

DIAMETER STRUCTURE OF A BEECH PARENT STAND AT SHELTERWOOD CUT PHASES

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Abstract: Barna, M., Marušák, R.: Diameter structure of a beech parent stand at shelterwood cut phases. In *Folia oecologica*. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 91–98.

The work deals with development of diameter distribution at diameter classes at a beech parent stand on four plots. In February 1989, shelterwood cuts of various intensities were applied at partial plots. Particular intensities correspond to particular phases of shelterwood cut. Data from 1989, 1996 and 2001 were used for dynamics of trees diameter investigation. The highest increase of trees number in 1996 was obtained in diameter class 42 cm on all partial plots (PP) with cut. On the PP H (high cutting intensity) an increase in diameter class 46 cm was also recorded. That means a shift by two diameter classes was only recorded on PP H. A marked increase of trees number on this plot in 2001 was in diameter class 50 cm (increase from 1.8% to 14.3%). On the other plots the increase was lower. On the PP M (medium cutting intensity) the increase was from 3.7% to 6.4% and on the PP L (low cutting intensity) from 1.7% to 1.8%. An influence of cutting on shift of trees to a higher diameter class on this plot was marked only during the first period (7 years). Average stand diameter was increasing with cutting intensity, but standard deviation and coefficient of variation were decreasing.

Key words: diameter structure, shelterwood cut, *Fagus sylvatica*

Introduction

The diameter structure of the forest stand is determined by the trees number distribution in diameter classes. Its theoretical and practical meaning results from the fact, that the tree dimensions directly influence the utility value of produced wood.

In the even-aged pure stands a unimodal distribution of diameters frequency is characteristic. Their shape is not simple and is influenced by various factors (tree species, way of stand establishment and stand tending, site conditions, age and area). Within a period when the crown canopy is full, the diameter distribution is generally symmetrical. In this period, the influence of factors retentive and retaining trees growth is being mutually balanced. Later a certain degree of asymmetry is created. It is influenced by the trees competition and tending (ŠMELKO et. al. 1992). The tree species influence on the diameter structure is expressed by different biological properties of the species. The main difference is between groups of light-demanding and shade-loving species. In consideration of large plasticity of the shade-loving species (beech, fir) when suppressed trees are being kept alive for a long time, the diameter range is large and the diameter curve is relatively flat (HALAJ 1957). For light-demanding species (oak, pine) it is different. An improvement of yield class and age

increasing influences the diameter distribution in such a way, that the range is larger and the tapering is smaller (WENK et. al. 1979). Stand area has also similar influence.

Mentioned factors make possible to estimate actual and future tree distribution in the diameter classes in the forest stand. Their imperfection is, that they do not receive enough development changes which influence the diameter structure during the stand life. A very actual task of present research is searching of the dynamics regularity of the diameter distribution and their mathematical quantification (ŠMELKO et al. 1992). Dynamics during 12-years period as reaction on changed growth conditions after shelterwood cut phases in a beech stand is solved in the paper. Obtained results can be used at cutting control of forests managed by shelterwood system (ŽÍHLAVNÍK, 2000, 2001; MAJOROŠ, 1999, 2001; MARUŠÁK 2001).

Material and methods

The research was conducted in a beech stand at the Ecological Experimental Station (EES) the Western Carpathians Slovakia (48° 38' N, 19° 04' E). The beech stand in the EES is 100 years old and is situated on a 12-20° western slope at 470 m above sea level. The mean annual temperature (1978-1997) was 8.2 °C (during the vegetation period 14.9 °C), and the mean annual precipitation was 664 mm (370 during the vegetation period). In terms of forest typology, EES belongs to 3rd altitudinal zone, fertile site B, forest type group *Fagetum pauper-inferiora* – forest type 3312 (KUKLA 1997).

When the EES was establishing, the forest stand was composed of mixed 85 (78–90) years bole stage with composition of beech 62%, fir 22%, oak 7%, hornbeam 6%, lime 3% and uneven stocking 0.8–0.9. In February 1989 the shelterwood cut of various intensities took place so that particular plots correspond to particular shelterwood cut phases. The target was to regulate the tree species composition and stocking on particular plots. The original stand stocking changed to: **0.3 – PP H** (high cutting intensity), **0.5 – PP M** (medium cutting intensity), **0.7 – PP L** (low cutting intensity). One partial plot remained without cut and with original stocking **0.9 (PP C – control)**. The intention was mainly to remove dying, ill and low-quality trees to make beech as dominant (VOŠKO et al 1986). After the cutting, diameters of all remaining trees were measured. Other measurements were made after 7 vegetation periods (spring 1996 – first investigation period) and then after the next 5 vegetation periods (spring 2001 – second investigation period). All trees were sorted into diameter classes (range of 4 cm) according to their diameter. Further information are mentioned by BARNÁ (2000), KELLEROVÁ et al. (1997), KODRÍK (2002), KOVÁČOVÁ and SCHIEBER (2003).

Results and discussion

A curve of diameter frequency of shade-loving trees is generally less peak and has a higher variation range than the curve of light-demanding trees. These facts are visible on all searched plots (Fig. 1) because the shade-loving trees predominate.

Light-demanding trees in representation of oak (*Quercus dalechampii* Ten.) range from 5.3% to 1.1% of total trees frequency (Table 1).

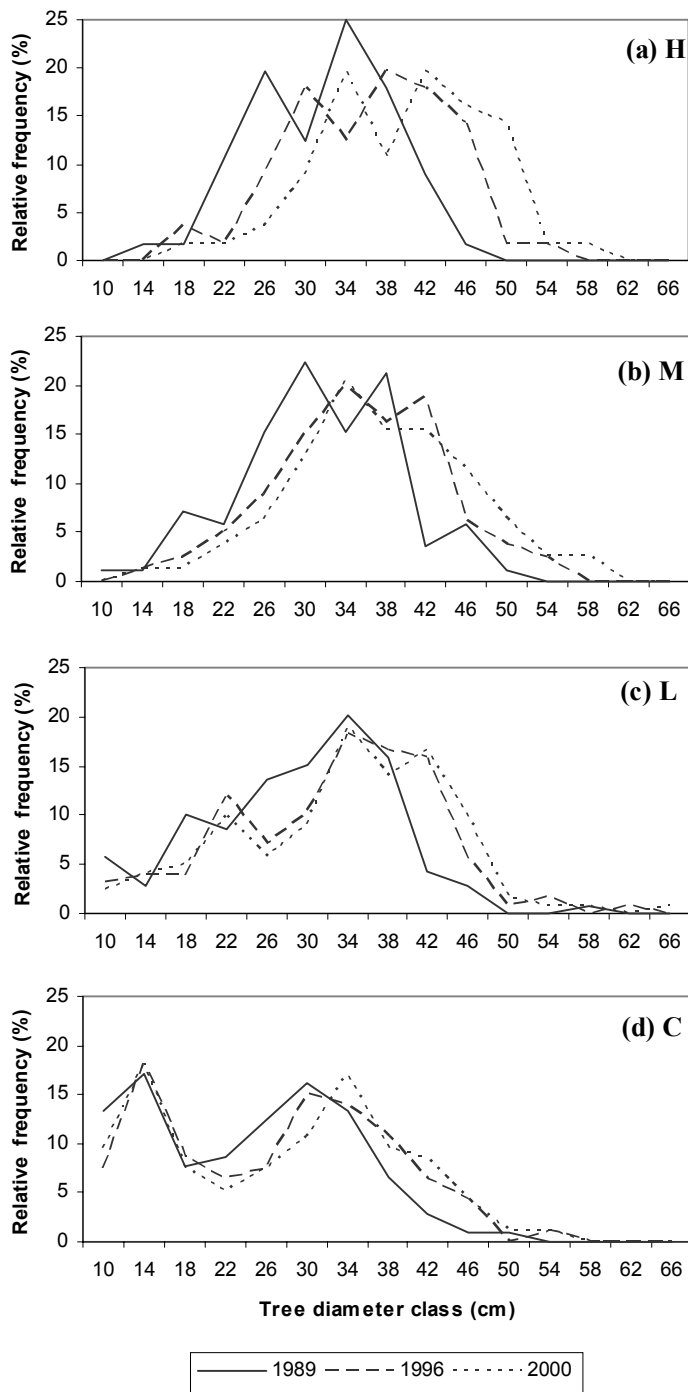


Fig. 1. Diameter distribution of particular permanent plots (H – high cutting intensity, M – medium cutting intensity, L – low cutting intensity, C – control plot)

Table 1. Development of relative tree species composition in 1989, 1996, 2001 (in %) (H – high cutting intensity, M – medium cutting intensity, L – low cutting intensity, C – control plot)

Tree species	Permanent plot / Year											
	H			M			L			C		
	1989	1996	2001	1989	1996	2001	1989	1996	2001	1989	1996	2001
<i>Fagus sylvatica</i> L.	92.9	92.9	92.9	87.1	90.0	91.0	76.3	81.7	84.3	89.5	94.7	94.7
<i>Quercus dalechampii</i> Ten.	5.3	5.3	5.3	3.5	3.8	3.8	3.6	2.4	2.5	1.9	1.1	1.1
<i>Carpinus betulus</i> L.	1.8	1.8	1.8	2.3	2.5	2.6	0.7	0.8	0.8	2.9	2.1	2.1
<i>Abies alba</i> Mill.	0.0	0.0	0.0	7.1	3.7	2.6	19.4	15.1	12.4	5.7	2.1	2.1

HALAJ (1957) found out that particular trees, with equivalent height position in mixed forest stands, had the same diameter distribution as pure stands. Decreasing mean stand diameter, mostly influenced by age and site class, frequency curves are moved in the axis x to higher values and their tapering is less (they are more flat) and variation higher. In our case mean stand diameter increased with higher cut intensity and frequency curves had higher tapering and less variation (Table 2).

Table 2. Statistic characteristics of diameter distribution in partial plots

Characteristic	Permanent plot / Year											
	H			M			L			C		
	1989	1996	2001	1989	1996	2001	1989	1996	2001	1989	1996	2001
Mean value (cm)	32.02	36.76	40.08	31.64	35.53	37.37	29.37	32.62	33.78	24.13	26.47	27.07
Error of mean value	0.96	1.03	1.11	0.83	0.91	0.98	0.78	0.89	0.97	1.01	1.15	1.21
Standard deviation (cm)	7.20	7.73	8.28	7.61	8.18	8.65	9.20	10.04	10.70	10.35	11.23	11.82
Variance (%)	51.8	59.8	68.6	58.0	66.9	74.8	84.6	100.7	114.5	107.2	126.1	139.6
Coefficient of variation (%)	22.58	21.03	20.67	24.06	23.02	23.15	31.31	30.76	31.68	42.90	42.43	43.65
Difference min-max (cm)	34.70	35.70	37.80	36.60	40.33	42.50	51.30	52.43	56.55	42.80	46.99	48.00
Minimum (cm)	13.30	17.00	18.25	11.70	13.97	14.65	6.70	9.33	9.35	6.20	6.80	7.30
Maximum (cm)	48.00	52.70	56.05	48.30	54.30	57.15	58.00	61.75	65.90	49.00	53.79	55.30
Curtoses	-0.22	-0.33	-0.31	-0.08	0.07	0.02	0.03	-0.09	-0.02	-1.03	-1.00	-1.06
Skewness	-0.26	-0.33	-0.43	-0.19	-0.15	-0.11	-0.23	-0.27	-0.23	0.08	0.06	0.07

H, M, L, C – see Table 1

The frequency curve of control plot has two peaks. The first is in diameter class 14 cm and the second during the research moved from diameter class 30 to 34 cm. The same diameter distributions before cutting were also on the other PPs in 1988 (ŠTEFANČÍK 1994). According to ŠMELKO (1992), it can be caused by the silvicultural methods performed on the plots before the research.

The frequency curve on all plots with the shelterwood cut decreased the most steeply in the diameter class of 42 cm (Fig. 1). The biggest shift of the frequency curve on the axis

x to the right was recorded on the plot H at the left side (growing side of distribution) by 2 diameter classes, by one in each study period, and at the right side (decreasing) by 3 diameter classes. A similar development was also recorded on the plots M and L , but in a smaller extent, adequate to the cut intensity. In 1996 we saw a double increase of the tree number on the plot H in the diameter class of 42 cm, on the plot M it was 5.4 times and on the plot L 3.7 times increase. In the diameter class of 46 cm it was as follows: H – 5.1 but on the plot M there was no increase and on the plot L only 1.9. It means a shift by two diameter classes only on the plot H (Fig. 2b). In the year 2001 (Fig. 2c) there was an increase of the number of trees in the diameter class of 50 cm on the following plots: H from 1.8% to 14.3%, M from 3.7% to 6.4% and L from 1.7% to 1.8%. It means a significant shift on the plot H , smaller one on the plot M and practically no shift on the plot L . The shift on the plot L in the second period of observation is identical to the control plot, i. e. the influence of the shelterwood cut on the tree shifting to higher diameter classes lasted only during the first period of observation (7 years).

The division of the number of trees n_j by the diameter classes d_j can be numerically expressed by a whole range of statistical characteristics. According to ŠMELKO (2000) the most important ones for practical needs are the following: arithmetic mean, standard deviation and coefficient of variation.

The arithmetic mean (\bar{d}) characterizes the average diameter (the diameter maturity) of the stand and it indicates a position of the diameter distribution on the axis x in the graph. We can see from the Table 2 that the largest mean diameter was recorded on the plot H with the strongest cut and the smallest one was recorded on the control plot C without any cut during all periods of observation. If we compare the relative increments (Table 3) between the individual periods of observation or for the overall period there was a decreasing tendency from the plot H to the plot C . It was caused by the methodology of the shelterwood cut application, the intention of which is explained in the chapter Material and Methods. Relatively thicker and healthier trees, which had a better position in the stand and therefore they had bigger increments, remained on the plots with a stronger cut.

The standard deviation (s_d) characterizes variability of values of the diameter d_j around the diameter \bar{d} in such a way that it indicates the limits $\bar{d} + s_d$ (in cm), in which a certain number of all values d_j occurs. Almost all values of the tree diameter in the stand are included within the $6 \cdot s_d$ (ŠMELKO 2000). This rule of 6-multiple of s_d is valid according to PRODAN (1965) also for the case of completely asymmetric distribution. The bigger the value s_d is, the more various are the diameters of trees in the stand and vice versa. The values of the standard deviation for the stands of experimental plots were increasing with the stand age and density (Table 2). The explanation of this dependency comes out from the same principle as for the diameter; the differences come out from the methodology of the shelterwood cut application.

The coefficient of variation ($s_d\%$) is the relative rate of the diameter variability. It expresses the standard deviation in percentages from the arithmetic mean and in this way it allows a mutual comparison of the diameter diversity also of such stands, which have different average diameter (e. g. young and old stands). We can see from the Table 2 that the coefficient of variation goes drops with increasing cutting intensity. The highest one of 43.65% is on the control plot, and the lowest one of 20.67% is on the plot H . From the viewpoint of time a

decline of the values of coefficient of variation occurred only on the plot *H*, the time dependency was not found out on other plots. HALAJ (1957) derived the empiric tables indicating a relative division of the tree number and stock on the basis of two arguments: mean stand diameter and three degrees of the diameter dispersion. They resulted in very important information about the coefficients of variation of the tree diameters, which for the beech are in the range of 24–46%. We can see from the Table 2 that values for the plots *C* and *L* belong to this range, values for the stand *M* with medium intense cutting are marginal and values for the plot *H* with intense cutting are 3.33% under the observed range. It demonstrates that the stand structure becomes the most effective, with low diameter variability after the seed cutting and light felling in the shelterwood regeneration.

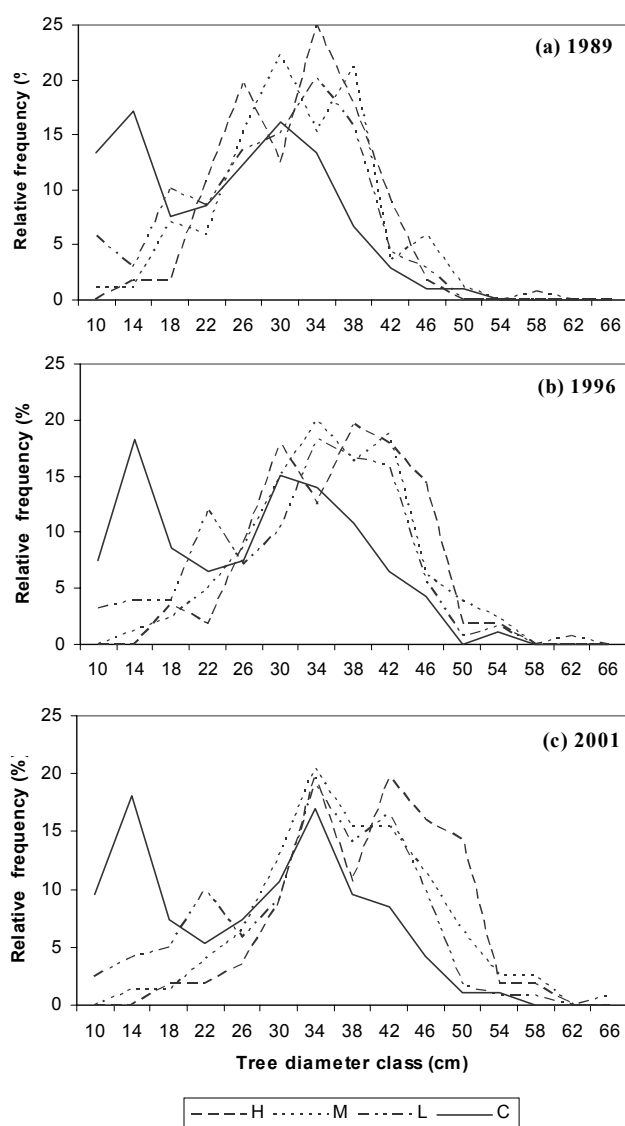


Fig. 2. Diameter distribution in particular periods (H – high cutting intensity, M – medium cutting intensity, L – low cutting intensity, C – control plot)

Table 3. Relative increments of mean diameter between periods 1989–1996, 1996–2001 (a) and 1989–2001 (b)

Permanent plot	H			M			L			C		
	1989	1996	2001	1989	1996	2001	1989	1996	2001	1989	1996	2001
Increment (%)	a	14.8	9.0	12.3	5.2		11.1	3.6		9.7	2.3	
	b	25.2			18.1			15.0			12.2	

H, M, L, C – see Table 1

Conclusions

The distribution of the number of trees at diameter classes changes in the course of the stand life. The changes are of two kinds: mechanical – they are caused by the thinning and shelterwood cuttings, by which the situation suddenly changes and dynamic – caused by the diameter increase in consequence of the tree growth. They are taking place continuously and they are the function of all factors influencing this growth. We can see according to the values of statistical characteristics of the tree diameter distribution on observed plots (Table 2) that the dynamic changes of stands are the more quick the more intensive cutting was applied (Fig. 1). By above-mentioned statistics we independently described the individual properties of the diameter distribution. At modeling of the diameter structure it is possible to use its mathematical formulation by means of the frequency functions (in particular: Charlier A-function, Beta-function, Gamma-function, Weibull function and others). The actual tendency leads to the models that allow estimating the diameter structure of the stand not only to a certain instant of time, but also predicting its future development from the known initial state.

Acknowledgement

The authors are grateful to the Slovak Grant Agency for Science (VEGA) for partially supporting this work.

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HRÚBKOVÁ ŠTRUKTÚRA BUKOVÉHO MATERSKÉHO PORASTU V OBNOVNÝCH FÁZACH CLONNÉHO RUBU

Súhrn

V práci skúmame vývoj rozdelenia počtu stromov po hrúbkových stupňoch v bukovom materskom poraste na štyroch plochách. Vo februári 1989 na skúmaných plochách bol aplikovaný ťažbový zásah rôznej sily, ktorá zodpovedala jednotlivým fázam clonného rubu. Dynamiku rozdelenia hrúbok stromov sme skúmali a matematicky kvantifikovali z údajov v rokoch 1989, 1996 a 2001. Na všetkých plochách s ťažbovým zásahom najväčší nárast počtu stromov v roku 1996 nastal v hrúbkovej triede 42 cm a na ploche H s najsilnejším zásahom aj v hrúbkovej triede 46 cm. To znamená, že posun o dva hrúbkové stupne bol iba na ploche H. V roku 2001 najvýraznejšie zvýšenie počtu stromov na tejto ploche bolo v hrúbkovej triede 50 cm – z 1,8 % na 14,3 %, na ploche so stredným zásahom (S) z 3,7 % na 6,4 % a na ploche M s miernym zásahom z 1,7 % na 1,8 %. Vplyv ťažbového zásahu na presun stromov do vyšších hrúbkových tried trval na tejto ploche len počas prvého skúmaného obdobia (7 rokov). Priemerná hrúbka porastu rástla so silou zásahu, ale smerodajná odchýlka a variačný koeficient sa znižovali.