Timber production and ecological characteristics of trees in coppice forest in the Voskop nature reserve in Český kras – a case study

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ABSTRACT: A new approach to forestry that increasingly values non-timber forest functions brings new interest and value also to coppice forests. A case study in the Voskop nature reserve located in the Český kras Protected Landscape Area was focused on a comparison of the timber production of individually growing trees and in multistemmed trees resprouting after cutting (stools). We recorded tree ecological characteristics of trees such as existence of stem cavities, whether the tree grows individually or from a stool and whether or not the tree is broken, dead or has a dying crown. In total 2,670 trees were sampled on a 1,875 ha sample plot. The main tree species forming coppice stands are *Quercus petraea* and *Carpinus betulus*. The total stock volume of only 136 $m^3 \cdot ha^{-1}$ is very low at 84 years of age. The stock volume of individually growing trees is 84 $m^3 \cdot ha^{-1}$ and the stock volume of trees in stools is only 52 $m^3 \cdot ha^{-1}$ although the number of individually growing trees is lower.

Keywords: stools; site index; stock volume; *Quercus*; *Carpinus*

There has been a long history of coppice forest management in Central Europe (Gross, Konold 2009; Hédl et al. 2011; Kadavý et al. 2011; Machar et al. 2012). However, with the onset of intensive forestry in Central Europe at the beginning of the 19th century, coppice forests and coppice-with-standards forests have gradually vanished (Ningre, Doussot 1993). Nowadays, in certain cases, the coppice forest experiences its revival because its management is cheap and its rotation cycle is short in comparison with the high forest. It can also support higher biodiversity of organisms linked to forest ecosystems including organisms living in dead wood (Konvička et al. 2004; Kadavý et al. 2011). Although non-timber production functions are very important, timber production should not be overlooked. Earlier studies stated that at younger age the increment of coppice forest was higher than that of high forest, although the maximum total mean increment occurred at younger age and the diameter and height increment curve decreased faster (Vyskot et al. 1978). Recent studies however showed that the increment is more dependent on natural conditions than on the method of woodland management (Utínek 2004). There is an anecdotal evidence that coppice forests could have comparable production to high forests even at higher age (Kadavý et al. 2011). Nevertheless, the abandoned coppice forests in the Czech Republic do not provide sufficient data to support this.

Regeneration of coppice forest is determined by sprouting capacity of the tree species forming the stands. Typical coppice forest consists of coppiced stools. During the stand development the number of trees in stools decreases either naturally or artificially by tending. In old untouched remains of coppice forests stools survive to older age. However, the ratio of stools to the total number of trees and their timber production at older age have not been studied. Similarly, the difference between trees in stools and trees growing individually remains unknown, although the spatial structure in coppice forests has been compared to other forests by Rozas et al. (2009).

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Total stock volumes of coppice forests were investigated in beech, chestnut and oak stands (Canellas et al. 2004; Ciancio et al. 2006; Short, Hawe 2012; Spinelli et al. 2014) but without comparison of the production from stools and individual trees. Due to abandonment of coppice forest management, the over-matured remnants of these forests exist only in nature reserves and in forest estates of smallholders (AOPK ČR 2010; Kadavý et al. 2011).

The coppice forest management appears somewhat controversial. On the one hand, coppice stands can maintain higher biodiversity (Konvička et al. 2004; Machar, Drobilová 2012), but on the other hand, they enable the spread of non-native species (Radtke et al. 2013). In the altered landscape of Central Europe the maintenance of biodiversity is very important but the aspect of timber production should not be completely discarded. The coppice forests have been managed mainly by smallholders and the management has been developed mainly to fulfil their need for ongoing production (Kadavý et al. 2011). Our study evaluates the production and differences between trees growing in stools and individually in over-matured coppice forest in Central Bohemia (Czech Republic).

The main hypothesis deals with differences between stools and trees growing individually. The Occurrence of cavities should be higher in stools than in individual trees and the number of dead and dying trees should be also higher within stools. Moreover, it is supposed that basic mensurational data (diameter at breast height and height) will be higher within individual trees than within stools.

MATERIAL AND METHODS

The study was conducted at the Voskop nature reserve composed of coppice forests. They were left without intervention for decades because the locality belonged to the area of the limestone quarry Čertovy schody, which was originally designated for deforestation and subsequent mining. However, later on the area was taken out of mining operations and designated as a nature reserve. The rectangular sample plot of 125 m by 150 m in size has been established in the centre of the reserve. The centre of the sample plot has the coordinates 49°54'23.596''N; 14°4'2.724''E. The average annual precipitation is 660 mm and the mean annual temperature is 9.0°C (UHUL 2000). The plot includes groups of forest habitat types 1W – Limestone Hornbeam-Oak, 1A – Stony-colluvial Maple-Hornbeam-Oak and 1X – Cornelian Cherry-Oak (Podhorník 2001) within the Czech forest habitat type classification (Viewegh et al. 2003).

Two sets of data were collected for every tree measured in the plot. The first set included mensurational data such as tree species, diameter at breast height (DBH), tree height (h) and crown base height using the electronic calliper (65 cm Caliper Haglof Mantax Digitech) (Haglöf AB, Långsele, Sweden) and land laser hypsometer (LaserVertex) (Haglöf AB, Långsele, Sweden). The second dataset contained ecological data such as existence of cavities in stems, whether the tree grows individually or from a stool and whether or not the tree is broken, dead or with a dying crown. In total 2,670 trees were measured.

The age of the stand was verified by counting tree rings in increment cores collected at random using Pressler's increment borer (10 mean oaks and 10 mean hornbeams). In the map of forest management plan the stand is depicted by number 9, which also means the age class (81–90 years).

The stock volume was calculated using volume tables (ULT 1951). The height was fitted based on the tree diameter using logarithmic regression Eq. 1 (Šmelko 2000):

$$y = a \times \ln(x) + b \quad (1)$$

where:
a, b – parameters,
y – fitted height,
x – diameter at breast height.

As the stands are mainly composed of oak and hornbeam, only characteristics of these two species were used for a statistical analysis. For the data describing tree characteristics, the relative value, i.e. the ratio between the number of trees with given characteristics and the number of all trees in one species, was used. A two-sample simple *t*-test was used to compare the difference between the two groups of trees.

The relationship between ecological data and diameter classes for *Q. petraea* and *C. betulus* was also assessed using the Pearson correlation coefficient. The analyses were performed in the STATISTICA (StatSoft, Tulsa, USA) and Microsoft Excel software.

RESULTS

The age of the sample stand was 84 years. We identified and measured 2,670 trees of 10 species from which 1,135 trees grew individually and 1,535 grew in stools. Only trees with merchantable timber were measured (DBH > 7 cm). The tree species in the plot included *Acer campestre, Acer platanoides, Carpinus betulus, Cerasus avium, Fagus silvestris, Quercus petraea, Pyrus pyraster, Sorbus aria, Sorbus torminalis* and *Tilia cordata*. Although the number of trees growing in stools was higher, the stock volume consisted mainly of trees growing individually (84 m^3 vs 52 m^3 per ha – 62% vs 38%). The total mean increment for the whole stand was 1.66 $m^3 \cdot ha \cdot yr^{-1}$, for *Q. petraea* 1.15 $m^3 \cdot ha \cdot yr^{-1}$ and only 0.29 $m^3 \cdot ha \cdot yr^{-1}$ for *C. betulus*.

Within the same stand the mean DBH and height of trees growing individually are higher than dimensions of trees growing in stools (Table 1). As the proportion of *Q. petraea* and *C. betulus* is the highest and both species account for approximately 90% of the stand, the comparison of three types of mensurational data for these tree species was tested statistically – DBH, height and ratio between crown length and tree height. The differences between trees growing individually and trees growing in stools were significant at $P < 0.05$ except the difference in DBH for *C. betulus* which was nonsignificant (Fig. 1).

A comparison of ecological data for each tree species confirms that trees growing in stools have the ratio of dead wood (dead trees, snags and trees with dying crown) higher than trees growing individually. This is true also of the ratio of trees with cavities (Table 2).

The number of trees with cavities and dying crowns as well as the number of dead trees and snags decrease in relation to increasing diameter of both main trees in both groups except for hornbeams with cavities growing in stools (Table 3).

The majority of the stand is composed of *Q. petraea* and *C. betulus*. The frequency distribution curves are similar for trees growing individually and in stools within each species. However, they differ between the tree species. While the curve of frequency distribution for *Q. petra*ea is similar to Gaussian curve, curves for *C. betulus* are similar to inverse J-shape (Fig. 2).

DISCUSSION

The production of the coppice forest on sample plots is very low in comparison with high forest under the same natural conditions (the same groups of forest type) while the site indexes of trees vary from 6 to 14 and they are

Table 1. Basic differences between trees growing individually and in stools

	n	Mean		Volume ($m^3 \cdot ha^{-1}$)	Volume per 1 ha	Reduced area (ha)	Tree species composition	Site index
		diameter at DBH (cm)	height (h)					
Individually								
A. campestre	41	13	9	2.01	1.07	0.01	2	10
F. silvestris	17	28	14	8.78	4.68	0.02	3	14
S. torminalis	55	18	10	4.35	2.32	0.02	3	10
Q. petraea	660	20	12	126.46	67.44	0.47	74	12
C. betulus	329	11	9	11.76	6.27	0.1	16	10
P. pyraster	3	12	9	0.17	0.09	0	0	10
A. platanoides	18	20	11	3.16	1.68	0.01	2	12
S. aria	8	10	7	0.17	0.09	0	0	8
C. avium	4	8	10	0.08	0.04	0	0	10
Total	1,135			156.94	83.70	0.63	100	
Stools								
A. campestre	22	11	7	0.65	0.34	0.01	2	8
F. silvestris	34	18	11	5.11	2.72	0.02	4	12
S. torminalis	17	16	10	1.56	0.83	0.01	2	10
Q. petraea	518	16	10	55.75	29.73	0.26	45	10
C. betulus	877	11	9	30.66	16.35	0.25	43	10
A. platanoides	54	14	11	4	2.13	0.02	4	12
T. cordata	6	11	12	0.27	0.14	0	0	12
S. aria	7	11	6	0.14	0.074	0	0	6
Total	1,535			98.14	52.34	0.57	100	

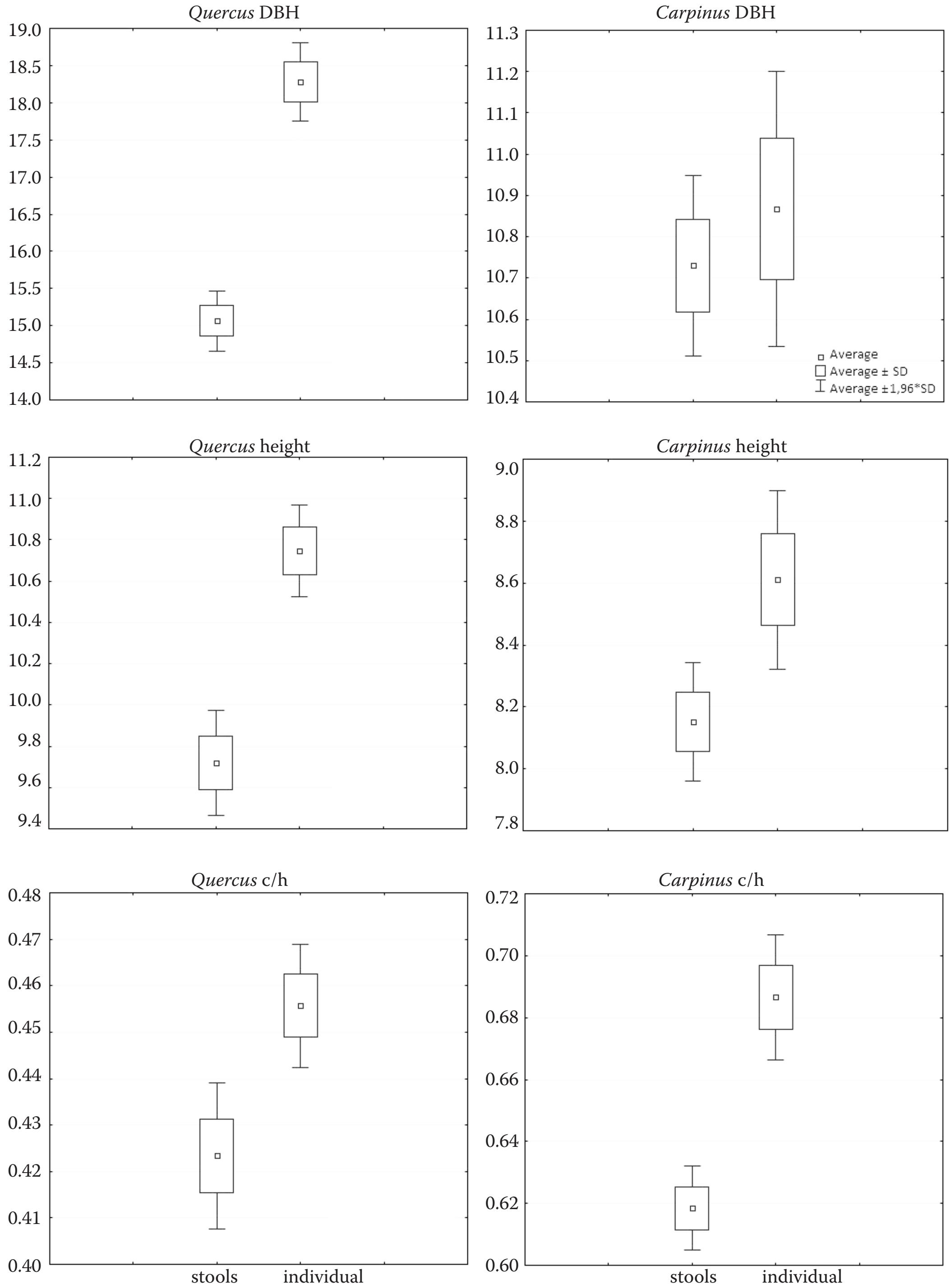

Fig. 1. Comparison of basic mensurational data (DBH, height and c/h – ratio between crown length and tree height) between trees growing individually and in stools for *Q. petraea* and *C. betulus*

lower than the poorest site index displayed in yield tables (UHUL 1990). The site indexes for main tree species in high forest are higher, for *Q. petraea* between 12 and 20 on the same forest habitat types (UHUL 2000). In comparison with the production of other coppice forests the total stock volume of 136 m^3 per ha and increment of 1.15 $m^3 \cdot ha \cdot yr^{-1}$ for *Q. petraea* and 0.29 $m^3 \cdot ha \cdot yr^{-1}$ for *C. betulus* are lower than the production of beech coppice or chestnut coppice on various sites. If the stand consisted only of monocultures of *Q. petraea* or *C. betulus* with the same parameters (DBH, height), the values of total mean increment according to the yield tables would be 1.54 $m^3 \cdot ha \cdot yr^{-1}$ and only 0.83 $m^3 \cdot ha \cdot yr^{-1}$, respectively.

Coppini and Hermain (2007) reported the stock volume of 314 m^3 for beech coppice, and increment of 4.49 $m^3 \cdot ha \cdot yr^{-1}$; according to Ciancio et al.

Table 2. Indexes of ecological data for tree species growing individually and in stools

	Cavities	Dead	Snags	Dying crown
Individually				
A. campestre	0.293	0	0.048	0.024
F. silvestris	0.471	0.059	0.117	0.411
S. torminalis	0	0	0	0
Q. petraea	0.109	0.094	0.03	0.018
C. betulus	0.513	0.036	0.131	0.149
P. pyraster	0	0	0	0
A. platanoides	0.722	0	0.056	0
T. cordata	no trees	no trees	no trees	no trees
S. aria	0.75	0.125	0.25	0
C. avium	0	0	0	0
Stools				
A. campestre	0.545	0.045	0.045	0.091
F. silvestris	0.352	0.205	0.205	0.118
S. torminalis	0.118	0	0	0
Q. petraea	0.086	0.189	0.032	0.01
C. betulus	0.44	0.071	0.139	0.117
P. pyraster	no trees	no trees	no trees	no trees
A. platanoides	0.388	0	0	0
T. cordata	0.658	0	0	0
S. aria	0.142	0.285	0.429	0
C. avium	no trees	no trees	no trees	no trees

(2006) beech coppice had the stock volume of 338 m^3 and increment of 6.37 $m^3 \cdot ha \cdot yr^{-1}$, and according to Spinelli et al. (2014) beech and chestnut coppice had the stock volume from 231 m^3 to 420 m^3 and their increments varied from 3.95 $m^3 \cdot ha \cdot yr^{-1}$ to 21.0 $m^3 \cdot ha \cdot yr^{-1}$ (chestnut coppice).

Naturally, conditions in the above studies are different but the production on our sample plot is very poor and it is even lower than the production of coppice forest composed of *Quercus pyrenaica* (site index 16 to 20), although we can compare only the site index because Canellas et al. (2004) reported only mean heights in 30 years old stands. Oak coppice stands in the poorest sites reach the stock volume of approximately 150 m^3 at 80 years of age (Vyskot et al. 1978).

Table 3. Relationship between diameter classes and occurrence of ecological factors expressed as Pearson correlation coefficients (R) between trees growing individually and in stools for *Q. petraea* (*Q. pet*) and *C. betulus* (*C. bet*)

		Cavities	Dead	Snags	Dying crown
Q. pet	indiv.	−0.6464	−0.6824	−0.7744	−0.5040
	stools	−0.3323	−0.7616	−0.5043	−0.4337
C. bet	indiv.	−0.9532	−0.8165	−0.8893	−0.9251
	stools	−0.0544	−0.7420	−0.8722	−0.8135

The stand where the sample plot is located has not been managed for more than 50 years, thus the number of trees growing in stools is relatively high because the common management oriented to removal of shoots in stools was absent. Although the number of trees growing in stools is higher, the stock volume consists mainly of trees growing individually. Their more pronounced vertical differentiation explains higher stocking, which is approximately 20% higher than the optimal density according to yield tables (UHUL 1990).

The mensurational characteristics of individual trees are also better than the characteristics of trees growing in stools except for DBH of *C. betulus*. It forms the understorey layer and conditions for diameter increment seem to be similar there for both groups.

Trees growing individually have longer crowns (expressed by the ratio of crown length to tree height)

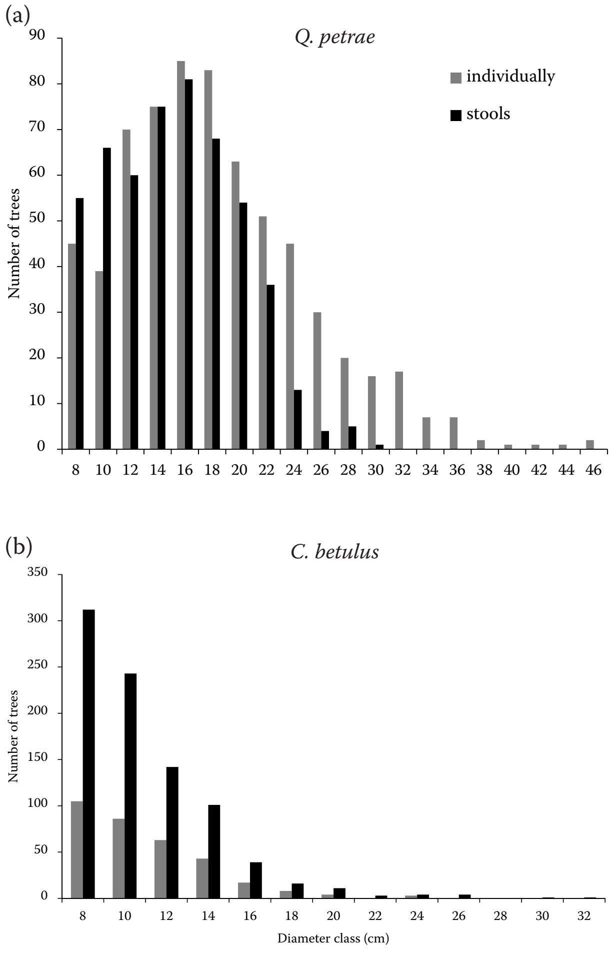

Fig. 2. Frequency distribution for *Q. petraea* (a) and *C. betulus* (b) growing individually and in stools

than trees growing in stools, which largely form the understorey and experience thus more shade.

Even though the difference in the mean height between the two main tree species is not large (*C. betulus* reaches 82% of the height of *Q. petraea*), their frequency distribution is quite different. *Q. petraea* has the curve corresponding to even-aged forest while *C. betulus* has the curve of distribution similar to uneven-aged selectively managed stand. The shape of *C. betulus* curve is probably affected by its higher numbers growing in stools.

The maintenance of a two-storied stand is a desirable management strategy to increase timber production and quality.

However, the trend is different when biodiversity of organisms linked with dead wood is taken into consideration, as the higher levels of biodiversity are maintained in stands with higher proportion of dying and dead trees as well as trees with cavities (Konvička et al. 2004; Machar, Drobilová 2012).

The number of trees with cavities is lower in higher diameter classes but only in trees growing individually. This relationship does not exist in trees growing in stools so the stools should be maintained. The total number of trees containing dead wood (dead trees, snags and trees with a dying crown) is also lower in higher diameter classes. The number of dead trees only is higher in stools than in trees growing individually for both main tree species. This fact further supports the importance of maintenance of stools in stands.

The study shows two contradicting results. On the one hand, the over-matured coppice forest without improvement by tending does not support any meaningful timber production but on the other hand it maintains conditions for higher biodiversity in comparison with managed high forest regardless of silvicultural practice (including the forest managed according to principles of close-to-nature forestry). Maintenance of unmanaged coppice forest corresponds to the concept of ecological forestry which maintains also trees with dead wood in stands (Franklin et al. 2007).

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