EuroCoppice COST Action (FP1301) - STSM Report

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Period	*01/03/2016-31/03/2016*

Case study from Bosnia and Herzegovina: Ecology and productivity of European beech coppice stands

Introduction

European beech (*Fagus sylvatica* L.) is a tree species that has very important ecological and economic role in European forestry, nevertheless, its coppice forests in Bosnia-Herzegovina have not received the attention they deserve. The reason for that is that management focused mostly on high beech forests. As a result, studies in coppice forests were very rare.

Silvicultural measures in Bosnian coppice forests have been usually conducted in a way that certain number of standards (trees of generative origin) remain in a stand. However, in practice the share of standards can very vastly, or some coppices are completely without standards.

Purpose of STSM

The purpose of this STSM was to enhance scientific cooperation between faculties of forestry in Krakow and Banja Luka, and also to lay solid ground for prospective scientific publications.

Study area and data collection

Three coppice beech stands located in the forest management area "Donjevrbasko" close to Banja Luka, in the north-western part of Bosnia and Herzegovina were studied. These coppice stands grow in different conditions; namely, according to available eco-vegetation maps, first beech coppice stand develops in favorable site conditions with high wood production potential for beech. Thereby, previously in the fieldwork we chose such stand which on the first look had fairly good quality of stools. This stand (37a) is located in forest management unit (FMU) „Dubička Gora“. The age of trees in the stand ranged between 60 and 70 years. In addition, we observed that our first coppice stand could be defined as a coppice with standards due to somewhat higher share of standards.

The second coppice stand (39b) was also located in FMU „Dubička Gora“ and also grows in good site conditions where high production potential can be expected for beech, but in this case we selected for measurement the stand with poor technical quality of trees and poor health state. The trees in this stand were 40-50 years old. Third coppice stand (27b) was located in FMU "Piskavica", grows in very poor site conditions where low production potential can be expected for beech. The age of trees in this stand ranged between 30 and 40 years.

Considering data collection in the field, three observation plots (OP) were set in studied coppices, that is, in each stand one plot. The size of each OP was 1 hectare (100 x 100 m). Data collection was organized in two phases. First phase was conducted during the summer when canopy openness was sampled by taking systematically the hemispherical photographs at 1,30 m above ground in a grid 25 x 25 m with Nikon COOLPIX 5000 digital camera equipped with a Nikon FC-E8 fisheye lens. During the summer also samples about harmful insects and fungi were collected on deceased trees, whereas phyto-sociological records of herbaceous species were conducted on 20 x 20 m sub-plots placed in the center of each large 1 ha plot.

Second phase started in November since we wanted to measure heights of beech trees when they have no leaves for better precision. This phase included the measurements of tree heights and diameters at breast height (1,30 m above ground). Also, on each OP the increment cores were recently extracted including ten rings representing last ten years. The increment sampling comprised 10 trees in each dbh class (the width of dbh class was 5 cm). In addition, six soil profiles were opened, by two on each OP.

Data analyses

During the first week of STSM in Poland we conducted the modeling of site classes for each coppice stand based on diameter-height relationships. Prior to coming to Poland, the datasets from large-scale inventory of coppice forests from the area "Donjevrbasko" were prepared. These data were used for parameterization and construction of preliminary standardized site classes ranging from class I to V (on the scale from I to V, site class I represents the best site conditions). Construction of new site classes and yield tables is important because currently used yield tables in Bosnia are outdated as they originate from old German yield tables from the first half of 20th century. This causes numerous problems with biomass assessment. Therefore, learning the parameterization technique and actually constructing the preliminary standardized site class models and defining equations for wood volume estimation of beech coppice forests was one of the most important outcomes of STSM at Krakow University. After this, we fitted the height curves from three OP into preliminary created system of site classes.

As in other European countries, many coppice forests in Bosnia-Herzegovina have been neglected (abandoned, not managed) in last several decades. The reason for that has been the migration of people from rural areas toward urban centers (Ciancio, 2006a; Nocentini, 2009). This was also the case in our study area, however, even "neglect" has not been the same in all stands. Consequently, our second major goal of STSM was to examine the effects of lengthening the rotation periods on wood production in studied coppices.

In the second week the calculations of measures of central tendency concerning diameters and heights were carried out as well as laboratory analyses of 18 samples for determination of chemical properties of soil from three studied OP. Third week was used for calculations of basal area, growing stock and volume increment of coppice stands, and for the analyses of diameter structure especially in terms of ingrowth of younger trees into the upper stand story.

During the third week the hemispherical photographs were processed for the purpose of determination of canopy openness by using software programs GLA 2.0 and WinSCANOPY. In the fourth week IUFRO classification was applied to assess the quality and vitality of trees. In this period also the regeneration and diversity of herbaceous plants were studied, and the most harmful fungi and insects that were found in the studied coppices were described.

All distributions (diameters, heights, wood volume) and histograms (IUFRO classifications on tree vitality, health state, quality of trunk, etc.) are expressed in percentages for clear graphical insight into differences between studied coppices. Absolute values are provided in the text. Finally, based on the obtained results we tried to define the most appropriate silvicultural measures that shall be applied in the studied coppice stands.

Results

The determined number of trees per hectare on OP1, OP2 and OP3 was 939, 308, and 2000, respectively. The stands are significantly different in terms of the number of trees, which was to be expected due to different age of stands. The OP1 with 939 trees/ha (at the age of 60-70 years) indicated that the silvicultural measures have not been performed recently. On the contrary, on the OP2 tree number was drastically lower and canopy openness was 26%.

The mean diameter of stands ranged from 13,17 cm on the OP3, over 22,9 cm on OP1, and up to 24,45 cm on the OP2. Mean tree heights ranged between 12,6 m in OP3, then 16,4 m on the OP2, and up to 22,9 m on the OP1.

The preliminary equations for calculation of wood volume in beech coppices based on apriori prepared larger datasets are given in Table 1.

Table 1. Parameterized models for wood volume of beech coppices

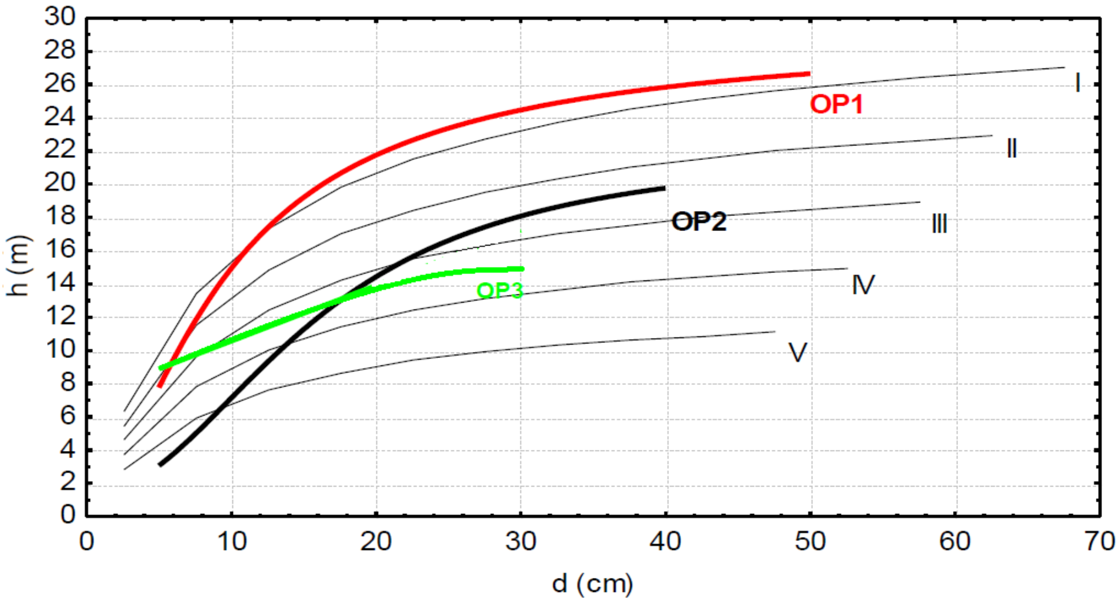
Site class		Functions for wood volume calculation in beech coppices based on diameter and site classes
I	:	$v = -0{,}03662494+0{,}00518391*d+0{,}00096941*d^2-0{,}00000058*d^3$
II	:	$v = -0{,}02092986+0{,}00329591*d+0{,}00084002*d^2-0{,}00000056*d^3$
III	:	$v = -0{,}00707555+0{,}00149138*d+0{,}00073056*d^2-0{,}00000073*d^3$
IV	:	$v = 0{,}00409305+0{,}00001870*d+0{,}00062901*d^2-0{,}00000095*d^3$
V	:	$v = 0{,}00642995- 0{,}00029552*d+0{,}00050354*d^2-0{,}00000084*d^3$

Site quality for beech was determined by comparing the constructed height curves of observation plots (Table 2) with preliminary created standardized system of site classes for coppice beech forests for the management area "Donjevrbasko", as shown in the Figure 1.

Table 2. Statistics for diameter-height curves in studied coppices

Observation plots	Parameters of diameter-height regression			Standard error of regression (m)	R^2
	a	b	c		
OP1	0,0353	0,1638	2,1639	1,98	0,65
OP2	0,0492	-0,1430	13,6539	1,95	0,63
OP3	7,2173	0,3343	n/a	2,36	0,31

Figure 1. Determination of site classes in study coppices



According to compared curves, the site where OP1 is located, belongs to the first class. Height curve for OP2 partly deviates from the standardized curve lines, which sometimes happens when comparing real stands with generalized height models, however, most trees from OP2 have heights closest to the line of standardized class III. Therefore, we could say that OP2 is located on the third site class. The relationship between diameters and heights is most irregular on the OP3, and for this reason we applied linear function instead of Lorey's formula. Constructed height curve for OP3 lies between third and fourth site class.

The basal areas amounted to 14,5 m^2/ha, 27,3m^2/ha, and 38,7m^2/ha, on OP2, OP3, and OP1, respectively. Determined volume on the OP1 was 339 m^3/ha for the entire wooden mass (>5 cm), thanks to a large number of trees and a large proportion of trees with seed origin. The volume on the OP2 was very low (134,5 m^3/ha) due to the reduced number of trees, whereas on the OP3 wood volume amounted to 241,3 m^3/ha. Nevertheless, the volume increment was rather similar among observation plots (8,19 m^3/ha on OP1, 8,51 m^3/ha on the OP2, and 9,50 m^3/ha on OP3). Over-stocking, dense canopy and average diameter of 22,9 cm on OP1 induced the reduction of tree crowns and decrease of diameter growth of individual trees. As a result, volume growth rate on OP1 was lower compared to other two observation plots, as well as significantly lower percentage of increment (1,5%) and thus the volume increment. The results above refer to last 10-year period. In fact, even last 15 analyzed tree rings from OP1 showed decreasing growth rate; therefore, it is clear that this stand has been "neglected" for longer period of time than the other two stands.

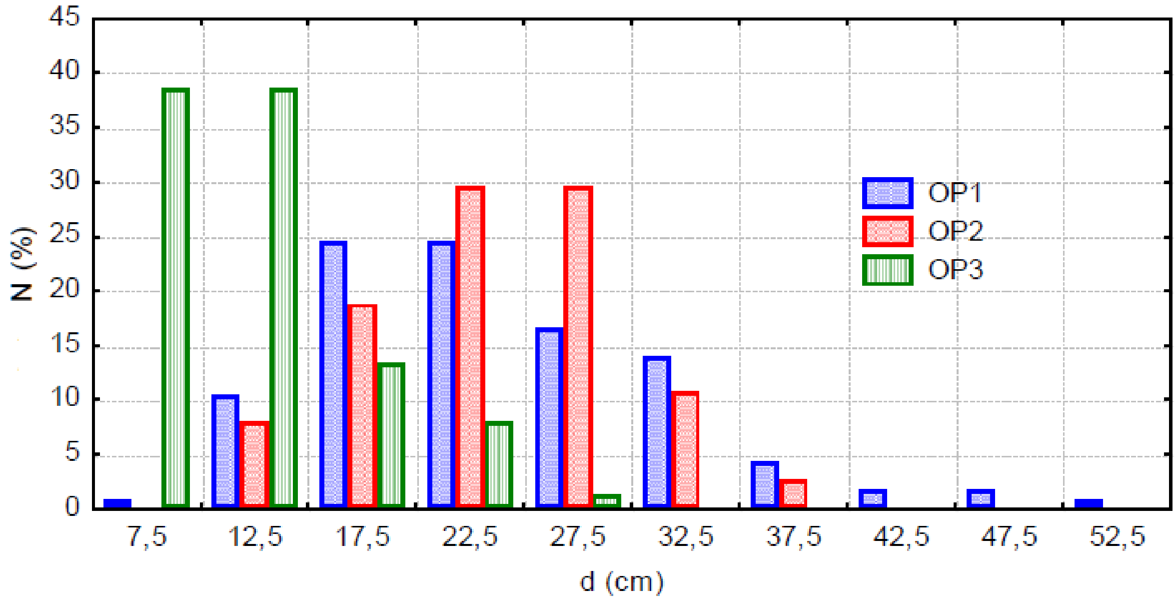
For a detailed view of diameter stand structure, the numerical indicators were used such as arithmetic mean ($\overline{X}$), median (Me), standard deviation (Sd), coefficient of variation (Cv), asymmetry coefficient (α3), and kurtosis (α4). The values of diameter numerical indicators in the observation plots are shown in Table 3. Mean diameters on the observation plots 1 and 2 were fairly similar and greater compared to those on the OP3.

Table 3. Measures of central tendency and variability of diameter structure

Measures		N	$\overline{X}$	M_e	Sd	C_v	α_3	α_4
Observation plots	OP1	939	21,46	20,00	8,03	37,44	0,86	3,74
	OP2	308	23,03	23,00	5,58	24,21	-0,08	2.63
	OP3	2000	12,04	11,00	4,86	40,33	1,01	3,36

The coefficients of variation of tree diameters were high. The highest Cv for diameter of trees was 40% on OP3. Coefficients of asymmetry on OP1 and OP3 indicated strong positive asymmetry of distribution, whereas the OP2 had symmetrical diameter distribution. Besides, distribution for OP1 and OP3 are "flattened" on the sides and elongated vertically compared to the normal distribution, while the OP2 had flattened top and stretched sides compared to the normal Gaussian distribution. On the Fig. 2 it is evident that OP1 and OP2 represent classical even-aged structure, whereas the distribution for OP3 tends to indicate uneven-aged or selection structure. Nevertheless, such structure probably does not have perspective to be maintained in the closer future due to absence of seedlings and saplings in the understory.

Figure 2. Diameter structure of studied coppices



The values of numerical indicators of height structure are shown in the Table 4. The arithmetic mean height ranges in the interval from 11,2 m on the OP3, on the OP2 it reached 15,4 m, and on the OP1 amounted to 22,1 m. Variation of tree heights was considerably lower than the variation of tree diameters. The largest height variation was observed on OP3, and the smallest variation on OP1. The distribution of tree heights on the OP3 was uniform (symmetrical), the OP1 expressed moderately negative asymmetry, whereas the OP2 exhibited strong negative asymmetry. The distribution on OP3 is normally flattened, while OP1 and OP2 have side-flattened elongated distributions compared to normal distribution, so that emphasized differentiation occurs in studied coppices (Table 4 and Figure 3).

Table 4. Measures of central tendency and variability of diameter structure

Measures		N	$\overline{X}$	M_e	S	C_v	α_3	α_4
Observation plots	OP1	939	22,13	22,40	3,28	14,81	-0,26	3,18
	OP2	308	15,35	15,70	3,25	21,16	-0,68	3,55
	OP3	2000	11,24	11,00	2,88	25,61	-0,08	3,06

Figure 3. Tree height structure of studied stands

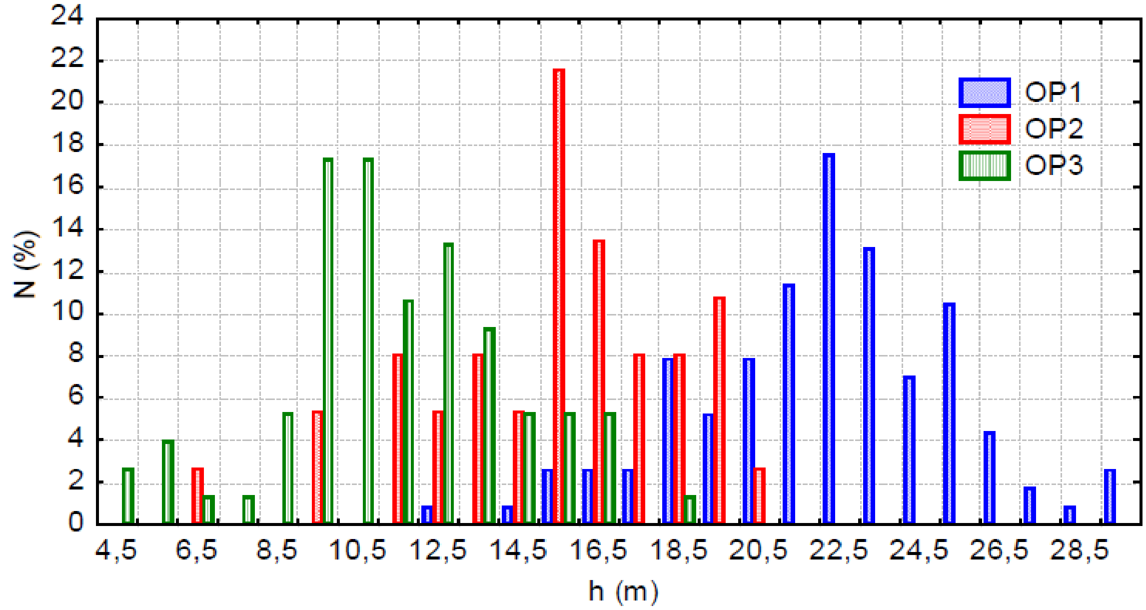
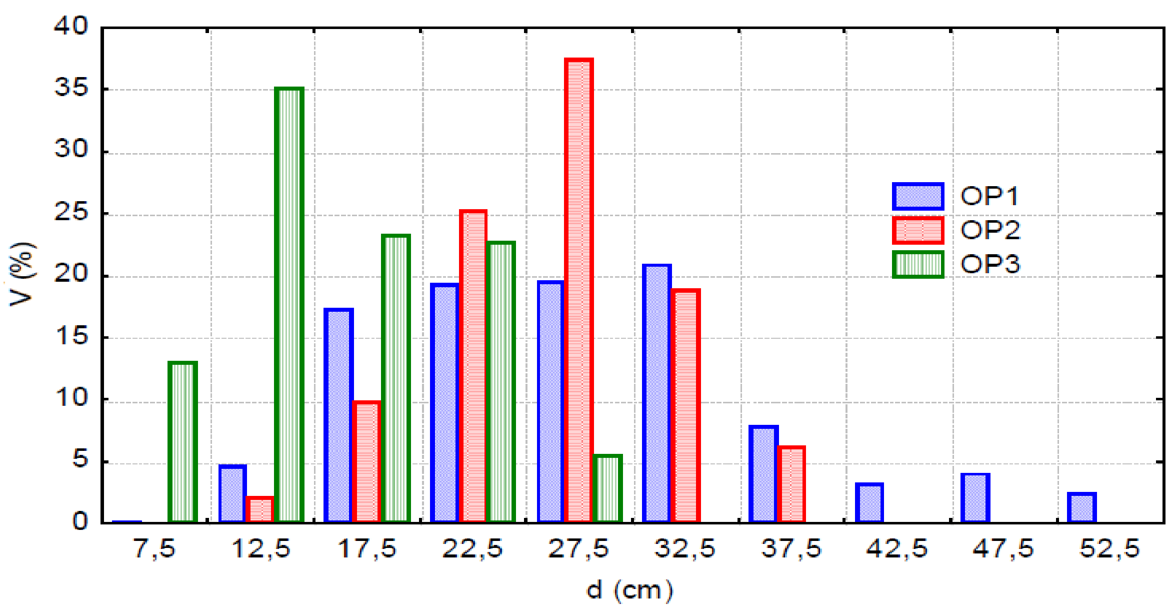


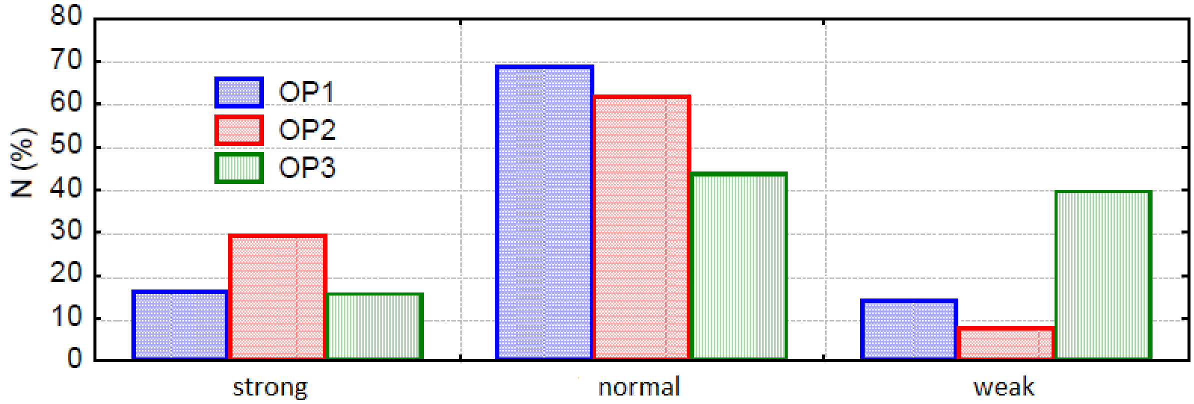
Figure 4 shows the distribution of volume across diameter classes. On the OP1, up to 80% of wood volume was produced in diameter classes ranging from 15 to 35 cm. On the OP2, 80% of volume was accumulated in diameter range between 20 and 35 cm, whereas 80% of wood volume on OP3 was stocked up in diameter classes ranging from 10 to 25 cm.

Figure 4. Distribution of wood volume across diameter classes



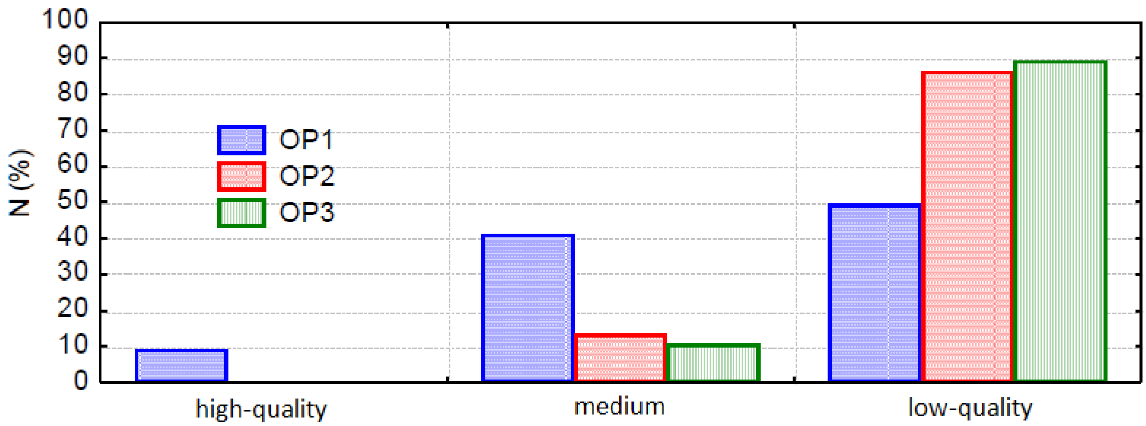
When it comes to the vitality of trees based on IUFRO classification, with Fig. 5 we notice that vitality of trees on OP1 and OP2 was rather satisfactory (the share of normal trees and those with strong vitality was over 85%), while the share of trees with weak vitality on OP3 was fairly high (40%).

Figure 5. Vitality of trees



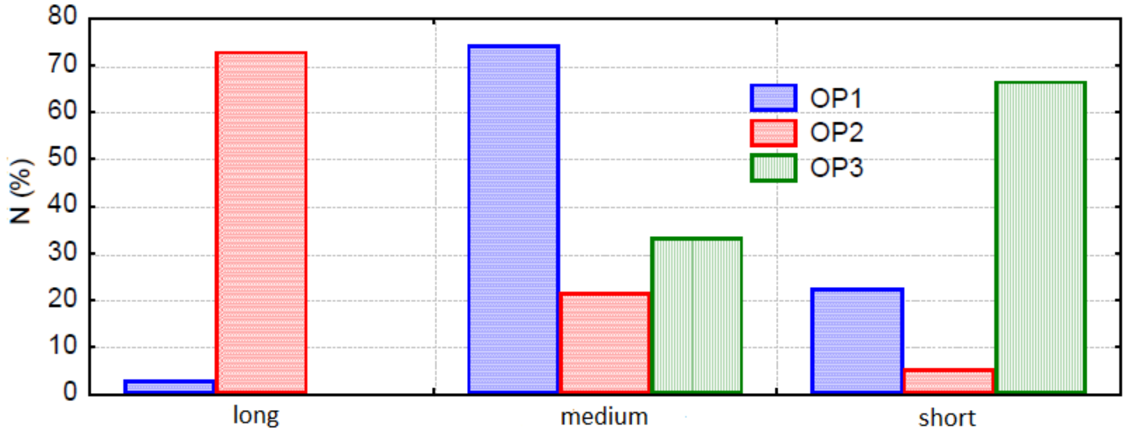
Following criteria of IUFRO classification for stem (trunk, bole) quality, the quality of trees on the OP1 significantly differed from the quality on the other two OP (Figure 6). Namely, OP2 and OP3 had no stems of excellent quality and even the share of normal quality trees was relatively low (up to 15%). On the other hand, OP1 had 10% of excellent quality and 41% of normal quality trees.

Figure 6. Quality of trees



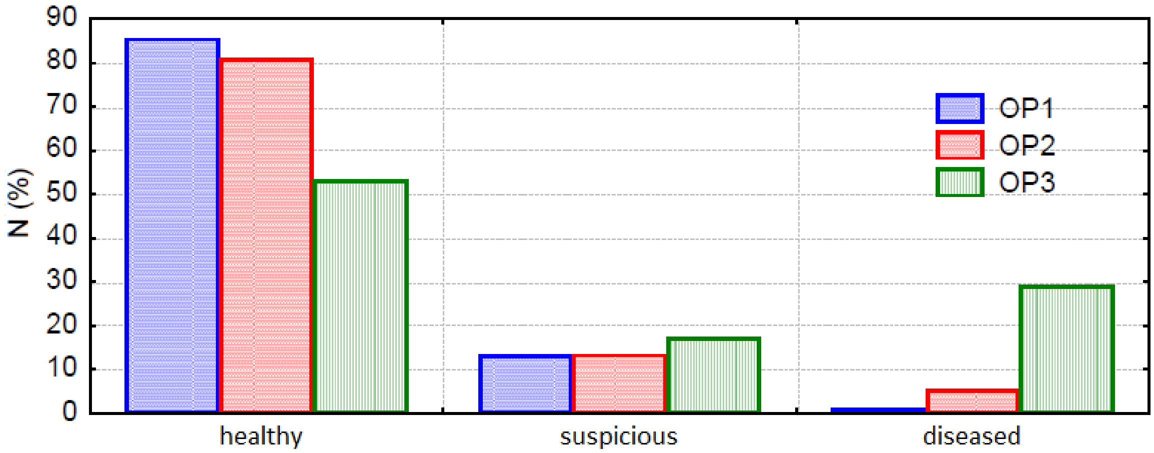
In terms of the length of tree crowns, studied coppices differed significantly (Figure 7). On the OP2 dominate trees with long crowns (74%), which was a consequence of reduced tree number per unit of area. The OP3 was dominated by trees with short crowns (68%). On the OP1 the most common trees had crowns of medium length, which generally should be beneficial in terms of vitality and growth of trees. However, due to very high number of trees for a given age and strong competition for resources among the trees on the OP1, crowns on this area had small volume and small surface projections, which actually negatively affected volume growth of whole trees, and eventually volume growth of the whole stand.

Figure 7. Length of tree crowns in studied coppices according to IUFRO classification



Considering the health status of trees, the situation on OP3 differed significantly from the state on the other two observed plots. The proportion of diseased trees on OP3 amounted to 30%, and together diseased trees and trees of suspicious health status equaled 45%. On the other hand, the share of diseased trees on the OP1 was only 1% (Fig. 8.).

Figure 8. Health state of trees according to IUFRO classification



Ecological aspects

The results regarding ecological aspects of studied coppice stands include regeneration, ground flora, soil properties, canopy openness, and harmful fungi and insects. Considering soils, physical properties were determined during the fieldwork, whereas chemical properties were determined during this STSM in the laboratory of the host university. In first coppice stand (OP1) the soil type of brown rendzina on dolomite was determined. The following soil horizons were identified: O–A–A(B)– C. The O horizon was 4 cm thick (including all three sub-horizons: Ol, Of, Oh); the A horizon – 15 cm, a A(B)C – 29 cm. A(B) horizon had larger share of loam compared to horizons above it. Measured pH in horizon A was 6,19 and in horizon A(B) 6,59, which indicated light acidity of this soil type, however, with depth the pH reaction became neutral. Physiologically active profile was 48 cm, hence, the productivity of brown renzina on dolomite in OP1 can be assessed as relatively high and favorable for growth of beech trees. The A horizon was very humus, and as a result the content of available N, P, K nutrients was high. The share of humus amounted to 15,71%, which is probably due to favorable stand conditions. This soil was also found to be very rich with nitrogen (N=0,86). The ratio C/N indicated high microbiological activity and favorable conditions for mineralization of organic matter on the forest floor.

The carbonate rendzina on dolomite was determined on OP2. This soil sub-type was less productive compared to OP1. The following profile of horizons was identified: O–A–C. Total profile depth was 18 cm. Because of total profile shallowness, this soil probably does not have good water retention capacity. The pH reaction in this soil ranged from 7,90 to 8,40, which could be defined as moderately alkaline. High values of pH were caused due to increased share of carbon (C). The share of humus in this soil was 9,26 %, much lower compared to brown rendzina. Nevertheless, the share of N was relatively high (0,45). This soil had small amount of available phosphorus (P), while the presence of potassium (K) was small to moderate. In addition, carbonate rendzina had lower share of loam component in transitional A(B) horizon compared to brown rendzina, which indirectly indicated that the latter is already in the evolutionary process toward brown soil.

In the third stand (OP3) the morphology of profile indicated distric cambisol on silicate bedrock. In this profile the following horizons were identified: O–A–(B)–C. The pH reaction of A horizon was 4,90, and of B horizon 4,70. The analyzed profile thus can be characterized as very acid soil in which pH value declined with soil depth (contrary to rendzina soils on OP1 and OP2). The share of humus was 6,5 %, however, chemical properties of this soil type were not favorable (strong acidity, scarcity of N, P, K nutrients). Besides, A horizon had low total sum of bases (19 cmol/kg), and B horizon 4,60 cmol/kg. The presence of active K was moderate (11 mg/100 g of soil), wheres P was on very low level (5 mg/ 100 g of soil). Despite unfavorable chemical properties, C/N ratio was favorable (>15). This soil had relatively favorable physiological depth, structure and texture, hence our presumption is that it could have potentially greater productivity than it was determined in our study. It is also important to notice that studied coppice stand (OP3) on distric cambisol was under coppicing cutting regime which certainly influenced productivity, whereas other studies were rare and conducted only in preserved and silviculturally well-tended high beech forests of seed origin. Therefore, further investigation of this soil type and its productivity in coppice forests is needed as our results were somewhat different from previous studies (*e.g.*, Kapovic, 2013; Knezevic *et al.*, 2011).

Canopy cover, ground flora and regeneration

There was no significant difference in results concerning canopy openness when different sofware programs (GLA 2.0 and WinsCanopy) were applied. On average, calculated canopy openness amounted to 4%, 26%, and 5%, on OP1, OP2, and OP3, respectively. Consequently, due to dense canopy and low transmitted light in the first and third coppice stand, the regeneration was not present on set observation plots. On the OP2 canopy was more open (26%), hence the regeneration was present with uneven spatial distribution. The density of regeneration up to 50 cm in height was 14722/ha on this OP, whereas the regeneration 51-130 cm high was less present amounting to only 251/ha. The vitality of regeneration was assessed as moderate, and out of total regeneration density the young trees of vegetative origin made 72% and those of seed origin 28%.

There was no significant difference in terms of herbaceous species and shrubs that were registered on OP1 and OP2. The following species were identified: *Festuca drymeja, Dentaria bulbifera, Galium odoratum, Dentaria enneaphyllos, Polygonatum multiflorum, Lonicera alpigena, Melica uniflora, Carex silvatica, Sanicula europaea, Aremonia agrimonioides, Arum maculatum, Dryopteris filix-mas, Prenanthes purpurea, Rubus hirtus, Luzula luzulina, Asarum europaeum, Lamiastrum galeobdolon, Platanthera bifolia, Viola reichenbachiana, Anomodon viticulosus, Platygyrium repens, Euphorbia amygdaloides, Mercurialis perennis, Asperula odorata, Sambucus nigra, Geranium robertianum, Glechoma hirsuta*.

On the OP3 the following herbaceous species and shrubs were determined as most dominant: *Oxalis acetosella, Veronica officinalis, Luzula luzuloides, Pteridium aquilinum, Hieracium umbelatum, Deschampsia flexuosa, Sambucus racemosa, Sambucus nigra, Rubus sp., Genista sp., Juniperus communis, Crataegus monogyna, Genista tinctoria.*

Harmful fungi and insects

On the observation plots as most harmful fungi the following species were detected: *Hypoxylon deustum* (Hoffm.ex Fr.) Grev., *Pholiota adiposa* (Fr.) Kummer, *Armillaria mellea* (Vahl. ex Fr.) Karst, *Ganoderma applanatum* (Pers.ex Wallr.) Pat., *Fomes fomentarius*(L.)Fr. *Nectria ditissima* Tul.& C.Tul., *Nectria coccinea* (Pers. Ex Fr.) Fries. in cooperation with insect species *Criptococus fagisuga* Lind.

Among harmful insects the following species were identified: *Phyllaphis fagi* L., *Agrilus viridis* L., *Cerambyx scopoli* Fuessl., *Rhynchaenus fagi* L., *Mikiola fagi* Htg., *Operophthera brumata* L., *Dasychira pudibunda* L., and also above-mentioned *Criptococus fagisuga* Lind., which enables the infection of beech trees with fungus *Nectria coccinea.*

Conclusions and silvicultural recommendations

Considering the presented results, especially considering productivity, health status and quality of trees in studied stands, the practical recommendations for forest management can be drawn. As the first coppice stand (OP1) contained sufficient number of good quality trees, this stand could be completely converted into high silvicultural form where trees regenerate entirely from natural seed. In this regard, selective thinnings seem to be the appropriate approach until the final cut, after switching from coppicing to shelterwood system.

Second coppice stand (OP2) had disturbed canopy and low quality of trees. Consequently, there are two potential solutions through direct conversion. Namely, after clearcutting it might be possible to conduct re-planting of beech. The second solution might be conversion by species substitution. In that case, after clearcutting of beech, the preferable species for planting would be Austrian pine (*Pinus nigra* J.F. Arnold) and/or Scots pine (*Pinus sylvestris* L.), as those species would be able to maximally use the productive potential of the given site (shallow soil and dolomite bedrock).

Third studied coppice stand (OP3) was located in conditions which naturally lead to high productivity of beech. However, in our study the OP3 exhibited very low wood quality and was under strong attack of harmful fungi and insects. Because site conditions are favorable, but the overall state on OP3 (health, quality) is very bad, we propose complete removal of standing trees and re-planting of beech. The remaining stumps could be treated with appropriate arboricides in order to prevent their coppicing growth. Additionally, it is also possible to admix sycamore maple (*Acer pseudoplatanus* L.) with beech since maple has fairly high resistance toward mentioned harmful fungi.

The above-mentioned strategies are recommended for domestic forest managers that recently more and more plan switching from coppicing to high forests with seed origin. Nevertheless, it is possible that some of these stands remain under coppicing management regime (with rotation up to ten years), which in practice will basically depend on the local demand for firewood from beech coppices.

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Appendix

Figure 9. Observation plot 1 (OP1)

Figure 10. Observation plot 2 (OP2)

Figure 11. *Nectria galligena* (Bres.) on OP3

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Declaration of acceptance of STSM report by the host institution

The Faculty of Forestry in Krakow hosted dr. Srdjan Keren, teaching assistant at the Faculty of Forestry in Banja Luka (Bosnia and Herzegovina) on the basis of Short Term Scientific Mission within COST Action FP1301 (EuroCoppice). He successfully worked together with me and the other colleagues at our Department on his materials concerning the productivity and ecology of coppice beech stands. The STSM lasted from 1st until 31st of March, 2016.

After reviewing the submitted STSM report, I confirm the acceptance from my side.

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