Personal data (internal report, not published).

shade-tolerance of oriental beech, the crown dimension (a diameter of 5–12.5 m, Amani and Hassani, 1998) and the satisfactory development of natural regeneration in medium-sized groups (0.02–0.05 ha), it can be concluded that the group selection system, with the removal of two to four main trees, could be a suitable method for managing beech stands. However, it should be mentioned that the recommendation given in this study is a working hypothesis and would need to be validated by further investigations.

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