FORESTRY IDEAS, 2012, vol. 18, No 2 (44): 196–202

INVESTIGATION OF THE ABOVEGROUND PHYTOMASS AND ANNUAL GROWTH OF BEECH FORESTS IN BULGARIA

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Received: 26 Yune 2010 Accepted: 13 November 2012

Abstract

Beech forests are among the most widely spread forests in Bulgaria. They have a significant economic importance for the country and for that reason they are an object of a great number of studies. The aim of the present study was to analyse the growth and the increment of beech communities in five permanent sample plots and to quantify the distribution of aboveground phytomass of the trees together with the annual increment for two beech communities. The studied phytocoenoses are related to the associations *Festuco drymejae-Fagetum sylvaticae* and *Asperulo odoratae-Fagetum sylvaticae* (habitat *Asperulo-Fagetum* – 9130) and to the association *Luzulo luzuloidis-Fagetum sylvaticae* (habitat *Luzulo-Fagetum* – 9110) in the region of Petrohan (the West Balkan Mountains, Bulgaria). The results for the phytomass stores (between 488 $t \cdot ha^{-1}$ and 612 $t \cdot ha^{-1}$) and for the annual biomass increment (correspondingly between 12 $t \cdot ha^{-1}$ and 23 $t \cdot ha^{-1}$) were obtained using the method of the average tree model. These values allow us to relate the phytocoenosis of the first plot to the middle productive plant communities while the second phytocoenosis can be assigned to the high productive plant communities.

Key words: communities, sample tree, annual increment, primary production, West Balkan Mountains.

Introduction

Among the most important criteria to be considered during the investigation of functioning of plant communities are the phytomass stores and production. We can judge the state and the processes in these communities through the changes of the values of these criteria.

Growth and productivity of European beech forests, their dynamics and increment depend on various factors, which determine the site quality and capacity. A great number of abiotic and biotic factors such as habitat, age of trees, climate, various pathogen diseases, pollutions and silvicultural treatments have an influence on these site characteristics and on the functioning of forest communities.

The beech communities on the territory of Petrohan experimental and educational forestry enterprise (EEFE “Petrohan”) have been a subject of studies at different scales – at local, regional and national levels, aiming their classification and determining their ecological characteristics, conservation status, and habitats (Pavlov and Dimitrov 2003, Tzonev et al.

2006). These forests are also a part of the forest ecosystems subjected to intensive monitoring Bulgaria (Kolarov et al. 2002).

The biomass and productivity of beech communities have been a subject of investigations in our country as well. They have been first announced in the paper of Garelkov and Turlakov (1978). Later on the studies on beech forests in Bulgaria have been summarized in a book by Garelkov and Stiptcov (1995). Kostov (1992) studied the biomass of spruce-fir-beech communities. Vulchev (1999) and Kolarov et al. (2002) investigated aboveground phytomass and productivity of *Fagus* sp. relying on stem analysis. Similar investigations have been also conducted abroad (Le Goff and Ottorini 2000, Zianis and Mencuccini 2002, Wutzler et al. 2008).

The aim of the present study was to assess the phytomass stores and the production of the studied beech communities.

Object of Investigation

The objects of investigation were pure even-aged beech communities in the region of the West Balkan Mountains (Fig. 1).

The plots are situated on the territory of the Petrohan experimental and educational forestry enterprise. Area is situated in the North Bulgarian climate zone with temperate-continental climate, with average annual rainfall between 700 and 1000 mm, being one of the highest of the country. The soils are Dystric Cambisols.

The environment of the region is slightly impacted by different sorts of pollution. The characteristics of sample plots are presented in Table 1.

Methods

To quantify the dynamics of growth process in all five sample plots, an intrinsic intercept natural coefficient of height WH_O was calculated using the “Natural coefficients” method (Duhovnikov and Mihov 1983, Mihov and Tonchev 2010). For that purpose a sample tree with diameter and height close to the mean diameter and height of the stand for each plot was determined. Then a stem analysis was performed for determining the height growth for ages from 20 to 100 years. Based on these data and using software, especially developed for the purpose, the natural coefficients were calculated.

The stand growth in the sample plots was revealed through the evaluation of main stand characteristics (average and

Fig. 1. Location of the Petrohan beech experimental forest.

Table 1. Characteristics of the plots.

Plot, No	1	2	3	4	5
Habitat	9130	9130	9110	9130	9110
Compartment	Petrohan, 99a	Petrohan, 94e	Petrohan,142e	Petrohan, 155d	Petrohan, 142 g
Altitude, m	1600	1450	1100	700	1100
Age, years	115	135	140	140	135
Basal area, m^2·ha^{-1}	47.9	46.4	30.8	50.3	29.4
Mean diameter, cm	25.0	39.2	28.0	47.9	25.5
Stem volume, m^3·ha^{-1}	489	564	316	709	369
Exposure	W	S	SW	W	SW
Slope, degrees	20	5	22	6	28
Soil, FAO code	CMd	CMd	CMd	CMd	CMd
Density, N·ha^{-1}	955	385	500	279	575
Syntaxa	*Asperulo odoratae-Fagetum sylvaticae* Sougnez et Thill 1959 variant *Senecio nemorensis* Pavlov et Dimitrov 2003	*Asperulo odoratae-Fagetum sylvaticae* Sougnez et Thill 1959 variant *Salvia glutinosa* Pavlov et Dimitrov 2003	*Luzulo luzuloidis- Fagetum sylvaticae* Meusel 1937 subas. *vaccinietosum myrtilli* Dzwonko et al. 1999	*Festuco drymejae-Fagetum sylvaticae* Reşmeriţă 1977	*Luzulo luzuloidis- Fagetum sylvaticae* Meusel 1937 subas. *vaccinietosum myrtilli* Dzwonko et al. 1999

dominant height, average diameter, basal area and volume per hectare) 140 years backward from the present moment. Also the variation of current and mean annual increment was determined using the “Analysis of stand” method and software especially developed for the purpose (Mihov et al. 2008). This method is based on data derived from the values of the present stand characteristics of sample plots and from the values of the intercept natural coefficients appearing in Table 2.

The studies of the aboveground phytomass and the annual productivity were carried out according to the methodological leads of Rodin et al. (1968).

The plant communities were determined from phytocoenological relevés and by referring to the phytosociological literature (Braun-Blanquet 1964, Pavlov and Dimitrov 2003, Tzonev et al. 2006).

Results and Discussion

Height growth of the mean sample trees in each of the five permanent sample plots and the values of intercept natural coefficients (WH_0) are presented in Table 2.

Table 2. Height growth of the mean sample trees and values of intercept natural coefficients (WH_0) for the five sample plots.

Age, years	Number of sample tree				
	1	2	3	4	5
	Height, m				
20	4.4	5.3	2.2	4.4	2.4
30	6.5	7.0	4.1	7.2	3.6
40	8.6	10.5	8.5	9.5	4.7
50	11.4	12.0	12.6	11.4	5.9
60	13.3	13.6	15.7	14.0	7.0
70	15.5	15.7	18.4	17.7	8.6
80	17.0	18.0	20.6	20.6	10.2
90	18.8	21.1	22.2	23.0	12.6
100	20.3	23.2	23.3	26.3	13.7
WHo	0.79	0.8	0.33	0.55	0.54

The high values of intercept natural coefficients indicate a rapid height growth during the early ages (20–40 years) and a decreasing rate of growth in the phase of maturity and vice versa for low values of the indices.

Data show that values of intercept natural coefficients for the sample plots are relatively low being in the range of 0.79–0.80 for sample plots No 1 and No 2, 0.54 and 0.55 for sample plots No 4 and No 5 and presenting a minimal value of 0.33 for sample plot No 3. These patterns could be associated with a rate of growth increasing parallel with age, which is characteristic for shade tolerant tree species with slow juvenile growth like European beech. In the range of each site index class such rate of growth is an indicator for a higher wood productivity in certain site conditions.

The biggest yield reaching 511 $m^3 \cdot ha^{-1}$ at the age of 100 was observed in sample plot No 4, which is located at 700 m a.s.l. on a rich site, followed by sample plot No 2 (453 $m^3 \cdot ha^{-1}$ at the age of 100) at 1450 m a.s.l., and then sample plot 1 (438 $m^3 \cdot ha^{-1}$ at the age of 100) at 1600 m a.s.l. The lowest yield was observed in sample plots No 3 and No 5 (274 and 212 $m^3 \cdot ha^{-1}$, respectively) located at 1100 m a.s.l. with sunny exposure and steep slopes. The age of maximum current annual volume increment was in accordance with the course of the growth rates: the earliest culmination occurred for sample plots No 1 and No 2 at the age of 50–60, followed by sample plots No 4 and No 5 and at last for sample plot No 3 at the age of 80–90.

The comparison of current annual volume increment values observed for investigated stands to the data of corresponding yield tables used in forestry practice for European beech stands in Bulgaria (Nedyalkov 1960) is of special interest (Table 3).

Data depicted in Table 3 show that CAI of the investigated stands exceed very much the values from the yield tables applied to these stands. It is especially true for sample plots No 1 and No 2 and even more for sample plot No 4 for which the observed values of CAI exceeded the respective yield table values 2.5 times.

The total aboveground phytomass at the age of 100 for the tree layer of the investigated phytocoenosis was 612 $t \cdot ha^{-1}$ for sample plot 4 and 488 $t \cdot ha^{-1}$ for sample plot 2 as shown in Table 4.

The phytomass of tree compartments decreased from stem to branches to leaves. The stem containing 85–89 % of the total phytomass accumulated represents the main part in the distribution of biomass in fractions.

In branches 9–13 % of the total phytomass was concentrated. The other compartments were less represented in the distribution with lower percentage: leaves less than 1 %.

The investigated phytocoenosis can be assigned to 9 degree – broadleaved forests with brown forest soils according to Bazilevich and Rodin (1971) classification for the distribution of aboveground communities related to biomass. Sample plot 2 was close to the upper end of the range while sample plot 4 was somewhat above the given values.

Another important index for functioning of plant communities is their productivity. Aboveground annual production of the tree layer for the investigated communities was respectively 23 t·ha^{-1} and 12 t·ha^{-1} for sample plot 4 and sample plot 2. The distributions by different tree fractions are given in Table 5. The analysis of tree fractions showed that stems provide the largest part of biomass production – 16 and 8 t·ha^{-1} per year, respectively, which is about 67 % of the total biomass production. The production of branches amounted to 3 and 1 t·ha^{-1}, for sample plot 4 and sample plot 2, respectively, which is 15 and 12 % of the total. The production of leaves was between 4 and 3 t·ha^{-1}, i.e. 16–22 % of the total production. The quantity of the total dry matter per unit leaf mass was 6.15 for sample plot 4 and 4.5 for sample plot 2.

The values of aboveground annual productivity observed allow us to assign the phytocoenosis of sample plot 2 (ass. *Asperulo odoratae-Fagetum sylvaticae*) to the moderately productive plant communities while sample plot 4 phytocoenosis

Table 3. Values of current annual volume increment (CAI) of sample plots and yield tables at the age of 100.

Data origin	Sample plot, No				
	1	2	3	4	5
	CAI, m^3·ha^{-1}				
This study	4.0	4.1	2.9	6.0	3.3
Yield tables	1.9	1.9	1.8	2.3	1.8

Table 4. Aboveground phytomass of the tree layer for beech phytocoenosis /t·ha^{-1}, a.d.w.; %/.

Sample plots /SP/	Stem	Branches					Leaves	Total
		Annual branches	Perennial branches diameter			Total		
			<3 cm	3–5 cm	>5 cm			
SP 4, Petrohan, t·ha^{-1}	522.985	0.852	18.204	29.170	37.418	85.644	3.671	612.291
SP 4, Petrohan, %	85.4	0.1	3.0	4.8	6.1	13.9	0.7	100.0
SP 2, Petrohan, t·ha^{-1}	438.858	0.541	24.556	9.243	12.688	47.028	2.725	488.611
SP 2, Petrohan, %	89.8	0.1	5.0	1.9	2.6	9.6	0.6	100.0

Table 5. Annual phytomass production for the tree layer in beech phytocoenosis /t·ha^{-1}, a.d.w.; %/.

Sample plots /SP/	Stem	Branches					Leaves	Total
		Annual branches	Perennial branches diameter			Total		
			<3 cm	3-5 cm	>5 cm			
SP 4, Petrohan, t·ha^{-1}	15.532	0.851	0.540	0.866	1.111	3.368	3.671	22.571
SP 4, Petrohan, %	68.8	3.7	2.4	3.8	4.9	14.9	16.3	100.0
SP 2, Petrohan, t·ha^{-1}	8.207	0.541	0.459	0.172	0.237	1.409	2.724	12.342
SP 2, Petrohan, %	66.4	4.4	3.8	1.4	1.9	11.5	22.1	100.0

(ass. *Festuco drymejae-Fagetum sylvaticae*) can be assigned to the high productive plant communities.

Conclusion

Analysis of the results of our study showed that Beech communities in the region of study are characterised by increasing rate of growth and late culmination of the current volume increment. The results confirmed that CAI reaches very high values for mature ages – 100 and over. The registered very high annual biomass productivity places these stands as ones with high growth potential and abilities to withstand adverse anthropogenic and biotic factors.

Acknowledgements

The authors are grateful to University of Forestry, Sofia for supporting the work through project No 108/2008.SRS/UF – "Effect of anthropogenic and biotic stressors on the phytosanitary status and biological productivity of the beech forests".

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