RESEARCH ARTICLE **(Open Access)**

Effect of Uniform Shelter-Wood Cutting Method on Forest Regeneration in Beech (*Fagus sylvatica* L.) Virgin Forests in Albania

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Abstract

This study aims to assess the state of forest stands regeneration in old-growth beech forest areas treated with shelter-wood cutting 2010-20 and determine the necessity of intervention with silvicultural measures, to restore the ecological balance in the forest stands. The object of the assessment were the forest areas exploited within the frame-work of long-term exploitation contracts. The National Forest Agency reports on 10 long-term contracts concluded between forest exploitation subjects and 4 Municipalities (Librazhd, Elbasan, Korça & Gramsh). This paper sought to answer whether or not shelter-wood cutting system was successful in our study area by evaluating the effect of shelter-wood cutting in 2015 and 2024, in stand structure (tree DBH, basal area, crown diameter, tree height) and regeneration density. Since the exploited areas are virgin forests, in this study we will also give our opinion on whether these interventions have been reasonable in terms of European Objectives for the preservation of virgin beech forests, as well as in the rehabilitation of coniferous forests in Albania, especially silver fir (Fig. 1). The aim of this study was to analyze natural regeneration reliability under favorable conditions in treated beech stands.

Key words: *virgin forests, close-to-nature silviculture, shelterwood cutting, natural regeneration, beech forest*

1. Introduction

The presented paper deals with regeneration in some unmanaged beech (*F. sylvatica* L.) forests in Albania after the implementation of uniform shelter-wood cuttings. Old deciduous forests in Europe are of particular importance for bio-diversity protection and are highly adaptable to climate change (Scientific Advisory Board on Forest Policy 2022). The shelter-wood cutting system has been widely used in Albania from the 1950s to the present day, and the results have been very good, with excellent regeneration in the forests (Fig. 2). But after the 1990s it has not been implemented correctly, especially in beech forests. Logging operations has leaded to severe disturbing effects on forest ecosystems and has negatively affe-cted the soil and regeneration. The implementation of shelter-wood system in Albania is done in this way: Cuttings are applied when the stand has reached the stage of exploitation and are of 3 types: seed cutting, light cutting and final cutting. In special cases, cuttings are preceded by a preparatory cutting. Prepa-ratory cutting (optional) represents a light thinning of the stand applied 5-10 years before the seed cutting and aims to favor the development of tree crowns for good seed production. The intensity was ≈20% of the stand volume. Seed cutting was applied to create favorable conditions for the germination of seeds. It was necessary that seed cuttings to be applied in mast year. Seed cutting aims to ensure a uniform distribu-tion of new natural regeneration (Ashton & Kelty 2018). Site preparation (scarification) was often used to create forest floor conditions for seed germination. The cut is considered strong when the amount of material extracted was up to 40%. Light cutting was applied to allow more light to enter on the soil, to give the installed seedling the opportunity to develop better. Light cutting was applied ≈5 years after seed cutting, removing max. 40 % of the existing volume. Removal cut was carried out to remove the last remaining trees of the old stand. Other species were often introduced to improve the composition of the stand. Basic hypothesis of the study was: Natural regene-ration has not been ensured at the minimum level, because technical procedures of shelter - wood system have not been implem-ented correctly. Medite-rranean ecosystems are very

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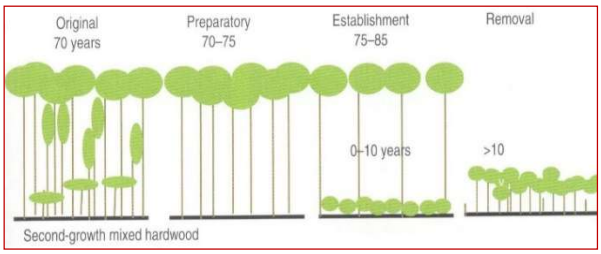
sensitive to climate change (Muscolo et al. 2017) and therefore there is an urgent need to conserve in situ coniferous species.



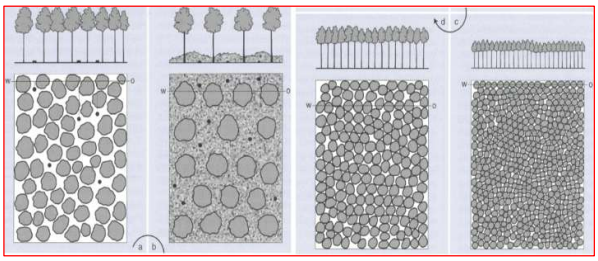


Fig. 1: Scheme of implementation of shelter-wood cuttings in USA and Germany

Fig. 2. A 70-year-old beech forest, resulting from uniform shelter-wood cutting in the 1950s (NP Shebenik, Librazhd) & a 45-year-old beech forest resulting from uniform shelter-wood cutting in the 1980s (Bukanik, Elbasan)

2. Material and Methods

All study areas are located between 1,300 & 1,500 m above sea level. Due to a good nutrient and water supply (annual rainfall ≈ 2.600 mm), and balanced climatic conditions, there are favorable conditions for forest development. Data were colle-cted in 2023-24 on Research Plots (RPs) in size 0.25 ha from treated shelter-wood with seed cutting. Study areas were provided with a fixed 50x50 m grid (Fig. 3) and the standing timber stand (>7 cm DBH) was recorded with regard to diameter, height and 8 crown radii (30-50 trees per RP) and polar coordinates. All individuals of height ≥ 10 cm and DBH <4 cm present in the plots of 10 m^2 were included in natural regene-ration. Crown maps of the study areas were compiled using the coordinates of the living trees in conjunction with the crown width functions derived for each study area and tree crowns were represented as circles based on the Middle Circle Model (Tabaku & Meyer 1999). On treated stands, shelterwood cuttings (seed cuttings) with intensity of 40%-60% were conducted in 2013-19 (Table. 1).

Table 1. Preliminary data on the studied stands

STANDS	Forest Parcel nr.	Forest Management Unit	Area in ha	Year of exploitation	Exploited volume m^3	Tree species
ELBASANI	54/b	Shpat - 1	7.1	2019	223	Beech (Fir)
LIBRAZHDI	85/a	Dardhe-Xhyre	41.0	2016	2.066	Beech
GRAMSHI	17/a	Holte-Lukove	37.7	2014	2.435	Beech (Fir)
KORÇA	9/b	Bofje-Dushar	24.5	2017	2.790	Beech

RP-Research Plot, V-volume (calculated for timber **>7** cm of diameter over bark (m^3/ha), G-basal area (m^2/ha), N-number of trees per ha, D mean-mean DBH (cm), H mean-mean height (m). GPS: **KO**-BD-09=40°35'48"N & 20°24'07"E, **LB**-DX-85=41°05'24"N & 20°21'21"E, **EL**-SH-54=41°02'25"N & 20°15'22"E, GR-HL-17=41°03'11"N & 20°22'07"E, Control Stand-41°06'01"N and 20°22'14"E (Librazhd)

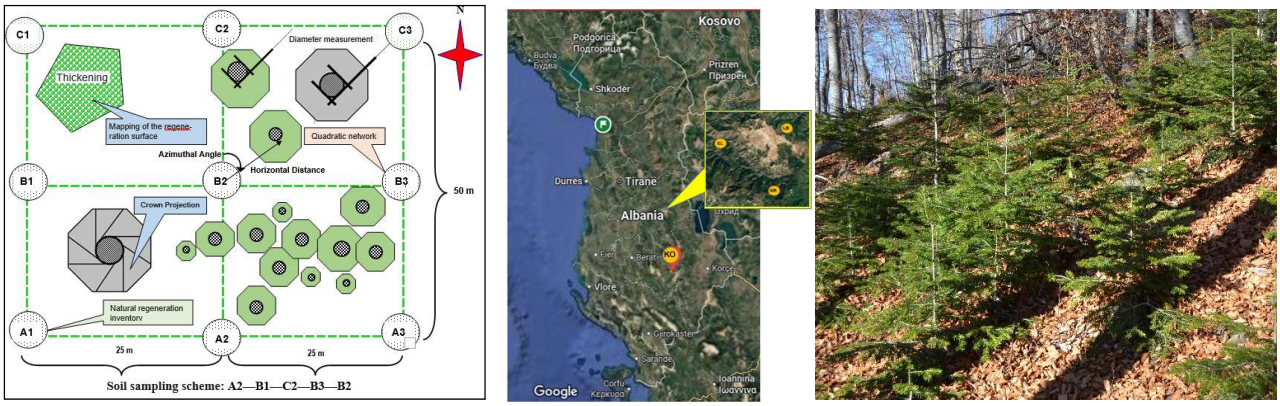


Fig. 3. Scheme of measurements in the research plots and their location in Albania (RP or Gramshi)

Table 2. Overview of basic characteristics of Research Plots

RP	Forest stand	V m^3/ha	G m^2/ha Before & After cutting	N / ha Before & After cutting	D_{mean} (cm) Before & After cutting	D_{mean} (cm) of cutting trees	Intensity by basal area %	H mean	Crown Cover (%)	Age (years)	Altitude (m)	Exposure Slope (%)
1	KO-BD-	**318**	**31.61 /**	**668 / 480**	**24.6 / 18.8**	**35.2**	**58.0**	**27**	**90**	**190**	**1550**	**N-25**
2	LB-DX-	**202**	**81.28 /**	**952 / 762**	**33.1 / 27.2**	**42.2**	**54.5**	**30**	**85**	**165**	**1530**	**S-18**
3	EL-SH-	**226**	**44.65 /**	**632 / 432**	**30.1 / 23.2**	**41.0**	**59.0**	**17**	**75**	**160**	**1380**	**E-35**
4	GR-HL-	**492**	**48.65 /**	**1.044 / 920**	**24.4 / 19.9**	**45.6**	**41.4**	**18**	**80**	**170**	**1450**	**SW-30**
5	Control	**608**	**40.87**	**560**	**30.2**			**33**	**100**	**195**	**1500**	**W-20**

3. RESULTS

3.1. The stand structure in relation to DBH

The following figures show the diameter distributions for the stands in 4 cm diameter classes. The diameter distribu-tions for the diameter classes are shown a Plenter-like distribution. As is also evident from the tree distribution plans all the three primeval forest stands are characterized by a high degree of DBH differentiation and a very smallscale mixture of strong and weak trees. Dengler 1931 also points to the plenter structure of the Albanian virgin beech forest.

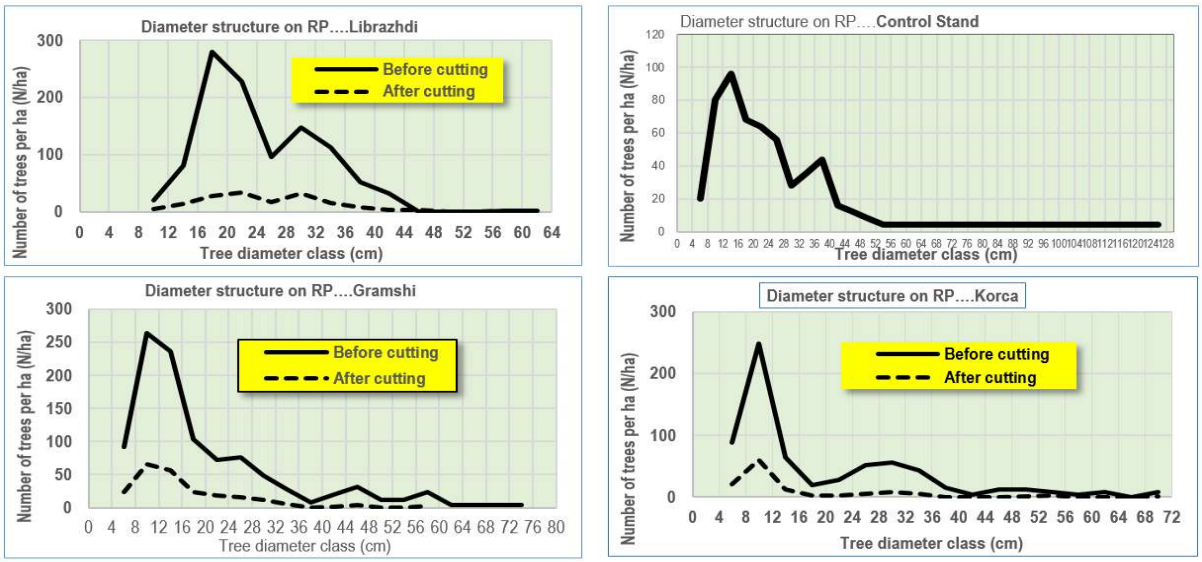


Fig. 4. Diameter structure of research stands

3.2. Crown map of the research stands

From the crown map of the research stands, we have calculated for each tree the projected crown area and the total crown canopy area for the plot. The crown map for Korça (Fig.4): green=remaining trees, red = removed trees). The values for the accumulated canopy area (circle model; trees are assigned to the quadrate in which they are located). We have calculated the relative canopy area per quadrate: e.g. **Q1** (A1A2-B1B2): In total = 1333+384 =1717/625 = 274%. Removed=213%, remain=384=61%. We have also given the number of seedlings per ha to compare with the crown coverage in quadrats. The table shows that natural regeneration in the studied stands is very weak, below the minimum necessary for the future of the stand. The data are given in Table 3.

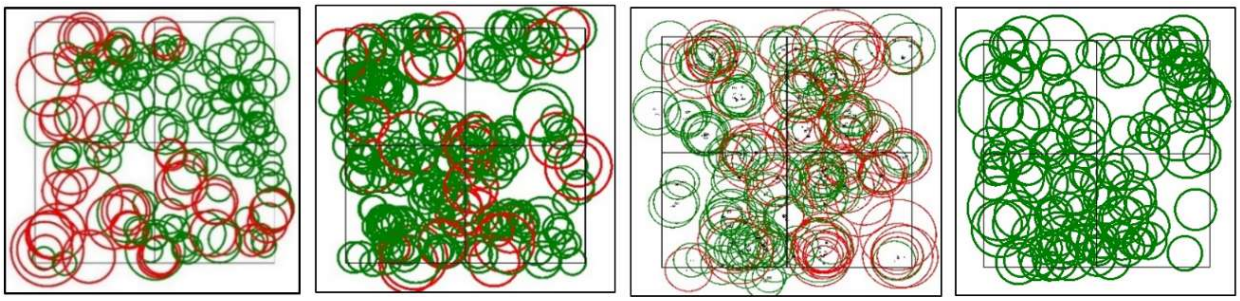


Fig. 5. Crown map of the research stand of Korça, Gramshi and Librazhdi (before and after cuttings)

The regeneration in the studied stands is very weak (Tab. 3). The main reason is that the seed cutting was not done in a mast year, which is the no. 1 condition for the shelter-wood system. The felling has been very heavy (over 40% of the stand volume). This is criterion no. 2 that has not been respected. Beech is a typical shade tree species which cannot regenerate at a very high light level in the stand. Criterion no. 3 that was not respected is the uniformity of cutting the trees were selected according to the interests of the company that exploited the forest. According to forest typology classifications, natural regeneration is assessed according to this scale: Very good regeneration (> 40.000 seedlings/ha), Good regeneration (25.000-40.000 seedlings/ha), Satisfactory regeneration (15.000-25.000 seedlings/ha.

Table 3: Crown Projection Area (CPA) by quadrants (total stand/removed trees) in RPs & in Control Stand

Quadrate	Tree Number	CPA (m²) N	CPA (m²) Y	Σ CPA in 625 m²	Relative CPA %	Remuved CPA %	Remain Real CPA (m²)	Seedlings per ha
Crown Projection Area (CPA) in KORÇA								
(Q1) A1A2B2B1	N16 / Y14	1.333	384	1.717	Total 274 / Remuved 213	77.7 / Remain 61	384,0	5.250
(Q2) B1B2C2C1	N13 / Y29	823	911	1.734	Total 277 / Remuved 132	47.6 / Remain 146	910,5	4.250
(Q3) C2C3B3B2	N16 / Y32	839	1.013	1.852	Total 296 / Remuved 134	45.3 / Remain 162	1.012,7	3.750
(Q4) A2A3B3B2	N2 / Y45	83	1.435	1.518	Total 243 / Remuved 13	5.35 / Remain 230	1.434,6	4.000
Crown Projection Area (CPA) in GRAMSHI								
(Q1) A1A2B2B1	N8 / Y42	237	1245	1482	Total 237 / Remuved 38	16.0 / Remain 199	1245	4.750
(Q2) B1B2C2C1	N9 / Y87	253	2446	2699	Total 432 / Remuved 41	9.5 / Remain 391	2446	2.500
(Q3) C2C3B3B2	N7 / Y66	218	2051	2269	Total 363 / Remuved 35	9.6 / Remain 328	2051	4.000
(Q4) A2A3B3B2	N7 / Y35	238	1190	1428	Total 228 / Remuved 38	16.6 / Remain 190	1190	3.500
Crown Projection Area (CPA) in ELBASANI								
(Q1) A1A2B2B1	N10 / Y50	1.122	3.071	4.193	Total 671 / Remuved 179	26.8 / Remain 492	3.071	4.500
(Q2) B1B2C2C1	N12 / Y37	1.058	2.046	3.104	Total 497 / Remuved 169	34.0 / Remain 328	2.046	8.000
(Q3) C2C3B3B2	N33 / Y29	2867	1.877	4.744	Total 759 / Remuved 459	60.5 / Remain 300	1.877	18.500
(Q4) A2A3B3B2	N24 / Y43	2.266	2.586	4.852	Total 776 / Remuved 363	46.8 / Remain 413	2.586	18.750
(Q1) A1A2B2B1	45			2658	425			0
(Q2) B1B2C2C1	27			1496	239			0
(Q3) C2C3B3B2	32			1908	305			0
(Q4) A2A3B3B2	32			1826	292			0

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4. DISCUSSION

One of the features of shelter-wood cutting method is maintaining forest canopy at some degree, which can reduce harvesting damage to forest ecosystem (Bradley et al 2001). As stated by Bílek et al (2009), the density of young seedlings is negatively influe-nced by the presence of older cohorts. Studies of similar mixed-mountain old-growth forests in Europe have reported a decline in silver fir (Vrska et al. 2009). Due to damage from browsing and of decades being under the cover of beech, the fir trees are without tops and have no prospects for further development. The idea that managing forested landscapes with ecologically based forestry ("close-to-nature" forestry in Europe) supplants the need for a segregated approach to forest mana-gement, whereby forest land is divided into areas focused on intensive wood production and protected areas focused on ecological functions, is gaining incre-ased attention in Europe (Boncina 2011). Recent work, in fact, suggests that Triad Forest Management (Seymour & Hunter 1999), consisting of an intensive management zone focused on wood production, an integrated management zone that balances ecological and economic functions (similar to close-to-nature forestry in Eu.), and a reserve zone for restoration or protection of existing old-growth forest, may be a better approach to biodi-versity protection (Tittler et al. 2012). In this study, only 1 plot had densities exceeding 25.000 seedlings /ha. Advance regeneration confirms hypothesis that the presence of advance regeneration plays a crucial role in determining success of regene-ration after shelter-wood cuttings.

5. CONCLUSIONS

Beech seedlings survive for long periods at very low light levels (Relative Light Intensity, RLI=1%), but grow slowly (Collet et al., 2001). At light 20% < RLI <40%, F. sylvatica seedlings have a better morphology, than at high light levels. Beech seedlings are vulnerable to birds, rodents and other herbivores and are sensitive to frost and drought. Data from this study and the positive experience 1950-1990 show that a shelter-wood is necessary for natural regenera-tion of beech forests in Albania. We believe that this is one of the ways of conserving the forest ecosystem in response to the present-day challenges of how to stimulate natural regeneration in a way that would bring greater stability and resilience for the forests (Dubravac et al. 2024). Another interesting outcome of the study is that advance regeneration is relatively secure, whereas seedlings established after seed cutting are ephemeral (Madsen & Hahn 2008). However, some of the new seedlings may very well become future advance regeneration waiting for future disturbance (RP of Gramshi, Fig. 4). Other studies have shown that advance regeneration of beech can respond very rapidly to canopy opening and that very few seedlings die. Alternatively, a more traditional albanian silvicultural approach that involves soil preparation with the beech seed fall may enhance seedling establishment.

6. RECOMMENDATIONS

Aims in beech management: Today's objectives include sustaining multiple services and values from beech forests, often by mimicking the natural dynamics of unmanaged stands, increasing native tree species and their mixtures. Taking all ecological characteristics of the genus into account, to succeed with Fagus, natural regeneration methods must leave a dense shelter of old trees and require a long regeneration period.

The end of timber harvesting can lead to trade-offs between nature conservation goals on the one hand and the goals of climate protection and adaptation to global change on the other. Biodiversity can even decrease due to reduction in tree species richness and high stand density. From an overall socio-economic perspective, stopping the use of wood is not an efficient climate protection measure. For this reason, strict forest protection should be concentrated on areas with a high nature conservation value.

Albania is an important country for conservation of larger stands of primary forests of beech (F sylvatica), which is of global natural heritage. However, many of these areas of outstanding universal ecological and scientific value have been degraded during the past 30 years. This degradation and destruction continues at an alarming rate. At the moment we are facing one of the most serious losses of Euro natural heritage. The main direct threat to the primary forests in Albania is logging, both legal and illegal.

Albania mast start a process to create a National Catalogue of Virgin Forests. The criteria of the identifycation of primary forests for the National Catalogue of Virgin Forests need adjustment to ensure that they allow the inclusion of as many as possible of the remaining valuable forest stands and do not favor logging interests. All stands recorded to be older than 140 years old in the forest management plans, must be checked for potential inclusion in the National Catalogue, disregarding their functional sub-category. Provide sufficient public funds for experts and civil society

groups to ensure rapid and comprehensive mapping and field checks for the National Catalogue of Virgin Forests.

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