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# Regeneration process in natural uneven-aged Caspian beech forests of Iran (reviewed paper)

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Keywords: Uneven-aged; semi-virgin; *Fagus orientalis*; development stages; Iran. FDK 228 : 231 : (55)

**Abstract:** Regeneration process was studied within twenty-two gaps produced from natural falling of trees in a semi-virgin mixed forest of oriental beech in Iran. The area of the openings varied between 163 m<sup>2</sup> and 1683 m<sup>2</sup>, caused by falling of 1 to 6 trees. Natural regeneration depended on the gap size, and was established within the openings with different compositions.

**Abstract:** Der Verjüngungsprozess in urwaldähnlichen Orient-Buchenmischwäldern in Iran wurde in 22 natürlichen Lücken untersucht. Verursacht durch das Umfallen von einem bis sechs Bäume variierte die Lückengröße zwischen 163 m<sup>2</sup> und 1683 m<sup>2</sup>. Die natürliche Verjüngung hing von der Lückengröße ab und zeigte sich innerhalb der Öffnungen in unterschiedlichen Zusammensetzungen.

## 1. Introduction

The Caspian region is a mountainous humid zone in northern Iran, which extends from -20 meters below sea level in the southern coastal plain of the Caspian Sea to 2500 meters above sea level (m.a.s.l.) on the northern slopes of the Alborz mountains. This region is covered with temperate deciduous forests. Oriental beech (*Fagus orientalis* Lipsky) is the most important commercial species in the Caspian forests, which forms pure and mixed stands (*Fagetum hyrcanum*) in a belt between 700 and 2000 m.a.s.l. (SAGHEB-TALEBI & SCHÜTZ 2002).

Management plans are prepared for only 60% of the surface of Caspian forests while undisturbed, unmanaged and natural semi-virgin beech forests are still found within the region. The structure of undisturbed stands depends on the successional or development stages. Although definitions and the use of expressions vary in different European countries (PARVIAINEN *et al.* 1994), it has nevertheless been shown that three main stages of initial, optimum and decay can be distinguished in virgin and semi-natural forests (LEIBUNDGUT 1993, KORPEL' 1995, EMBORG *et al.* 2000). These stages occur simultaneously as a mosaic whereas the climax -or the aging phase- plays the main role concerning the time span and the spatial distribution (PARVIAINEN *et al.* 1994).

Studies in oriental beech forests indicated that the structure of such undisturbed beech stands are more or less irregular and uneven-sized (ESLAMI 2000, FALLAH 2000, SAGHEB-TALEBI & SCHÜTZ 2002) and that natural regeneration normally occurs in small gaps (SHAHNAVAZI 2001, MOUSAVI 2001, GHOURCHIBEIGY 2002, SAGHEB-TALEBI & SCHÜTZ 2002). Similar results have been reached in other studies on the beech virgin forests of Eastern

Europe (KORPEL' 1995, BURGER *et al.* 2001). In a slowly decaying stand, shade tolerant tree species regenerate underneath a spatially opened canopy and dominate throughout the entire cycle of development (PARVIAINEN *et al.* 1994).

The aim of this study was to survey the structure of undisturbed oriental beech stands and to study the relationship between regeneration and canopy openings in different development stages, in order to apply the results for selecting appropriate silvicultural operation that take the natural structure of the stand into consideration.

## 2. Material and Methods

A typical example of semi-virgin (natural, unmanaged) mixed forests of oriental beech was selected in Mazandaran province at 51°10' North and 36°35' East, extending between 1350 and 1650 m.a.s.l. The mean annual precipitation and temperature of the region reach 1800 mm and 8 °C, respectively. The soil type is forest brown soil with a 3-4 cm layer of humus. Soil texture is loam and clay-loam with a pH of 5,5. Since forest management in Iran started only 45 years ago and is therefore relatively recent, many parts of the Caspian forests are natural and unmanaged. This reserved beech forest has thus not been subject to silvicultural intervention in 45 years. Only 2 elm trees were eliminated because of Dutch elm disease.

Taking various definitions of development stages into account (LEIBUNDGUT 1993, PARVIAINEN *et al.* 1994, KORPEL' 1995, EMBORG *et al.* 2000) three main stages of initial, optimal and decay were distinguished in the stand. Initially, we planned to establish 3 sample plots in each development stage, but only two areas of optimal stage were found in the whole area studied. We therefore laid out eight main sample plots, each covering 1 ha (100 x 100 m), in different development stages of the studied forest with an area of 43 hectares, in order to study the structure and quantitative characteristics of the stand. All trees with a diameter of > 7.5 cm at breast height (d.b.h.) were recorded and the height of all trees within the sample plots were measured to allow the vertical structure of the stands to be studied. The number of dead laying trees in different diameter classes were also recorded.

In addition, four micro sample plots, each covering 25 m<sup>2</sup> (5 x 5 m), were laid out in the four corners of each main sample plot, in order to study the regeneration (Figure 1). All seedlings and saplings were recorded and divided into two groups: 1) seedlings smaller than 1,30 cm; and 2) seedlings and saplings higher than 1,30 cm. The second group was then divided into two subgroups of a) d.b.h. = 0-2,5 cm; and b) d.b.h. = 2,5-7,5 cm.

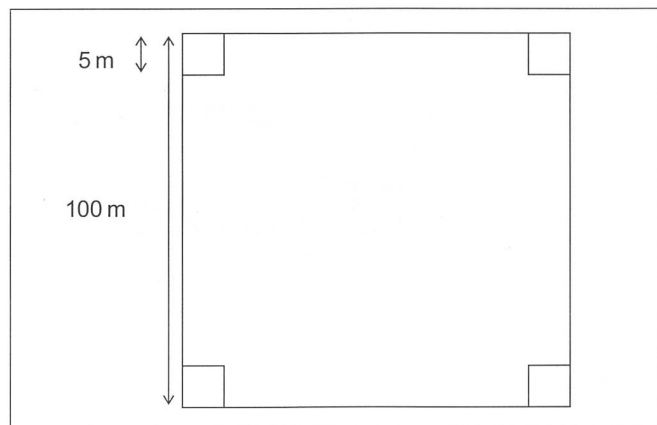


Figure 1: Pattern of the sample plots in the study area.

Abbildung 1: Design der Versuchsflächen im Untersuchungsgebiet.

Moreover, 22 gaps produced from natural falling of trees within the area were identified, and the surface of the openings as well as the regeneration process, studied.

Since we have the preliminary results of a whole project, this paper presents only the results of three sample plots, each in one development stage, without using any statistical test. The results of all sample plots, using statistical tests, will be processed with other studies and will be published in a separate paper in the future.

### 3. Results

#### 3.1 Stand

The percentage of number of stems, tree volume and dead trees for different tree sizes is shown in Table 1. The results showed that the stem number per hectare varied between 324 in the decay stage and 467 in the optimal stage. The percentage of stems per hectare for small timber was the highest with more than 60% in all stages; this accounted for less than 21% of the total volume.

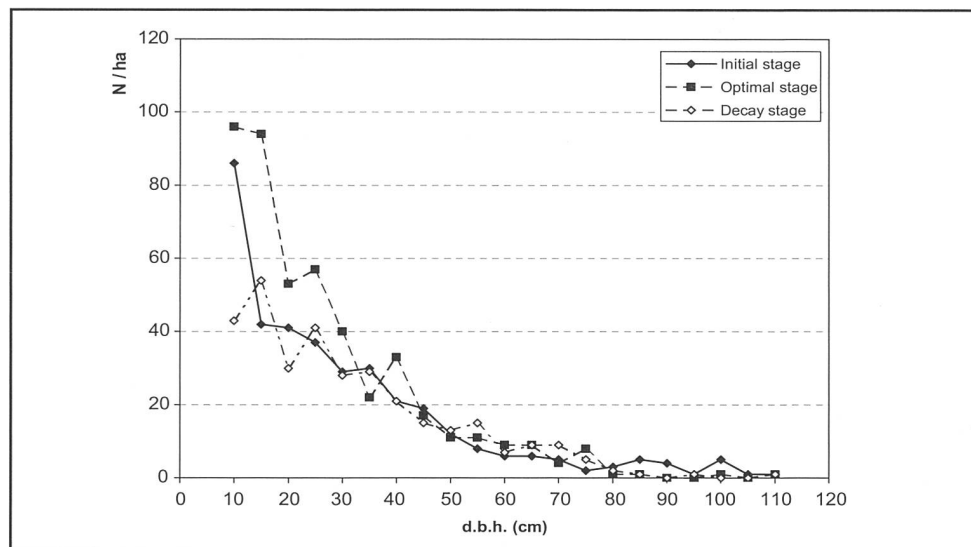


Figure 2: Diameter distribution of the studied beech stands.

Abbildung 2: Durchmesserverteilung der untersuchten Buchenbestände.

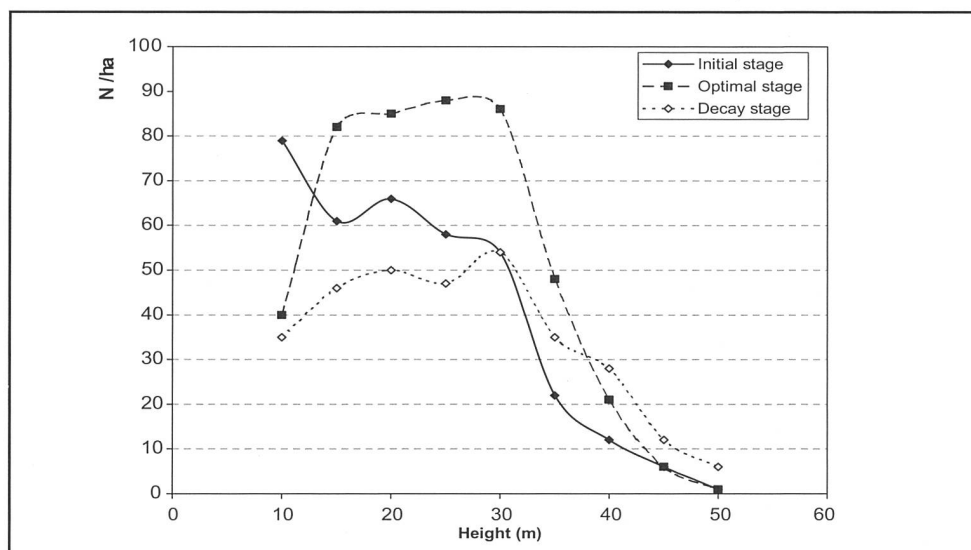


Figure 3: Height distribution of the studied beech stands.

Abbildung 3: Höhenverteilung der untersuchten Buchenbestände.

Table 1: Quantitative characteristics of development stages studied in mixed oriental beech stands.

Tabelle 1: Quantitative Charakteristiken der Entwicklungsstufen in den untersuchten Orient-Buchen-Mischwaldbeständen.

Development stage	Timber size (cm)	Number ha <sup>-1</sup>		Volume (m <sup>3</sup> ha <sup>-1</sup> )		Dead tree		
		N	%	m <sup>3</sup> ha <sup>-1</sup>	%	N	m <sup>3</sup> ha <sup>-1</sup>	%
Initial	Small (< 30)	235	64,6	56,5	11,2	8	1,6	0,3
	Medium (35-50)	90	25,0	153,7	30,5	-	-	-
	Large (> 55)	39	10,4	294,0	58,3	2	14,6	2,9
<b>Total</b>		<b>364</b>	<b>100,0</b>	<b>504,2</b>	<b>100,0</b>	<b>10</b>	<b>16,2</b>	<b>3,2</b>
Optimal	Small (< 30)	340	72,8	89,5	21,5	6	1,6	0,4
	Medium (35-50)	94	20,1	159,6	38,4	-	-	-
	Large (> 55)	33	7,1	166,1	40,1	-	-	-
<b>Total</b>		<b>467</b>	<b>100,0</b>	<b>415,2</b>	<b>100,0</b>	<b>6</b>	<b>1,6</b>	<b>0,4</b>
Decay	Small (< 30)	196	60,5	57,4	14,2	5	1,5	0,4
	Medium (35-50)	93	28,7	161,8	40,0	1	1,0	0,2
	Large (> 55)	35	10,8	184,9	45,8	1	16,6	4,1
<b>Total</b>		<b>324</b>	<b>100,0</b>	<b>404,1</b>	<b>100,0</b>	<b>7</b>	<b>19,1</b>	<b>4,7</b>

**Table 2:** Frequency and surface of studied openings according to number of fallen trees.

Tabelle 2: Häufigkeit und Fläche der untersuchten Lücken nach Anzahl gefallener Bäume.

Number of fallen trees	Number of gaps	Surface of the opening (m <sup>2</sup> )		
		Minimum	Maximum	Mean
1	7	163	563	363
2	8	248	798	552
3	4	267	721	540
4	1	–	1190	1190
5	1	–	1428	1428
6	1	–	1682	1682

**Table 3:** Number of seedlings and saplings in different development stages of studied beech stands.

Tabelle 3: Anzahl Sämlinge und junger Bäume in verschiedenen Entwicklungsstufen in den untersuchten Buchenbeständen.

Development stage	Seedling (h <1,30 m)	D.B.H. (cm)		Total
		0–2,5	2,5–7,5	
Initial	6200	3400	1400	11000
Optimal	5100	400	600	6100
Decay	17000	500	100	17600

The total volume varied between 404,1 m<sup>3</sup>ha<sup>-1</sup> in the decay stage and 504,2 m<sup>3</sup>ha<sup>-1</sup> in the initial stage. The percentage of volume per hectare for large timber was the highest with more than 40% in all stages; however the highest amount was recorded in the initial stage.

The number of dead trees per hectare varied between 6 in optimal stage, which was recorded in the small timber size, and 10 in initial stage, which was recorded in small and large timber size (Table 1). The volume of dead trees varied between 1,6 m<sup>3</sup>ha<sup>-1</sup> in the optimal stage and 19,1 m<sup>3</sup>ha<sup>-1</sup> in the decay stage; this accounted for 0,4 percent and 4,7 percent of the total volume per hectare, respectively.

The diameter distributions were heterogeneous and irregular, reverse J-shape, in all three stages and showed a general view of an uneven-aged stand (Figure 2). However, it was to be expected that this distribution would be similar to an even-aged stand in the optimal stage. This issue was more apparent in the distribution of stem number per height class. The height distribution was more uniform and regular in the optimal and decay stages, while it was heterogeneous in the initial stage and showed a vertical irregularity (Figure 3).

### 3.2 Gaps and regeneration

Results showed that the area of the 22 studied openings varied between 163 m<sup>2</sup> and 1682 m<sup>2</sup>, caused by the falling of 1 to 6 trees (Table 2). The highest frequency of gaps was observed with the falling of 2 and 1 trees, respectively, which created openings with an average surface of 360 to 550 m<sup>2</sup>. However, it should be noted that gaps were found in the initial and decay stages and no regeneration gap was observed in the optimal stage with regular structure.

Natural regeneration depended on the gap size, and was established within the openings with different compositions. As illustrated in Table 3, the least number of regeneration was observed with 6100 in the optimal stage, scattered over the whole area of 1 ha with no spatial pattern. The highest number of regeneration was found with 17 600 in the decay stage, con-

centrated in the gaps making a regeneration cone. Generally, the highest proportion of regeneration within the studied stands was observed as seedlings with a height of less than 1,30 m.

## 4. Discussion

Considering the results, one can conclude that the structure of studied undisturbed oriental beech forests is irregular and uneven-aged. Previous investigations confirm this finding too (ESLAMI 2000, FALLAH 2000, SAGHEB-TALEBI & SCHÜTZ 2002). But this structure is more apparent in the so-called initial and decay development stages, where the presence of dead trees and regeneration play an important role and support the vertical irregularity. Although the distribution of stem number per height class in the optimal stage illustrates a regular structure, a wide range of diameter distribution indicates uneven-sized stand. In this stage, presence of dead trees and regeneration are weak.

MOUNTFORD (2002) has shown in the near natural beech forest at La Tillaie reserve in France, that dead wood tends to pulse to high levels about every 200–300 years following the rapid break-up of old-growth stands. However, in his survey most material fell during windstorms in the 1990s. This occurs in our studied semi-virgin beech forests in the decay stage. On the other hand, in his comprehensive investigations in European virgin beech forests of Slovakia KORPEL' (1995) found that the development or life cycle of beech lasts between 220 and 250 years; the decay stage occurs during the last third of this cycle. Taking into account the high potential of shade tolerance, it is to be expected that the development cycle of oriental beech lasts longer than 250 years in the Caspian region.

The main frequency of natural openings in the studied undisturbed stands were produced by falling of one or two trees, which made a suitable condition for the presence of young generation in medium-sized groups. This supports the uneven-ageness and vertical heterogeneity. Studies of KORPEL' (1995) showed that the regeneration in European virgin beech forests occurs in small groups with a surface of 100 to 200 m<sup>2</sup>, and openings of over 2000 m<sup>2</sup>, which could be covered by regeneration in the late decay stage, are a seldom occurrence.

In order to manage such uneven-sized stands, we could learn about the natural development process in undisturbed forests. Determination of development stages, age-, diameter- and height structure of the stands could lead us to an application of appropriate silvicultural operations or treatments at every stage. This is very important for achieving and maintaining an irregular, uneven-aged structure as well as for sustainable management of beech stands. In order to counter the disadvantages caused by individualization in single-stem plentering for broadleaved species, SCHÜTZ (2002) suggests the possibility of a compromise: full irregular models based on the steering of beech in small clusters. He adds that this can be achieved by means of the classical technique of irregular group shelterwood felling, or by working with different size groups, arranged irregularly in time and space without further expansion of the openings. The dimensions of the openings can vary considerably depending on the light requirements of the target tree species.

Taking into account the stand structure and light regime in small and medium-sized gaps, the potential for the application of the group selection system in Caspian beech forests has recently been investigated (SAGHEB-TALEBI & SCHÜTZ 2002), where the removal of two to four main trees is proposed.

## Summary

In the Caspian region of northern Iran, research was carried out in semi-virgin (natural, unmanaged) mixed forests of oriental beech (*Fagus orientalis* Lipsky) covering an area of 43 hectares. Twenty-two gaps produced from natural falling of trees within the area were recognized, and the area of the openings together with the regeneration process was studied. Results showed that the area of the openings varied between 163 m<sup>2</sup> and 1683 m<sup>2</sup>, caused by falling of 1 to 6 trees. Natural regeneration depended on the gap size, and was established within the openings with different compositions. The regeneration process occurs in the so-called initial and decay development stages of virgin forests, which supports the uneven-ageness, heterogeneity and vertical irregularity of the stands. No regeneration gap was observed in the optimal stage with regular structure.

## Zusammenfassung

### Verjüngungsprozess in natürlichen ungleichaltrigen Orient-Buchenwäldern in Iran

Die Untersuchung wurde in urwaldähnlichen (natürlich, unbewirtschaftet) Orient-Buchenmischwäldern (*Fagus orientalis* Lipsky) am Kaspischen Meer in Nordiran auf 43 Hektaren durchgeführt. 22 Lücken innerhalb des Untersuchungsgebiets, die durch natürliches Umfallen der Bäume entstanden, wurden ausgewählt und zusammen mit dem Verjüngungsprozess untersucht. Die Resultate zeigen, dass, verursacht durch das Umfallen von einem bis sechs Bäume, die Lückengrösse zwischen 162 m<sup>2</sup> und 1683 m<sup>2</sup> variiert. Die natürliche Verjüngung hängt von der Lückengrösse ab und zeigt sich innerhalb der Öffnungen in unterschiedlichen Zusammensetzungen. Der Verjüngungsprozess erscheint in der Initial- und Zerfallsphase von Urwäldern, was Ungleichaltrigkeit, Heterogenität und vertikale Ungleichheit der Bestockung fördert. Keine Verjüngungslücke konnte in der Optimalphase mit gleichmässiger Struktur beobachtet werden.

Übersetzung: SANDRA HORAT

## Résumé

### Processus de régénération dans des hêtraies naturelles et inéquiennes d'Iran

L'étude a porté sur 43 hectares de hêtraies mixtes (*Fagus orientalis* Lipsky), primaires (naturelles, non exploitées) dans la région de la mer Caspienne, au nord de l'Iran. Au total, 22 trouées, dues à la chute naturelle d'arbres, ont été choisies dans le périmètre et étudiées conjointement avec le processus de régénération. Les résultats montrent que les ouvertures sont causées par la chute de un à six arbres et que leur surface varie de 162 à 1683 m<sup>2</sup>. La composition du rajeunissement naturel dépend de la grandeur des trouées. La régénération apparaît dans les phases initiale et de délabrement des forêts vierges, ce qui favorise les boisements inéquiennes, hétérogènes et irréguliers sur le plan vertical. Aucune trouée de rajeunissement n'a été observée durant la phase optimale, à structure homogène.

Traduction: CLAUDE GASSMANN

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