AAB BIOFLUX

Advances in Agriculture & Botanics-
International Journal of the Bioflux Society

Assessments regarding natural forest regeneration of beech (*Fagus sylvatica* L.) stands located in Niraj and Târnava Mică superior basins

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Abstract. Forest regeneration has always been of crucial importance, because it ensures the continuity of the forest. The goal of being sustainable in the process of managing the forest includes the need for wide spread naturally regenerated stands. The paper presents different aspects regarding the natural regeneration process in an area located in the superior basin of the Niraj and Târnava Mică rivers. It follows the evolution of different phases like fructification, seedling emergence and development, variation of the seedling number, seedling growth, all influenced by local environmental conditions. Conclusions drawn from the research can serve to better implement specific treatments, completing the understanding of specific influences caused by local environmental conditions. A structured, well regenerated forest can fulfill it's function and this aspect is of critical importance today, because the new forest has to cover both production demands and an ever growing need for social and environmental services.
Key Words: fructification, seedlings, saplings, natural forest regeneration, environmental factors.

Introduction. Achieving sustainable forest management must consider the need for correct implementation of adequate silvicultural treatments in close relation with specific climate and terrain conditions that will lead to a successful regeneration with minimum seedling damage.

The contribution of the forest to the wellbeing of human society is not limited only to supplying wood; there are also a wide range of services with a positive impact on man and environment (Barbir & Negrea 2014). Forest regeneration represents the first and most important silvicultural measure, meant to improve stand structure and increase productivity. The way in which the regeneration process evolves, determines the future stand quality and species composition (Barbir et al 2010; Roibu et al 2011). Stand typology and specific site conditions in the superior basin of the Niraj and Târnava Mică rivers create the need to implement a wide variety of silvicultural measures, in order to ensure the success of regeneration, a process that is perfectible only through continuous research. The knowledge supplied by the bibliography, on the matter, has relative applicability, in determined areas, which creates the need to further contribute, with knowledge gathered through local stand conditions research. Relations between the environment and forest are not unilateral, plant communities in general having a certain degree of influence on environmental factors. This dynamic interaction determines continuous changes within the forest as a community of plants and also at individual level.

The forest's "active surface" role, determines a series of modifications to the weather elements, which leads to the creation of a microclimate in forest areas, influenced by the general climate only through the circulation of air masses (Marcu & Bîcu 1981). Some internal characteristics of the forest like the species composition, age and density have the biggest influence in the creation of the specific forest microclimate.

It can be easily understood that any changes brought to these characteristics will trigger a chain of modifications to environmental factors and the forest.

The everlasting presence of the forest is due to a succession of generations that defines the regeneration process. The succession can happen naturally, artificially or by a combination of the two. The regeneration process is an important link in the forest life cycle, a permanent mean to conserve and perfect forest structure and functions, ensuring a continuous selection at different zoocenosis and phytocenosis levels and also a growing resilience when confronting biotic or abiotic interference (Florescu 1991). As a part of the complex mechanism of forest regeneration, natural regeneration stands as a permanent priority in forest management. A percentage growth of naturally regenerated forest area, from 30% in 1981 to roughly 45% in 2001 (Anonymous 2002) reflects the growing importance of the process.

The analysis of the environmental factors influencing stand regeneration represents a basis for ecological fundamenting of forest regeneration methods. Beside "the dissemination factor, the source for a new tree and shrub generation" (Agestam et al 2003) stand regeneration depends also on environmental factors that influence tree fructification (seed quality and quantity, spreading of seed) seed germination and seedling growth and development.

Research targets regarded a series of aspects like:

- studying the dynamics of the natural regeneration process in stands where different types of cuttings have been applied;
- establishing the limiting factors that influence fructification, seed quality, the growth and development of natural seedlings;
- the qualitative/quantitative outcome of the regeneration process following the implementation of different sylvicultural systems.

The research results will fundament the choice of certain treatments that will be applied in beech (*Fagus sylvatica*) stands from the superior basin of the Niraj and Târnava Mică rivers in order to maximize natural regeneration areas and create stand structures able to cover future cultural, economic and social demands.

Tree extractions shape the forest canopy, which is a fundamental issue influencing the photosynthesis process (so biomass production) and determines the usage of the nutrient potential of the site.

Material and Method. Forests located in the superior basin of the Niraj and Târnava Mică rivers served the research purposes, where mountain and hilly beech stands thrive. Factors like favorable rainfall regime, no late freeze danger and humus/base rich soils ensure optimum growth and development conditions for beech, in the area. The process of gathering research data used bibliography studies, observations, and experimental methods. Research activities were conducted during the 1995 (April) - 2001 (March) interval, in Sovata Forest District, located in the superior basin of the Niraj and Târnava Mică rivers. The selective method served for conducting data collection, involving systematic and stratified sampling.

The growth and the general evolution of the natural seedling were studied using permanent research areas, experimental plots and inventory strips.

When choosing the locations for the permanent research areas, the main concern was that the resulted number must ensure the reflection of a large variety of aspects of the regeneration process. The locations of the permanent research areas (1600 m^2, square shaped with materialized limits in the four corners of the square) were chosen judging by the representativeness for the main forest stand types. Inside every research area, at equal distances, a number of sixteen (1-2 m^2) experimental plots were marked off, being needed to conduct the inventory for the natural seedling. Experimental plots (1-2 m^2) and inventory strips (1 m wide by 2 or 3 m length) served for collecting fructification data, like the number of disseminated seeds or for the evaluation of the seedling growth. In stands with implemented group shelterwood system, the chosen placement of the experimental plots followed two patch diameters, one on the E-W direction and the other on the N-S. The plot placement in stands with implemented uniform shelterwood system followed the land contour line and the line of steepest slope.

The rating of seed quality followed quality indices from analysis bulletins issued by the Forestry Research and Management Planning Institute in Brașov, Romania. Regarding the measurement of light conditions, lux meters (interval: 0-100000 lux) were used for determining illuminance levels and for temperature, maximum and minimum thermometers.

Results

Research regarding the fructification process. On warmer sites from the altitudinal beech belt, at an average altitude of 850 m and north-western expositions, maximum dissemination occured around the 10th of October 1999, as for colder sites, between 1.050-1200 m in altitude, with nordic expositions the same peak was reached around the 20th of October 1999. It can be concluded that temperature is a critical factor in beech-nut dissemination, which explains why a cold rain or an early snowfall (as in 1999) during dissemination, delays the peak, as confirmed by other authors like Brega (1992) and Silva et al (2012).

In this situation the opened beechnut cups close and the dissemination rate drops, regaining momentum as the temperature increases. This was common for 1999, when the spreading process continued well after 10^{th} of November as confirmed also by seedling emergence percentage in the spring of 2000. In the researched forest stands, the largest quantities of beechnuts were on patches with consistency between 0.5-0.6, up to 264 seed/m^2 in 1999 and 116 seeds/m^2 in the year 2000.

It is well known that beech stands over 70-80 years of age pass through an active fructification period, characterized by a continous increase of seed production up the the age of 150-160. The explanation for this high productivity, besides any tree biological charateristics can be on the growing number of seed bearing trees and the access to more light due to decreasing consistency.

Seedling emergence and development. The upper storey ensures the protection of the new generation during the seedling emergence and development phases, against extreme temperatures, drought or weed invasion. As the seedlings grow and need more light and nutrients, the old stand becomes a competitor for these elements.

Based on observations and seed inventory over the 2000/2001 winter, results indicated a drop by 54-60% of the viable beech-nuts, in comparison with autumn numbers, with between 8 to 31% of the quantity of beech-nuts per square meter, found in different states of decomposition. The sprouted seeds represent 33-62% of the total quantity considered viable in february 2001. The april-mai, 1999 late freeze affected the fructification of stands situated under 800 m, but not stands above 800 m.

Observation began in the autumn of 1999 and followed the emergence of seedlings after the 1999 fructification. A set of conclusions are issued in the following paragraph, regarding the emergence and development of beech seedlings in two stands that constitute compartement 75A (Management Unit no. 1) and compartment 87B (Management Unit no. 2). Compartment 75 A (Photo 1) is characterized by altitudes between 790-920 m, 90 years of age, a consistency of 0.8 and north-western exposition. Compartment 87 B (Photo 2) has a northern exposition, 160 years of age, a consistency of 0.7 and altitude betwen 1.050 and 1.200 m. Incidental products have been extracted from both stands, resulted from snowbreakage and windfall.

Figure 1 ilustrates the fluctuation of the number of seedlings per square meter, based on compartment averages calculated at certain moments in time from plot data inventory.

Photo 1. Seedlings emerging in compartment 75A (Management Unit no. I).

Photo 2. Growing seedlings in compartment 87B (Management Unit no. II).

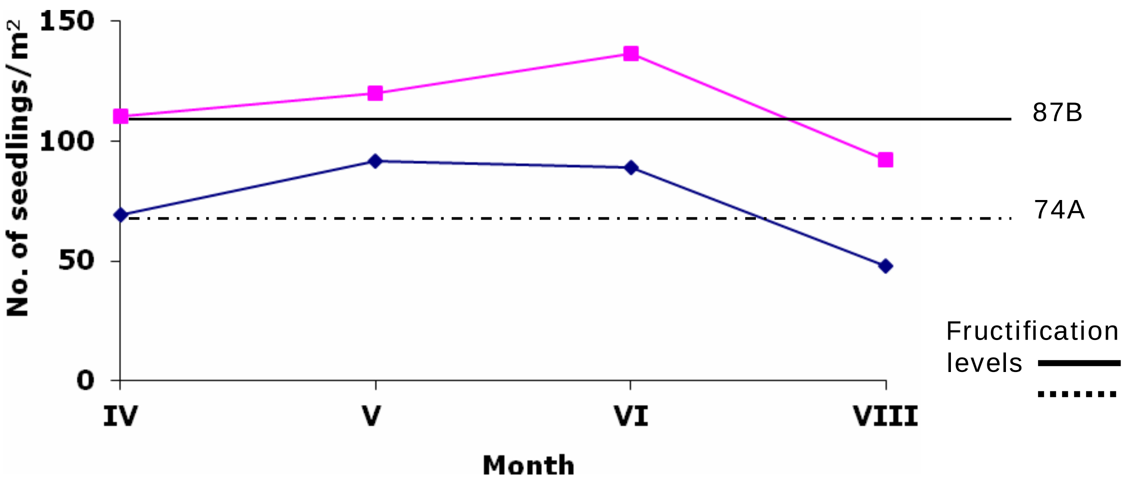

Figure 1. Variation of the number of seedlings in a certain time span.

It was concluded that the number of seedlings/m^2 is bigger than the seed number/m^2 determined after the october 10th (1999) inventory, in both 87B and 75A compartments, by 10% and 33%, which is a clear indication that dissemination continued after October 10th.

Conditions determining the variation of the seedling number. The same two compartments 87B and 75A were chosen for the variation of the seedling number analysis, a series of locations being picked depending on light conditions. On a shaded site (chosen in a full consistency stand part) in August 2000, the number of remaining seedlings represented 76% of the number from the early June inventory, on the same site, droping to 73-74% by the end of September. In comparison to open field light conditions, the shaded site receives around 20-22% illumination. In May when leafing is at an intermediary stage, at altitudes over 800 m, illumination levels reach 45-47% of the open field value. Ground level temperature differences between the shaded site and the open field were around 6.8-4.9^{o}C in the the period from May until August.

In gaps (with a diameter equal to the height of a tree) resulted from applying the group shelterwood system, differences have been noted, concerning seedlings/m^2, temperature and illumination. Observations and measurements were made for each gap sector and results from June were compared to August 2000 numbers. The biggest remaining seedling numbers per square meter were found in the south and west sector, followed by the central and est sectors, the lowest numbers corresponding to the northern sector. Illumination in the northern sector is 75-80% of that in full light conditions and 52-60% in the eastern sector, the lowest illumination percentage corresponding to the southern sector. Different light conditions determine differences in heat quantity reaching the forest floor.

On a logging road site, where full sunlight is received around 1.00 p.m. the August inventory showed that only 4% of the June 2000 seedling inventory were still viable. Figure 2 ilustrates the variation of the seedling number on sites with different light conditions. Considering the viable seedlings percentage and the illuminance measurement results it can be concluded that a maximum of 76% viable seedlings was reached at an illuminance level equal to 20-22% (which corespondes to a full consistency) of full light conditions.

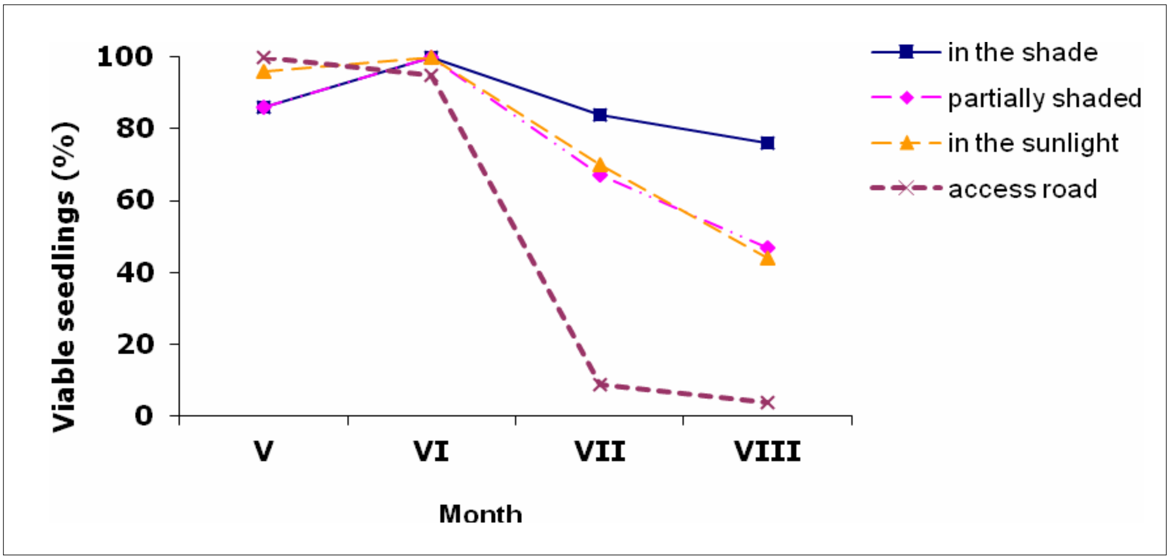

Figure 2. Variation of the seedling number on sites with different light conditions (year 2000).

Evolution of the number of seedlings. Data presented in Table 1 resulted from following the evolution of the sapling number in compartiment 87B (production unit no. II), an area with relatively uniform and homogeneous regeneration, from spring 1995 (initiation of the regeneration process) untill autumn 2001. The stand's consistency was around 0.6-0.7 and illuminance level equal to 25-30% of full light conditions.

Table 1

Seedling survival (%) in compartment 87B

Year	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*
Average seedling no./m^2	65	47	38	31	23	20	17
Seedling survival (%)	100	72	58	48	35	30	26

Seedling growth*.* Higher seedling growth rates, common in stands with a lower consistency index can be explained by the fact that the seedling growing season extends as more light reaches the forest floor (Madsen & Larsen 1997; Madsen & Hahn 2008; Achimescu 1971). For beech, height growth differentiation begins at ages around 4-5 years, continuing strongly if the old stand consistency decreases. It was determined that beech seedling around 6 years of age and 0.7-0.8 old stand consistency, reaches 25-50 cm in height. In addition, as long as 15 to 17 years can the seedlings withstand old stand cover, 20-25 years old specimens, 1.5 m in height, being found.

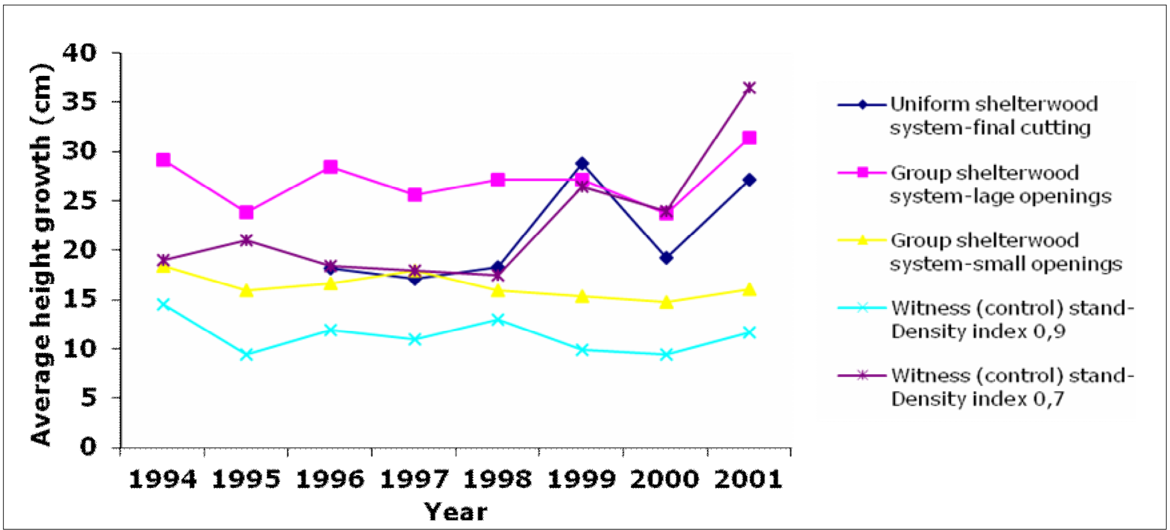

Figure 3. Average height growth (cm) in stands where certain types of treatments have been applied.

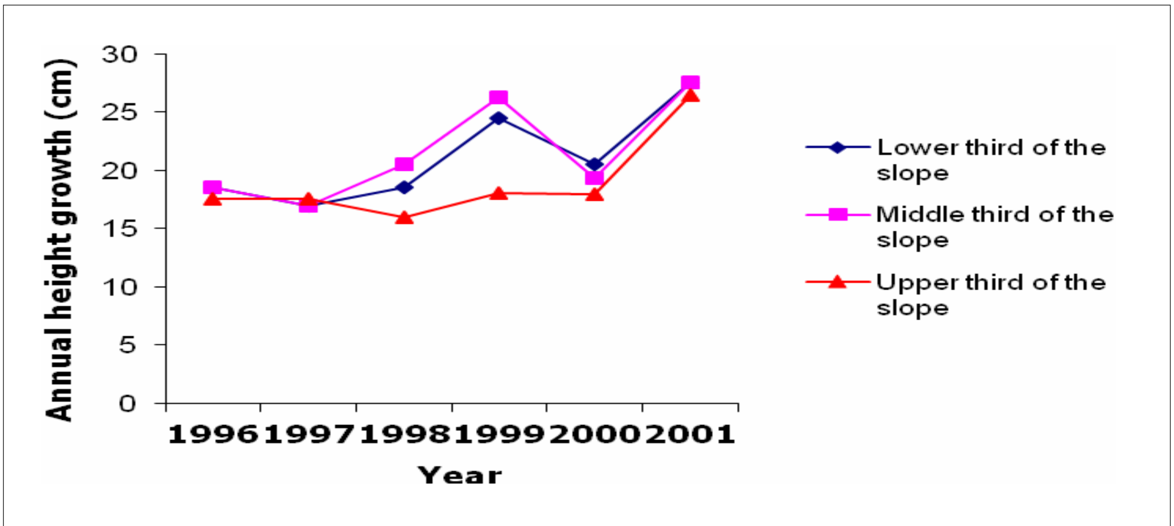

Figure 4. Seedling height growth (cm) in relation with slope conditions (on a normal beech stand where the uniform shelterwood system has been implemented).

In the control stand with 0.7 consistency and 15 years of age, average height was 2.34 m with an average annual growth of 16.4 cm in 35-57% illumination (of full light conditions). The other control stand with 0.9 consistency, 24-38% illumination (of full light conditions) same age and 11.4 cm average annual height growth, average height was under 1.62 m. Figure 3 ilustrates the average height growth in stand where different treatments have been implemented. Slope also influences seedling growth, as shown in Figure 4.

Conclusions. The paper is a look into the evolution of key components of the natural regeneration process, in forests from the superior basin of the Niraj and Târnava Mică rivers. Research conclusions presented below constitute a basis for improving forest management in the area, in order to cover the demands of sustainable management. Concerning the aspect of beech fructification, regardless of other local climate conditions, the determinant factor is air temperature. Cold rain or early snowfall determine the extention of the general dissemination period and delay the peak of the process. High temperature and long summer droughts cut dissemination duration and cause an early peak of the process.

On sites with roughly the same altitude, exposition determines fluctuations of the dissemination period, because of higher temperature values, on sites with southern exposition that receive more sunlight. Late freezes also determine changes of the fructification time period, extending it as site altitude increases, contrary to the known fact that the fructification time span decreases at higher altitudes.

Site exposition has a great impact on the natural regeneration process because it influences crucial site conditions as ground level humidity, litter thickness and heat. So on sites with a north-eastern exposition the number of decomposing seeds is double that on sites with southern exposition. Receiving more heat accelerates seed decomposition, on sites with sunny expositions, but lower humidity drops the sprouted seeds number. Litter thickness, higher humidity and a lower heat level, characteristic to shaded sites, increases the number of sprouted seeds. In the first year of life the beech seedlings have a low supportability towards light and heat. So on sunny, warm sites like logging roads or canopy gap sites where conditions are close to the open field, seedling mortality was total. Data indicated that shaded sites are ideal for the first stages of the seedling development.

Regarding seedling height growth, it has been shown that a higher illumination, achieved by opening the old stand canopy, activates strong growth, averaging 24-27 cm after definitive cuttings (part of the uniform shelterwood system). For beech, height growth differentiation begins at ages around 4-5 years and a sustained growth rate can be achieved ensuring an adequate illumination starting with the first stages of development.

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Received: 13 August 2014. Accepted: 25 October 2014. Published online: 13 November 2014.

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How to cite this article:
Negrea B. M., Covrig I., Oroian I. G., Barbir C. F., 2014 Assessments regarding natural forest regeneration of beech (*Fagus sylvatica* L.) stands located in Niraj and Târnava Mică superior basins. AAB Bioflux 6(3):155-162.