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Effect of Shelter-Wood Logging Method on the Quantity and Quality of Beech Natural Regeneration

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Abstract: The main objective was to determine the effect of shelter-wood logging method on the quality and quantity of natural regeneration of beech (*Fagus orientalis* Lipsky). To achieve this, an affectation of a beech forest district was chosen as the study site in N Iran (the western Caspian region) which has been logged by shelter-wood logging method. The random systematic sampling method with an intensity of 3.3% and a transect sampling was applied for the quantitative and qualitative studies, respectively. Four major silvicultural characteristics as healthy, mode of branching, mode of leaning and straightness were considered in transects. Present results showed that the quality and quantity of beech trees and the mixing ratio of regenerations were modified since the beginning of the shelter-wood logging period. This investigation revealed that eventually the beech regeneration quantity was in the weak class according to the classification of Forest and Range Organization of Iran (FRO). Quality of the beech regeneration was ultimately evaluated as a desired level however more than 90% of the regenerations was crooked relating to the effect of canopy gaps created by the shelter-wood logging method. High topography of the study site, dependency of the beech seed years on climatological factors, the high shade-tolerance of the oriental beech and ruinous effect of the forest dwellers as well as livestock overgrazing were combined to attain to a relatively unsuccessful shelter-wood logging method.

Key words: Beech forest, natural regeneration, qualitative and quantitative studies, shelter-wood logging method

INTRODUCTION

Forest management plans have been preparing for timber production in N Iran, Caspian forests, in order to put utilization practices on a sound and reasonable basis. Each forestry plan which is necessary for the economic and sustainable use of forests, propose a special logging method for utilization. The plans need to be evaluated definitely after the logging period is over. As the maintenance of species entirely depends on regeneration, one of the most prominent methods for this evaluation is investigations on the effect of management plans on the quality and quantity of dominant species regenerations. Consequently, researches of the effect of the logging method on the quality and quantity of the dominant species regenerations contribute to develop management methods with reduced effects. Changes in regeneration quality, quantity and diversity in response to the human activities are classified in several degrees as follows by Reader *et al.* (1991):

- Low impacts, if no modification in species richness occurs
- Intermediate impacts, if species richness is slightly modified and
- High impacts, if the number of present species in the system substantially declines. Forest and Range Organization of Iran (FRO) also categorized the composition (mixing ratio) and quantitative and changes in regeneration according to Table 1 and 2 (FRO, 1994).

One of the most important commercial species in the Caspian region of Northern Iran is Oriental Beech (*Fagus orientalis* Lipsky) which has pure and mixed forests in the 700-2000 m above the Caspian Sea level. The beech forests have been managed using an even-aged silvicultural system, mainly the shelter-wood method for the last three decades. This previously popular system has partly been successful due to regeneration problems (Sagheb-Talebi and Schutz, 2002). Although the impacts

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Table 1: Classification of Forest and Range Organization of Iran (FRO) for the mixing ratio of regeneration (Desired species here refer to regeneration of industrial species such as Beech, Alder, Oak, Maple, etc)

Regeneration ratio	Class
75% < Desired species	Very good
50 % < Desired species <75%	Good
25 % < Desired species <50%	Medium
Desired species < 25%	Weak

Table 2: Classification of Forest and Range Organization of Iran (FRO) for quantity of regeneration

Regeneration No. per hectare (N ha^{-1})	Class
N ha^{-1} < 1000	Low
1000 < N ha^{-1} < 3000	Weak
3000 < N ha^{-1} < 5000	Medium
5000 < N ha^{-1} <10000	Good
N ha^{-1} >10000	Excellent

of silvicultral. methods as well as shelter-wood logging on the diversity have been widely studied, a few researches describe the effect of human activities and management on the regeneration quality and quantity. Since the quality and quantity of regeneration could have important effects on the forest management and timber supply, the objective of the present study was chiefly to evaluate the effect of the shelter-wood logging method on the quality and quantity of beech natural regeneration.

The study was carried out in a beech forest located in N Iran which has been managed by the shelter-wood logging method. The first forestry plan was started implementing in 1962. Final goal of the plan was chosen as an even-aged high forest with regard to the annual growth of trees, slope of the region and quality as well as the seeding potential of the beech trees. Exploitation age 125 year and felling cycle 25 years were selected regarding the existed regenerations at beginning of the plan. The first reconsideration plan was prepared in 1979, after 17 years. In 1997, the second reconsideration plan was put in order for 10 years.

In the present research, we also evaluated the implementation of the shelter-wood logging method in the study site. The regenerations and trees in the affectation of the beech forest managed by the shelter-wood logging method were evaluated at three mentioned times, 1962, 1979 and 1997.

MATERIALS AND METHODS

Study area: The present investigation was performed in 2001 in the affectation of a beech forest district called as Lumir locates in N Iran (49° 01′ N, 37° 40′ E) (Fig. 1). The area of affectation located in the north-west of the forest district (Lumir district) was around 409 hectare. The main climatological and geographical characteristics of the study site were as follows: the mean annual precipitation: 1285 mm; the mean annual air temperature: 15°C; the mean

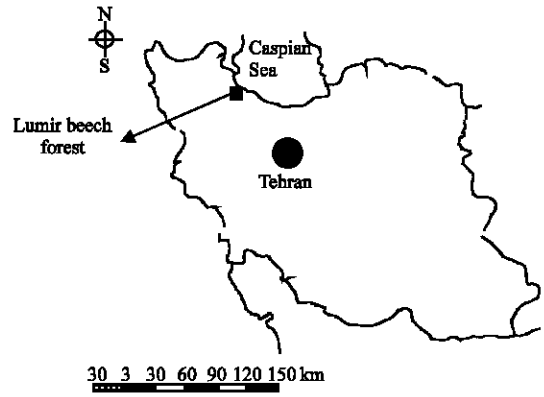

Fig. 1: Location of Lumir beech forest in the western Caspian region

relative humidity: 83% and altitudinal range: 900-1600 m. Major species of the forest district are Beech (*Fagus orientalis*), Birch (*Carpinus betulus*), Maple (*Acer velutinum* and *A. cappadocicum*), Alder (*Alnus subcordata*), Oak (*Quercus castaneifolia*), Ash (*Fraxinus excelsior*), Linden (*Tilia begonifolia*), Checkertree (*Sorbus torminalis*) and Sweet cherry (*Cerasus avium*).

Sampling methodology and analysis of the qualitative studies: Transect sampling (linear plots) was employed for the qualitative studies. Ten transects with 50 m lengths in the same geographical directions (eastern to western) were applied randomly in the forest using a clinometer. In each transect four important silvicultural characteristics of beech saplings (less than 12.5 cm, Diameter at Breast Height (DBH)) as well as of young trees (15-20 cm, DBH) were studied as follows (Bayramzadeh, 2000):

(A) Healthy, (B) mode of branching, (C) mode of leaning and (D) straightness.

Young trees were also evaluated assuming that shelter-wood logging might create them. The mentioned characteristics were divided into some sub-characteristics as below:

- (A_1) healthy and (A_2) browsed, cut and diseased
- (B_1) lean less and (B_2) leaned
- (C_1) branchless (C_2) twin and (C_3) forked shape
- (D_1) straight and (D_2) crooked

Ratio estimation of the characteristics means ($\bar{p}$) was computed with Eq. 1 (Taheri Abkenar, 2007)

$$\bar{p} = \frac{\sum_{i=1}^{n} x_i}{\sum_{i=1}^{n} y_i} = \frac{\bar{x}}{\bar{y}} \quad (1)$$

in which x is the number of samples which have a studied characteristic (e.g., crooked) in the length of a transect and y is the number of samples in the length of a transect and I (1,2,…,n) is the number of transects. The standard error of $\overline{P}$ was satisfied as Eq. 2:

$$S_{\overline{P}} = \sqrt{\frac{1}{(\overline{x})^2}} \times \sqrt{\left(\frac{S_y^2 + \overline{P}^2 S_x^2 - 2\overline{P}.S_{yx}}{n}\right)} \quad (2)$$

where $S_{\overline{P}}$ is the standard error, S_x^2 and S_y^2 are the variances of x and y characteristics, respectively. S_{yx} is the covariance of x and y and n is the number of samples. Confidence limit of a characteristic finally was calculated with Eq. 3 (Zobeiry, 1993):

$$E = \pm t \times S_{\overline{P}} \quad (3)$$

in which E is the confidence limit and t is the student-t described by the normal distribution.

Sampling methodology and analysis of the quantitative studies: The random systematic sampling method with an intensity of 3.3% was applied for the quantitative studies. One hundred forty circular fixed-sized sample plots with 0.1 hectare area were determined on the topography map with a grid dimension of 150×200 m (Zobeiry, 1993). DBH and height of all trees in the sample plots were measured. In each sample plot, co-centered circular micro sample plots with 0.01 hectare area were determined to count the numbers of saplings of different species.

All the samplings with less than 12.5 cm were counted and classified in three diameter classes and in one height class as 0-2.5, 2.5-7.5, 7.5-12.5 cm and shorter than 130 cm. The number per hectare of different species in 1962 and 1979 were obtained from the forest management plans prepared by Shafa-Rud Forest Company (1965 and 1979).

RESULTS AND DISCUSSION

Regeneration quantity and mixing ratio: The numbers of the regeneration per hectare of different species at the beginning of the shelter-wood logging method and after 35 years are demonstrated in Fig. 2. According to FRO classification of regeneration mixing ratio (Table 1), regenerations in both years, 1962 and 1997, were assessed in the very good classes since more than 75% of the regenerations were from desired species such as beech and maple. However mixing ratio of the regeneration has changed to a higher diversity. In other words, the numbers of beech regenerations have decreased

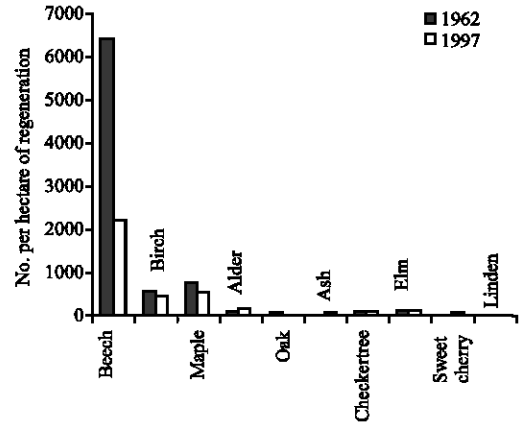

Fig. 2: The number per hectare of regeneration (less than 12.5 cm, DBH) of different species in the beech forest at the beginning of the forestry plan and after 35 years (The regeneration data of the first reconsideration plan, 1979, was unavailable)

dramatically. About 80% of the total regenerations in 1962 were dedicated to beech saplings nevertheless it deceased severely down to 62% in 1997. Decreasing the number of the beech regenerations can be due to the opening of canopy and consequently appearing the other light-demander species like maple and alder in the affectation.

In general, the shelter-wood logging method mimics the natural forest dynamics (Nagaike *et al.*, 1999) by opening the canopy, offering the favorable environmental conditions such as humidity, brightness and wind protection for regeneration. Opening the canopy allows other light-demanding species like birch, alder and maple to rehabilitate easier than beech and consequently alters the existence equilibrium. It should be noted that canopy gaps created by the shelter-wood logging method are usually much larger than those created naturally (Nakashizuka, 1984). According to Amani and Hassani (1998), crown dimension of each beech tree is around 5-12.5 m. In virgin forests, gaps only occur when old trees die and fall down.

The total number of regenerations was 7961 and therefore it was classified in the good class in 1962, while in 1997 was classified in the medium class, according to Table 2 and Fig. 2.

The authors prepared maps of the regeneration of all species as well as that of beech regeneration density (not shown) and classified the regeneration into five categories introduced by Table 2, assuming that each micro plot is a sample of a 3 hectare area (Table 3). Around 50 and 70% of the affectation area has been occupied by less than 3000 regeneration per hectare of all species and that of beech, respectively.

Table 3: Occupied areas of the affectation by all species and by beech regenerations (1997 data)

(Beech) regeneration density in each micro plot (0.01 ha)	FRO Classification	Occupied area (%) by all species regenerations	Occupied area (%) by beech regenerations
0-10	Weak	11	39
11-30	Low	40	34
31-50	Medium	24	17
51-100	Good	23	9
>100	Excellent	2	1

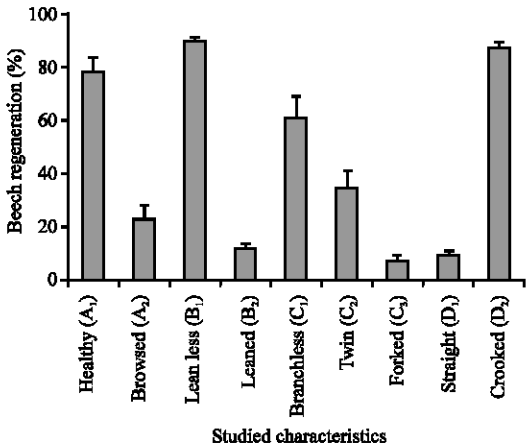

Fig. 3: The percent of studied characteristics of the beech regeneration (error bars show standard error of mean)

Present study ultimately revealed that the beech regeneration quantity in 1997 was in the weak class according to Table 2 since the beech regeneration number per hectare was between 1000 and 3000 (Fig. 2).

Regeneration quality: Distributions of the studied qualitative characteristics in beech saplings are available in Fig. 3. About 77% of the regeneration was healthy (A_1), 60% branchless (C_1) and 88% lean less (B_1). However, more than 90% of the regeneration was crooked as shown (D_2).

Opening of the canopy in the shelter-wood logging method could negatively affect the form of the beech saplings. It was also confirmed by the results of the previous studies (Brown, 1952; Sagheb-Talebi, 1995).

Table 4 shows the distribution of the desired qualitative characteristics of the beech saplings in the different diameter classes of regeneration. The desired characteristics of the beech regenerations were focused mainly in 0-7.5 cm diameter class (inconsistent category). It points out that large canopy gaps created by the shelter-wood logging method can affect the quality of the inconsistent regenerations which have good quality. In other words, inconsistent beech regenerations with good

Table 4: Distribution of the desired characteristics of the beech regeneration in diameter classes

Diameter classes (cm) (DBH)	Healthy (A_1)	Lean less (B_1)	Branchless (C_1)	Straightness (D_1)
0-7.5 cm (Inconsistent regeneration)	86	87	83	64
7.5-12.5 cm (Rehabilitated regeneration)	7	7	12	22
12.5-20 cm (Young trees)	7	6	5	14

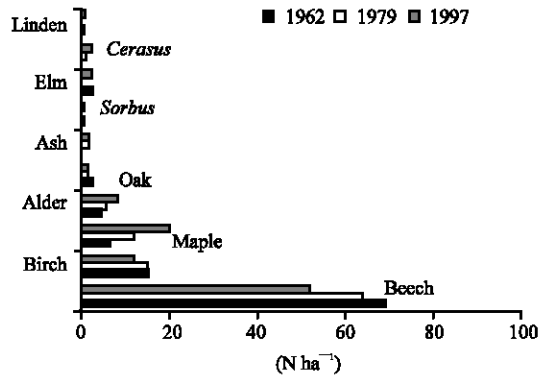

Fig. 4: Number per hectare of different species in the affectation at the beginning of the management plan (1962) and at the first and second consideration plans (1979 and 1997)

quality were deformed by the opening canopy at later stages (rehabilitated and young trees).

Species mixing ratio: Figure 4 shows the number per hectare of trees for different species at the beginning of the shelter-wood logging method (1962) and in the first and second reconsideration plans (1979 and 1997). The results proposed that the number of beech trees has decreased gradually from 1962 to 1997 and the number of maple and alder trees displayed increasing trends. Species diversity also displayed an increasing trend.

Opening the canopy and a focused demarcating on beech trees can be the most meaningful reasons to appear the other light-demander species like maple and alder in the affectation and decreasing the number of beech trees.

Residue trees in the affectation: In the shelter-wood logging method, trees should be totally removed to promote the regeneration. Present results showed that the number of the residue trees per hectare (trees >60 cm, DBH) and their volumes at the end of the method are 7.4 and 31 sylve, respectively.

By dividing the volume of a sample plot (V) to the number of trees exiting in it (N), we defined a ratio as V/N. By assuming that each sample plot is a sample of a 3 hectare area as stated before, Table 5 shows the affectation area occupied by the different values of V/N ratio. As shown, around 30% of the affectation area has

still a V/N ratio more than 0.61, i.e., there are still large-diameter trees in the affectation, concluding that calculation of the annual allowable cut and implementation of cuttings in the shelter-wood method have not been carefully done.

Evaluation of the implemented cuttings: Table 6 shows the number and volume per hectare of the beech trees classified into four diameter classes. The results present that the demarcating was centered on beech trees with more than 60 cm in diameter from 1962 to 1979. At the beginning, the number and volume per hectare of the beech trees with more than 60 cm in diameter were 25 and 63%, respectively and the values then have changed severely to 3 and 20%, respectively. From 1979 through the end, demarcating was focused on beech trees with 30-60 in centimeter necessarily. In general, increasing number per hectare of beech trees in 15-30 diameter class indicated that the beech trees has become younger than those of the beginning of the management plan. It is due to the demarcating concentration on the valuable species like beech at the first cuttings of the shelter-wood method.

Changing the mixing ratio also might be attributed to the intensive demarcating of the beech trees as mentioned previously. The shelter-wood logging method relies on the beech seeds induced and rehabilitated by preparatory and regeneration cuttings. However our results exhibited that the exploitation of the seed trees (mother trees) at the beginning stage of the shelter-wood method reduced the beech seeds and it was resulted in decreasing number of beech saplings.

Further, seeding years of the beech trees extremely depend on the climatological factors (Mossadegh, 1996) not much taken into account by the managers during the implementation of the shelter-wood logging method. Moreover, Table 6 shows that the accomplished forestry plan was unsuccessful to promote the forest to an even-agedness one which was the final goal in the shelter-wood logging method.

Correlation of the beech regeneration with canopy coverage, V/N ratio, slope and altitude: Figure 5 demonstrates the average number of beech saplings per hectare at different canopies coverage. It roughly showed that the beech regeneration had a positive correlation with canopy coverage, however, the results were not robust because of the data paucity or a few number of samples resulting in high standard errors as shown in Fig. 5. The canopy percentage for the optimum beech regeneration was reported between 50 to 70% by Godarzy (1996) in a beech forest in Livan Banafshtapeh, the eastern Caspian region, with less humidity than our sites. It can be related to the different climatic as well as edaphic factors in the investigated sites.

Table 5: Occupied areas of the affectation by the different values of V/N ratio

V/N ratio	Occupied (%)
0-0.25	16.4
0.26-0.6	53.6
0.61-2	25.7
>2	4.3

Table 6: No. and volume per hectare (%) of beech trees in the affectation at the beginning of the shelter-wood method (1962) and in the first and second reconsideration plans (1979 and 1997) classified into the four diameter classes

Diameter Classes(cm) (DBH)	1962 (N ha^{-1})	1962 (V ha^{-1})	1979 (N ha^{-1})	1979 (V ha^{-1})	1997 (N ha^{-1})	1997 (V ha^{-1})
	(%)					
15-30	30	5	70	25	87	47
30-60	45	32	27	55	11	39
60-80	16	32	2	14	1	10
>80	9	31	1	6	1	4

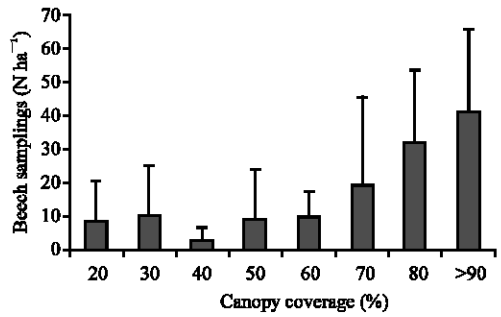

Fig. 5: Average number of beech sapling in different canopies coverage (error bars show standard error of mean)

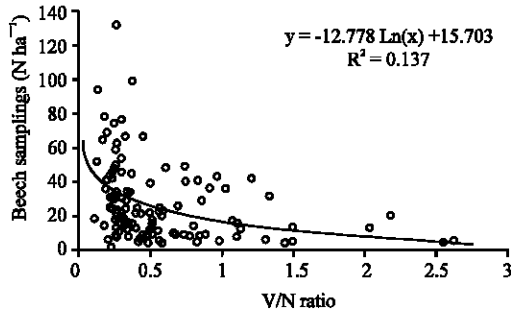

Fig. 6: The relationship between V/N ratio and number of beech saplings (Each circle refers to a sample plot)

The average V/N ratio plotted against the average number of beech saplings can be seen in Fig. 6. Although the best fit line showed a very weak relationship between the ratio of V/N and the number of beech saplings, it approximately demonstrated a decreasing trend, recommending that old beech trees with large diameter are less capable to produce high-quality seeds.

Present results showed the beech regeneration density was increased in the affectation where the slope was more than 50%. It pointed out a densely presence of

the forest dwellers and livestock in low slopes of the affectation of Lumir beech forest and accordingly a more harmful effect on the beech regenerations density (FRO, 1996).

It should be noted however the rehabilitation of beech seeds had less difficulty in the low slopes. The beech regeneration density was higher in the northern and north-western ecological aspects as reported by the earlier researches relating the higher humidity and fogginess of such aspects. Additionally, the beech natural regeneration revealed a positive correlation with altitude from the Caspian Sea level. However, they remain open for further investigations.

CONCLUSION

Lumir beech forest of the western Caspian region in N Iran managed by the shelter-wood logging method for 35 years could not be successful to reach an even-aged forest. The intense topography of the affectation of Lumir beech forest, the high dependency of beech seed years to climatological factors and high shade-tolerance of the oriental beech were found to be the most important reasons in this regard. Moreover, we found out that opening the canopy by shelter-wood logging method much larger than those created naturally allowed the other light-demanding species like birch, alder and maple to rehabilitate easier than beech on one hand and to deform the natural regenerations on the other.

Concerning the mentioned problems in implementing the shelter-wood logging method, we concluded that it is not suitable for the management of beech forests in N Iran.

It should be noted with less emphasize that the imperfect tree demarcating and also lacking precisions in the computation of the annual allowable cut were added to the above-mentioned reasons not attaining to the final goal of shelter-wood logging method, an even-aged forest, in Lumir beech forest.

Quality of the beech regeneration was valuated as the desired levels in spite of more than 90% of the regenerations were crooked. Quantity of the beech regeneration was assessed in the weak class according to FRO classification.

Positive and negative correlations were found out between the beech regeneration and canopy coverage and V/N ratio, respectively.

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