JOURNAL OF FOREST SCIENCE, *61*, 2015 (1): 27–34

doi: 10.17221/91/2014-JFS

The effect of coppice management on the structure, tree growth and soil nutrients in temperate Turkey

M. Šrámek[1], D. Volařík[1], A. Ertas[2], R. Matula[1]

[1]*Department of Forest Botany, Dendrology and Geobiocoenology, Mendel University in Brno, Brno, Czech Republic*

[2]*Department of Silviculture, Faculty of Forestry, Istanbul University, Istanbul, Turkey*

ABSTRACT: Coppicing was widespread throughout Europe for many centuries but was largely abandoned in the second half of the 19th century. Currently, there has been a renewed interest in coppicing for biomass production and nature conservation. We studied differences in soil chemistry and tree growth between active and abandoned coppices to highlight the impacts of coppice restoration on soil fertility and tree. Stand structure, collected soil samples and tree cores were compared on 46 research plots in temperate Turkey. The plots were set as actively managed and abandoned coppice stand. In our study no effect of coppicing on growth rate was confirmed. Active coppice stands had lower content of Ca, K, N and C:N and higher soil acidification than abandoned coppices. The tree growth rate was significantly higher on more nutrient-rich soils. Coppice restoration may not result in increased biomass production in long-term periods due to a negative effect on soil fertility.

Keywords: coppice; soil; growth dynamics; forest management, site fertility

Coppicing is one of the oldest forestry systems known from many countries worldwide (Evans 1992; Fujimori 2001). Coppices were usually used as a source of firewood until the second half of the 19th century (Buckley 1992; Peterken 1993). Since then, the conversion of coppices to high forests has been the principal trend especially in central and northwestern Europe (Matthews 1991; Peterken 1992), particularly due to demand for higher-quality timber (Hédl et al. 2010). Coppicing today remains a common forest management system in countries of south-eastern Europe (Vacik et al. 2009; Velichkov et al. 2009; Maděra et al. 2014) to provide firewood on the local scale. The importance of coppices increases in the field of nature protection where there is an increased growth (Mason, Macdonald 2002), and as a natural habitat for the reproduction and life of birds (Fuller 1992), small mammals (Gurnell et al. 1992) and invertebrates (Greatorex-Davis, Marrs 1992; Spitzer et al. 2008). Nowadays, with the growing interest in biomass as an alternative energy source, a growing interest in the potential renewal of coppicing can also be seen in countries of central and western Europe (Matula et al. 2012; Šplíchalová et al. 2012). Although the interest in coppicing is increasing, there is still a lack of information regarding the effect of coppices on site conditions and ecological characteristics, such as soil properties, growth properties of the tree species, and nature protection (Vacik et al. 2009; Matula et al. 2012). Van Calster et al. (2007) noted that long-term studies showed no effects on soil acidity or the herb layer in changing forest management; changes were attributed to atmospheric deposition and/or leaf litter (e.g. Persson et al. 1987; Thimonier et al. 1994; De Schrijver et al. 2006). Although the effect of tree species composition on soil chemistry has been well-known (Prescott 2002; Aubert et al. 2004; Reich et al. 2005), the effect of various management methods on changes in soil chemistry has not been sufficiently explored (Johnson, Curtis 2001). The analysis of 432 studies of soil C responses in temperate forests around the world found a significant impact of harvesting on soil C storage (Nave et al. 2010).

Supported by the Ministry of Education, Youth and Sports of the Czech Republic, Project No. LG12018

The knowledge of long-term growth dynamics of active coppices in respect to the high forest or abandoned coppices is of the same importance as information about the effect of coppicing on sites, especially if we are thinking about coppices as an alternative of short-rotation coppices and as a renewable energy source. Bühler (1922) stated that differences in mean annual growth between high and low forests (i.e. coppice) are indistinct, although the quality of the site plays an important role. A much faster growth of coppice was also reported compared to generative forest (Vyskot 1978).

In our study we focused on the effect of active coppicing on soil chemistry and individual tree growth in temperate forest in Turkey where many forests have been managed as active coppices for centuries. We also surveyed forest structure and assessed soil quality by measuring the content of macroelements in both active and abandoned coppices. Using the data on soil properties and tree growth from active and long-time abandoned coppices from the same site, we tested the hypothesis that active coppicing affects soil chemistry (*i*) as well as boosts individual tree growth (*ii*).

MATERIAL AND METHODS

Studied locality. The study was conducted in the European part of the Republic of Turkey, approx. 30 km north of the centre, Istanbul, in the research forest of the Forestry Faculty, Istanbul University in Istanbul, near the town of Bahcekoy Merkez Mh. (Fig. 1). The research forest stands are localized between (28°59'17'', 29°32'25''E) and (41°09'15'', 41°11'02''N), with the altitude ranging between 30 and 240 m a.s.l.

Total mean annual rainfalls are 1,074 mm; mean annual temperature is 12.8°C (Bahceköy meteorological station 1945–1970). According to Thornthwaite's metodology (Thornthwaite, Hare 1955), the studied locality has a wet mesothermal climate with an influence of the near sea and a slight water deficit in the summer.

Geological subsoil is composed of shale siltstone. Soils show moderate depths, without a skeleton, and are deeper and more skeletal at mountain peaks. The main type of soils is argillaceous – clay soil, soil type: Cambisol (Kavgaci 2001).

Predominant species in the research forest include sessile oak (*Quercus petraea* Matusch.), Italian oak (*Quercus frainetto* Ten.), Turkey oak (*Quercus cerris* L.), European hornbeam (*Carpinus betulus* L.) and sweet chestnut (*Castanea sativa* Mill.). Other present species include silver lime (*Tilia tomentosa* Moench), black locust (*Robinia pseudoacacia* L.), wild service-tree (*Sorbus torminalis* [L.] Crantz.), and tree heath (*Erica arborea* L.) (Kavgaci 2001).

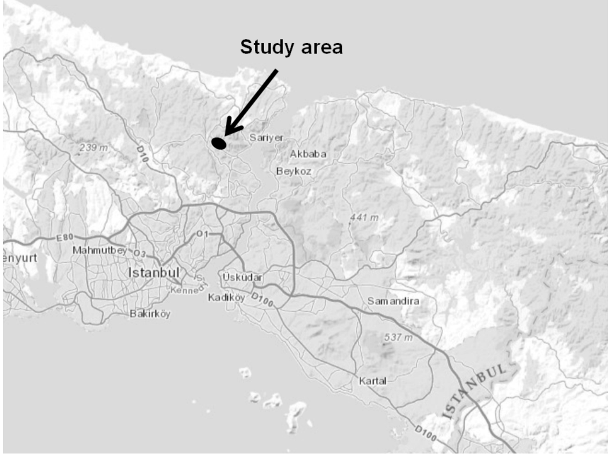

Fig 1. Localization of study area

Clear-felling management with rotation time between 20 and 30 years has been used on the studied active coppices during the last 100 years. The abandoned coppiced were managed in the same way but have not been affected by any kind of management activities for approx. 80 years.

Research plots. In order to locate the research plots, abandoned coppices were first selected and parallelly to them active coppice on the same sites. Both were compared on northern, southern exposure and peak of a hill. The design of the research plots was a line transect. In total, 15 line transects were marked out and 46 research plots were selected and measured (Table 1). A distance between research plots was at least 60 m. Unbalanced numbers of selected plots were due to the small number of suitable forest stands within the same site.

Data collection in the research area. The stand structure was studied in circular plots with 9 m radius using the FieldMap (laser distance meter, compass, resistant tablet, monopod, and FieldMap Data Collector software) (IFER, Ltd., Jílové u Prahy, Czech Republic). Positions of single-stem trees and polycormons were clearly defined and measured. Trees with multiple stems or any residues thereof (cuts, stubs) were considered as polycormons, which included both naturally multiple-stem shrubs and coppiced

Table 1. Table of research plots by the exposure

Type of coppice	Exposure		
	south	north	top of hill
Active	19	6	9
Abandoned	9	3	–

trees. They were individuals of vegetative origin irrespective of their mode of origination. Stem diameter at the height of 1.3 m (DBH) was measured in single-stem individuals. DBH > 2 cm was chosen as the registration threshold for tree measurements. Polycormons were measured if they contained at least one stem with DBH > 2 cm or at least one cut with the diameter larger than 5 cm, or if the polycormon dimension at the base was at least 10 × 10 cm. DBHs were used to calculate the circular basal area (BA). Furthermore, the representation of individual tree species was calculated in the plots according to their BA values. On each plot, cores were collected from oak and hornbeam trees – two cores per tree (other tree species were present with low frequencies) with the greatest DBH within each plot using Pressler's borer. The cores were taken in the perpendicular direction to the slope in order to eliminate any bias of the results due to the potential presence of reaction wood.

Soil samples were collected at 3 points of each plot from the A horizon – organic and mineral horizon (approx. 10 cm layer under the litter) and averaged. Essential soil macroelements (Ca, K, Mg, P, Na, N total, oxidized carbon – C_{ox}) and the soil reaction (pH_{KCl}) were analysed according to the Melich II methodology (Zbíral 2002).

Data evaluation. Soil analyses were evaluated by the Manual of Methods for Soil and Land Evaluation (Constatini 2009), and the C:N ratio was calculated. Potentially exchangeable soil reaction (pH_{KCL}) was primarily used to evaluate the soil pH value, which is more stable compared to active soil reaction (pH_{H_2O}) that shows considerable variability, for example, due to weather conditions.

The effect of environmental factors and forest structure and growth dynamics, differences in soil chemistry were analysed using general linear models (OLS). Plots of active coppices at the peak of the hill were removed from soil analyses because they were located in a more fertile site compared to the other plots. The analysis of the effect of coppice type on the nutrient contents in soils on the north exposure was inconclusive due to the small number of repetitions.

The following dependent variables were used as to test the effect of the forest structure (active/abandoned coppice) on soil chemistry: pH_{KCL}, Ca, K, Mg, P, Na, N – total, C_{ox}, C:N. Mean radial growth using the last 10 tree rings was calculated to test the relation between soil characteristics and forest structure. Mean growth rate was used as a dependent variable in OLS, while the following ones as independent variables: (*i*) For plots: the content of N, P, Na, K, Ca, Mg, pH, forest type, BA, aspect; (*ii*) For the individual: stem age, species. We analysed those variables separately including also an interaction effect with forest type (active coppices on slopes, active coppices on hilltop, abandoned coppices). The usual significance level of α = 0.05 was used. All analyses were carried out in the R environment (R Core Team 2013).

RESULTS

Stand structure

Stands with dominant hornbeam and oak trees were found in the research plots on both southern and northern exposures. The age of trees in abandoned coppices ranged between 70 and 75 years while the oldest stems within active coppice of plots on slopes were 35–50 years old. Chestnut trees dominated in the active coppice stands on the hill, being approximately 25 years old.

Characteristics of the coppice structure in the studied area are shown in Table 2. Differences between the active and abandoned coppices are evident in all characteristics, e.g. BA in active coppice reaches 76% of BA of abandoned coppices. Mean BA per polycormon was 0.03 m^2. Mean DBH of the active coppice was 50% of the mean DBH for abandoned coppice. Mean height of active coppice stands was 73% of the mean height of abandoned coppices.

Soil chemistry

The analysis of the management (abandoned coppice/active coppice) effect on nutrient contents in soils indicated significant differences in the contents of Ca, K, N, in pH and C:N ratio (Table 3). The pH and contents of all elements were lower in active coppices

Table 2. Forest structure characteristics

Forest form of coppice	Age (yr)	Average of DBH (cm)	Mean height (m)	BA ($m^2 \cdot ha^{-1}$)	Number of stems ($stems \cdot ha^{-1}$)			Average of stems per 1 polycormon (indd)
					Σ	generative	vegetative	
Abandoned	70–75	24.7 ± 9.4	19.3 ± 2.6	37.8	577	282	295	1.5 ± 0.7
Active	35–50	12.4 ± 3.8	14.0 ± 3.4	28.8	1320	396	924	2.4 ± 1.9

DBH – diameter at breast height; BA – basal area; ± SD – standard deviation

Table 3. Mean values of the studied soil characteristics for both types of coppice ($P < 0.05$, df = 2, 35)

	Abandoned coppice	Active coppice	F	P
pH_{KCL}	3.91	3.79	7.058	**0.003**
Ca (mg·kg^{-1})	911	588.1	14.80	**0.002**
K (mg·kg^{-1})	154.8	117.8	19.89	**< 0.001**
Mg (mg·kg^{-1})	271.9	230.6	3.88	0.064
P (mg·kg^{-1})	12.17	8.15	2.34	0.110
Na (mg·kg^{-1})	14.42	12.47	1.31	0.281
C_{ox} (%)	4.85	4.43	3.37	0.065
N – total (%)	0.24	0.19	10.98	**< 0.001**
C:N	21.02	24.23	4.99	**0.012**

in bold – significant at α = 0.05

– both oak and hornbeam ones – than in abandoned coppices (Fig. 2). We found significantly higher contents of most of the observed soil variables ($P < 0.05$) in active coppices on the hilltop compared to other active coppice stands.

Results of soil chemical analyses for abandoned coppice and active coppice are shown in Table 3. According to the classification used (Constatini 2009), the soils are strongly acidic in both management types. Oxidized carbon content in both management types is very high. When multiplying C_{ox} by the empirical coefficient 1.724, soils of the explored locality can be classified as strongly humus-rich soils (range 7.6–8.4). According to the N content, the soils in active coppice are classified as those with a good content of N, and stands of abandoned coppices have soils with a rich supply of N, meaning that their N content is higher. The

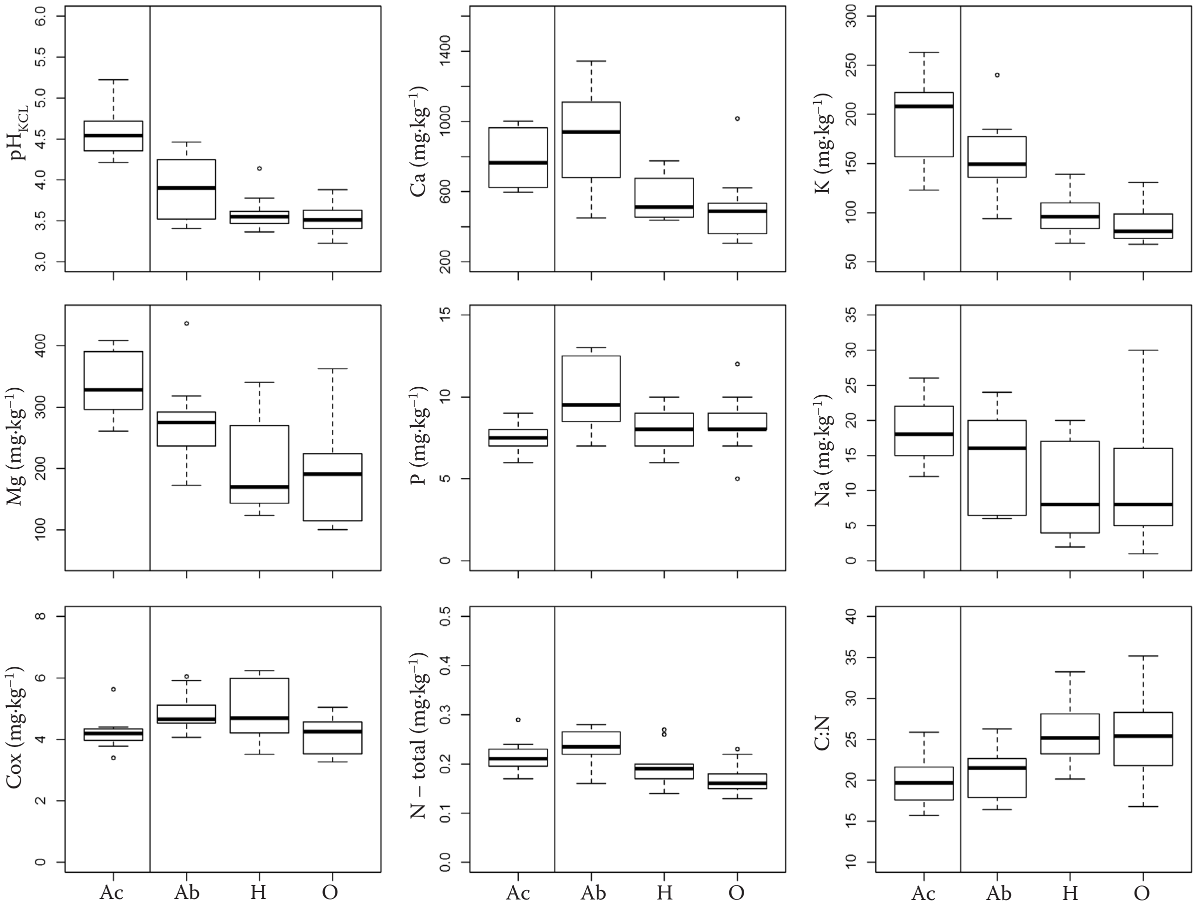

Fig. 2. Box plots of differences in soil chemistry for coppices

Ac – active coppices on the hill were not used in data analysis but, for comparison, they are shown separated from others by a vertical black line; Ab – abandoned coppices; H – active coppices with dominant hornbeam; O – active coppices with dominant oak

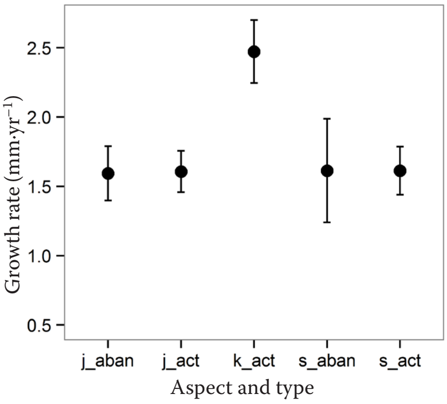

Fig. 3. The effect of aspect and coppice type on mean annual stem growth

dots – mean growth rate values, error bars standard error of the mean, j_aban – abandoned coppice on southern aspect; j_act – active coppice on southern aspect; k_act – active coppice on hilltop; s_aban – abandoned coppice on northern aspect; s_act – active coppice on northern aspect

C:N ratio showed higher values in active coppices compared to abandoned coppices. Active coppices on the hill were an exception, which showed significantly higher contents of most of the observed soil chemistry variables ($P < 0.05$). Both active coppices and abandoned coppices showed a high Ca content. A medium K level in soils and a high level of the soil magnesium were found in both forest types. On the contrary, in terms of P content in the soil, both forest types are classified in the low P content category. The studied area is thus poor in P, while the representation of the other macroelements is satisfactory. The analysis of the different exposure effect (north/south) in the same type of coppice on nutrient contents in soils did not indicate any significant differences either in active or in abandoned coppice. The analysis of the effect of coppice type on the nutrient contents in soils on the south exposure showed higher contents of Ca, K and N in abandoned coppice stands.

Growth dynamics

The mean annual growth analysis in the last 10 years did not show a significant difference between different coppices but it revealed significant effects of aspect, stem age and content of some macroelements in the soil. Individuals on the hill exhibited considerably higher growth than individuals on slopes ($P = 0.039$; Fig. 3). No significant differences were found between northern and southern aspects. The growth rate also decreased with increasing stem age ($P = 0.048$).

Soil macroelements including the interaction of forest type with mean annual growth showed a significant relation with calcium, magnesium, soil pH and C:N ratio in active coppices on the hilltop (Fig. 4; Table 4). The mean annual growth during the last 10 years increased with the increasing content of soil macroelements and increasing pH.

Table 4. The effect of soil characteristics on the mean stem growth rate in the last 10 years

Model specification*	*P*-value						
	pH	Ca	Mg	Na	K	P	C:N
Soil variable	**0.026**	0.784	0.186	0.572	0.156	0.980	0.841
Coppice type	0.126	**0.015**	**0.031**	**0.020**	**0.037**	**0.016**	**0.013**
Interaction	**0.039**	**0.023**	**0.011**	0.208	0.062	0.560	**0.017**

*including interaction with type, in bold – significant at $\alpha = 0.05$

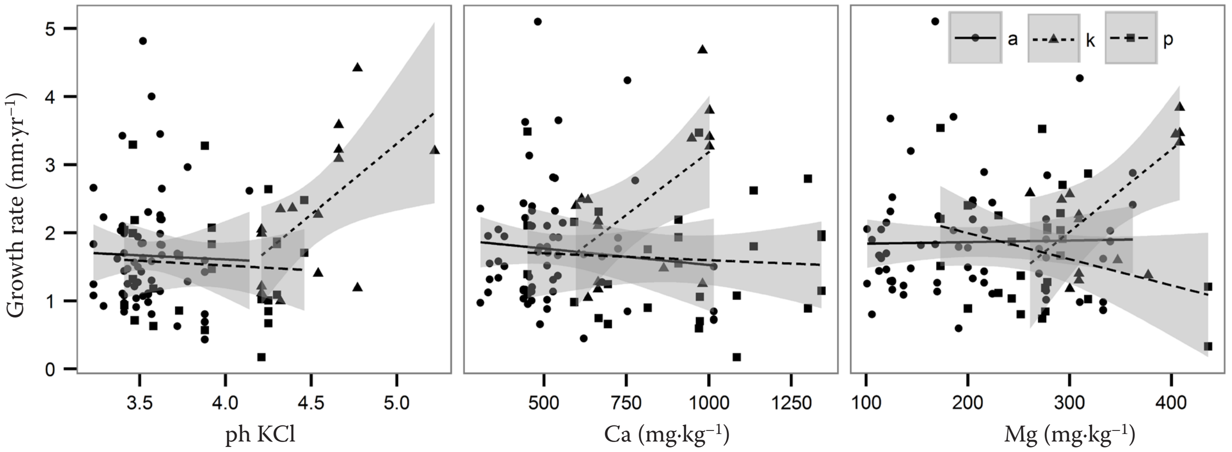

Fig. 4. The effect of soil macroelements and pH on the growth rate in the last 10 years in relation to different coppice type

a – active coppices on hillsides, k – active coppices on hilltop, p – abandoned coppice

DISCUSSION

Restoring of coppicing, particularly in countries of central Europe, motivated either by nature protection or biomass production, emphasizes the need of understanding the effect of this management system on site properties and growth dynamics which is still missing. Our study contributes to fill this gap, demonstrating a significant depleting effect of coppicing on soil fertility but no effect of the forest structure on growth, contrary to our hypothesis.

As far as production is concerned, our results indicate the lower values of basal area in active coppices by 24% compared to abandoned coppices, which is equivalent to the data of VIEWEGH (1957) and VYSKOT et al. (1978), who reported generally lower values of the basal area in coppices compared to high forests. Although the production of good-quality products of active coppices is lower compared to high forests or abandoned coppices (ŠNAJDAR 1943; ZLATNÍK 1957), differences in the total biomass volume of coppices fade away to a considerable extent, considering approximately three production periods of coppices in one production period of the high forest. Production of good-quality products in active coppices can be improved by growing mixed coppice stands, because SLÁVIK and KHUN (2014) demonstrated the influence of auxiliary species (for example hornbeam) on the qualitative parameters of oak stands.

The effect of coppicing on soil fertility still remains an open question. An increase in soil acidification after 46 and 38 years, respectively, was found in previous long-term studies focused on changes in soil acidification after the forest conversion from coppice with standards to high forest (VAN CALSTER et al. 2007; BAETEN et al. 2009). However, these changes in pH may also be related to changes in the environment seen in the recent decades, due to increased depositions of acid atmospheric pollutants (KUHN et al. 1987; THIMONIER et al. 1994; VAN CALSTER et al. 2007). A different finding was obtained by HÉDL and REJŠEK (2007), who found no significant changes in the soil reaction of coppices in the Czech Republic, which had not been actively managed by coppicing for 40 years. However, our study demonstrated higher acidification in active coppices compared to abandoned coppices.

Some of the first papers on coppices in central Europe note a potential threat of coppices in terms of a possible reduction in the nutrient capacity of soil at less favourable sites (GUTTENBERG 1911; FRIČ 1947). Results of our study also confirm these results, demonstrating lower contents of the majority of the studied macroelements in soils of active coppices. The carbon stored in forest soil is an important component of the global carbon cycle (NAVE et al. 2010). The effect of the management type on oxidized carbon content in soil was not found in our study. A similar finding was also reported by JOHNSON and CURTIS (2001) in their meta-analysis of the effect of various types of forest management on nutrient amounts in the soil, concluding that felling has only a low or no effect on carbon and nitrogen contents. Contrary to this, NAVE et al. (2010) found a reduction of carbon content by 8% on average after felling. Nitrogen is another important element in the soil, being one of the main nutrients necessary for the formation of biomass and for vital functions of organisms. Its content in the soil is relatively stable given that nitrogen is bound in compounds difficult to degrade both chemically and microbiologically (RICHTER 2007). For this reason, the content of total N in the soil is often expressed in relation to Cox using the C:N ratio. In their paper on the long-term effect of short-rotation coppices KAHLE et al. (2007) noted an increase in carbon and nitrogen contents in the soil after 12 years of operating short-rotation coppices of willow and poplar trees on previously arable land. On the contrary, the contents of phosphorus and potassium decreased within 6 years after coppice establishment. Our study showed a lower content of total nitrogen in the soil of active coppices. In our study, the C:N ratio showed higher values in coppices; coppices were thus poorer in nitrogen supply.

Considering the amount of macroelements in the soil, based on the classification used (CONSTATINI 2009) it can be noted that the studied area is poor in phosphorus contents. Calcium and phosphorus belong to the elements that showed lower values in active coppices compared to the values of abandoned coppices. Considering the function of calcium as an essential biogenic element and phosphorus as an element of biochemical functions of plants, particularly the growth, attention should be paid to their amount in the soil in localities with their low level to prevent their depletion below a threshold limit. Other analysed elements that showed lower contents in active coppices compared to abandoned coppices should not be depleted beyond threshold limits considering sufficient supply of trees.

Considering coppicing as a source of biomass, we could ask the fundamental question to what extent the radial growth of coppices differs from abandoned coppices or high forests. The effect of coppicing on growth rate was not demonstrated in our study; although ALTMAN et al. (2013) stated that forest management is an important factor that affects changes in the thickness of annual tree rings. The decrease of mean annual growth with age corresponds to findings that overaged coppice stands are characterized by a reduction in radial growth (Floret et al. 1989; Cañellas et al. 1996; Corcuera et al. 2005). In our study we observed a positive relationship between the radial growth rate and the amount of nutrients in the soil in the active coppice on the hilltop. Similarly, Cartan-Son et al. (1992) found that the radial growth of *Quercus ilex* in coppices in southern France was increased by nutrient supply (nitrogen, phosphorus, potassium). Although the content of some elements in the soil differed between active and abandoned coppices in our study, we demonstrated its effect on growth only in coppices on the hilltop but not in coppices located on slopes. This may be caused by a difference in nutrient availability in the soil and by the ability of the trees to take up the nutrients. This ability may be affected by numerous factors, such as interactions of roots with other organisms in the soil, heterogeneous nature of the soil, mycorrhizal symbiosis (allowing for, in particular, effective utilization of both highly dispersed and heterogeneously located nutrients in the soil), and soil pH, which has an impact on the availability of individual mineral nutrients.

CONCLUSIONS

In the context of renewed interest in coppicing, attention should be turned to countries where this management method is still used given that such countries can provide support materials and practical illustrations for scientific studies. Turkey is one of those countries, where both active and abandoned coppices can be found at the same site, and which thus enabled us to analyze the effect of coppicing on soil and growth. As a result of the present findings, we conclude that coppicing may have a negative effect on soil and site. Given the topicality of coppicing in recent years and ecosystem services of this type of management, similar studies will be needed in a broad range of site conditions in order to generalize the obtained results.

Acknowledgments

We would like to thank Jaromíra Dreslerová and the students Jan Svoboda, Jan Polák and Martin Mucha, who have taken part in data collection.

References

Altman J., Hédl R., Szabó P., Mazůrek P., Riedl V., Müllerová J., Kopecký M., Doležal J. (2013): Tree-rings mirror management legacy: dramatic response of standard oaks to past coppicing in Central Europe. PloS one, 8, e55770.

Aubert M., Bureau F., Alard D. et al. (2004): Effect of tree mixture on the humic epipedon and vegetation diversity in managed beech forests (Normandy, France). Canadian Journal of Forest Research, 1*:* 233–248.

Baeten L., Bauwens B., De Schrijver A.D., Keersmaeker L.D., Calster H.V., Vanderkerkhove K., Roelandt B., Beeckman H., Verheyen K. (2009): Herb layer changes (1954–2000) related to the conversion of coppice with standards forest and soil acidification. Applied Vegetation Science, 12: 187–197.

Buckley G.P. (1992): Ecology and management of coppice woodlands. London, Chapman and Hall: 339.

Bühler A. (1922): Waldbau. Stuttgart, Verlag Eugen Ulmer: 679.

Cañellas I., Montero G., Montoto J.L., Bachiller A., San Miguel A. (1994): Transformation of rebollo oak coppice (*Quercus pyrenaica* Willd.) into open woodlands by thinning at different intensities. Preliminary results. Investigacion Agraria. Sistemasy Recursos Forestales: 71–78.

Cartan-Son M., Floret C., Galan M.J., Grandjanny M.E., Le Floc'h E., Maistre M., Perret P., Romane F. (1992): Factors affecting radial growth of *Quercus ilex* L. in a coppice stand in southern France. In: *Quercus ilex L.* Ecosystems: Function, Dynamics and Management. Dordrecht, Springer: 61–68.

Corcuera L., Camarero J.J., Sisó S., Gil-Pelegrín E. (2006): Radial-growth and wood-anatomical changes in overaged *Quercus pyrenaica* coppice stands: functional responses in a new Mediterranean landscape. Trees, 20: 91–98.

Costantini E.A. (2009): Manual of methods for soil and land evaluation. Enfield, Science Publisher: 564

De Schrijver A., Mertens J., Geudens G., Staelens J, Campforts E, Luyssaert S, De Temmerman L, De Keersmaeker L, De Neve S, Verheyen K. (2006): Acidification of forested podzols in North Belgium during the period 1950–2000. Science of the Total Environment, 361: 189–195.

Floret C., Galán M. J., Le Flóch E., Rapp M., Romane F. (1989): Organisation de la structure, dela minéralomasse d'un taillisouvert de ch ˆene vert (*Quercus ilex* L.). Acta Oecologica, 10: 245–262.

Frič J. (1947): Forest Managament. Písek, Čs. matice lesnická: 516.

Fujimori T. (2001): Ecological and Silvicultural Strategies for Sustainable Forest Management. Amsterdam, Elsevier: 398.

Fuller R. J. (1992): Effects of coppice management on woodland breedings birds. In: Buckley G.P. (ed.): Ecology and Management of Coppice Woodlands. London, Chapman and Hall: 169–193.

Greatorex-Davies J.N., Marrs R.H. (1992): The quality of coppice woods as habitat for invertebrates. In: Buckley G.P. (ed.): Ecology and Management of Coppice Woodlands London, Chapman and Hall: 271–296.

Gurnell J., Hicks M., Whitebread S. (1992): The effects of coppice management on small mammalpopulations. In: Buckley

G.P. (ed.): Ecology and Management of Coppice Woodlands. London, Chapman and Hall: 213–233.

Guttenberg A. (1911): Forest Managament. Písek, Print Co. Theodor Kopecký: 367.

Hédl R., Rejšek K. (2007): Soil changes after forty years of succession in an abandoned coppice in the Czech Republic. Acta Agronomica Hungarica, 55: 453–474.

Hédl R., Kopecký M., Komárek J. (2010): Half a century of succession in a temperate oakwood: from species-rich community to mesic forest. Diversity and Distributions, 16: 267–276.

Johnson D.W., Curtis P.S. (2001): Effects of forest management on soil C and N storage: meta analysis. Forest Ecology and Management, 140, 227–238.

Kahle P., Hildebrand E., Baum C., Boelckeb B. (2007): Long-term effects of short rotation forestry with willows and poplar on soil properties. Archives of Agronomy and Soil Science, 53, 673–682.

Kavgaci X. (2001): Flora and Stand Structure in the Research Forest of Faculty of Forestry University of Istanbul. [Diploma Thesis.] Istanbul, Univerzity of Istanbul: 119.

Kuhn N., Amiet R., Hufschmid N. (1987): Veränderungen in der Waldvegetation der Schweiz infolge Nährstoffanreicherungen aus der Atmosphäre. Allgemeine Forst- und Jagdzeitung, 158: 77–84.

Volařík D., Matula R., Šenfeldr M., Dreslerová J. (2014): Structure of forest stands in the landscape with active coppice managament. In: Maděra P. (eds): Czech Villages in Romanian Banat: Landscape, Nature, and Culture. Brno, Mendel University in Brno: 348.

Mason C.F., MacDonald S.M. (2002): Responses of ground flora to coppice management in an English woodland – a study using permanent quadrats. Biodiversity and Conservation, 11: 1773–1789.

Matthews J.D. (1991): Silvicultural Systems. Oxford, Oxford University Press: 284.

Matula R., Svátek M., Kůrová J., Úradníček L., Kadavý J., Kneifl M. (2012): The sprouting ability of the main tree species in Central European coppices: implications for coppice restoration. European Journal of Forest Research, 131: 1501–1511.

Nave L.E., Vance E.D., Swanston C.W., Curtis P.S. (2010): Harvest impacts on soil carbon storage in temperate forests. Forest Ecology and Management, 259: 857–866.

Peterken G.F. (1993): Woodland Conservation and Management. London, Chapman and Hall: 314.

Persson S., Malmer N., Wallén B. (1987): Leaf litter fall and soil acidity during half a century of secondary succession in a temperate deciduous forest. Vegetatio, 73: 31–45.

Prescott C.E. (2002): The influence of the forest canopy on nutrient cycling. Tree Physiology, 22: 1193–1200.

R Core Team (2013): R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at http://www.R-project.org/

Reich P.B., Oleksyn J., Modrzynski J. Hobbie S.E., Eissenstat D.M., Chorover J., Chadwick O.A., Hale C.M., Tjoelker M.G. (2005): Linking litter calcium, earthworms and soil properties: a common garden test with 14 tree species. Ecology Letters, 8: 811–818.

Richter R. (2007): Dusík v půdě. In: Živinný režim půd. Available at http://web2.mendelu.cz/af_221_multitext/vyziva_rostlin/html/agrochemie_pudy/puda_n.htm (accessed 16 Jan, 2007)

Slávik M., Khun J. (2014): Vliv pomocných dřevin (habru a lípy) na kvalitativní parametry dubových porostů. Zprávy lesnického výzkumu, 59: 86–95.

Spitzer L., Konvicka M., Benes J., Tropek R., Tuf I. H., Tufova J. (2008): Does closure of traditionally managed open woodlands threaten epigeic invertebrates? Effects of coppicing and high deer densities. Biological Conservation, 141, 827–837.

Šnajdar F. (1943): Pařezina a rentabilita. Praha, Les: 9–11.

Šplíchalová M., Adamec Z., Kadavý J. et al. (2012): Probability model of sessile oak (*Quercus petraea* (Matt.) Liebl.) stump sprouting in the Czech Republic. European Journal of Forest Research, 131: 1611–1618.

Thimonier A., Dupouey J.L., Bost F., Becker M. (1994): Simultaneous eutrophication and acidification of a forest ecosystem in North-East France. New Phytologist, 126: 533–539.

Thornthwaite C.W., Hare F.K. (1955): Climatic classification in forestry. Unasylva, 9: 51–59.

Vacik H., Zlatanov T., Trajkov P., Dekanic S., Lexer M. J. (2009): Role of coppice forests in maintaining forest biodiversity. Silva Balcanica, 10: 35–45.

Van Calster H., Baeten L., De Schrijver A., Keersmaeker L., Rogister J.E., Verheyen K., Hermy M._(2007): Management-driven changes (1967–2005) in soil acidity and the understorey plant community following conversion of a coppice-with-standards forest. Forest Ecology and Management, 241: 258–271.

Velichkov I., Zlatanov T., Hinkov G. (2009): Stakeholder analysis for coppice forestry in Bulgaria. Annals of Forest Research, 52: 183–190.

Viewegh R. (1957): Contribution to conversion coppice to hight forest. Praha, Procceeding ČSAZV – Forestry: 167–176.

Vyskot M., Jurča J., Korpél Š., Reh J. (1978): Lesnictví. Praha, SZN: 448.

Zbíral J. (2002): Analýza půd I. Brno, ÚKZÚZ: 159.

Zlatník A. (1959): Výmladkové lesy s hlediska proměn lesů pod vlivem člověka a úloha ekologie při přeměnách a převodech výmladkových lesů. Lesnictví, 3: 109–124.

Received for publication August 7, 2014
Accepted after corrections December 9, 2014

Corresponding author

Ing. Martin Šrámek, Ph.D., Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 3, 613 00 Brno, Czech Republic, e-mail: martin.sramek@mendelu.cz