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Contribution to a discussion on the influence of coppicing on soil environment

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ABSTRACT: In 2011, soil properties and stand condition of four forest stands were evaluated at the Křtiny Training Forest Enterprise (Czech Republic). The stands were managed on a long-term basis as an oak-hornbeam coppice undergoing conversion to high forest over the last 110 years approximately. The aim of the study was to compare the current condition of stands and soils with that of 1959. The stands were subjected to (a) an analysis of changes in the species composition during the conversion to high forest, and (b) a soil survey carried out using restored soil pits set up in 1959, as well as shallow pits. Our results indicate significant differences in the content of K_2O and humus stability index according to Hock between 1959 and 2011. The differences in soil properties are caused rather by tree species composition and soil morphology then by forest management, which was concluded as a substantial result within the study. No major changes in soil properties were detected in relation to changes in management. No attributes of soil degradation have been identified.

Keywords: high forest; conversion; soil conditions; nutrient-rich soils

In the Czech Republic, coppicing has been a traditional management method at least since the 13th century (Kavuljak 1942). Since the 14th century onwards, there have been the first reported attempts to convert coppice into high forest in the territory concerned. The reason was mainly low timber production in coppice stands and subsequently timber shortage, especially construction timber (from the 18th century onwards) (Korf 1957; Szymura 2010). Clear evidence of coppicing at the Training Forest Enterprise of "Masarykův les" Křtiny (a special-purpose facility of Mendel University in Brno, Czech Republic) is available from the late 18th century (Macharáček 1961), while from the 19th century onwards, there are records of a specific form of coppice stands (Polanský 1966).

Historically, it was often pointed out to the negative effect of coppicing on soil properties in terms of degradation and reduced fertility and consequently even timber production, especially in stands of age up to 20 years (e.g. Pelíšek 1957; Switzer, Nelson 1973; Hansen, Baker 1979; Ranger, Bonneau 1986; Ranger, Nys 1996). Short rotations in coppice stands cause, compared with high forest, the utilization of nutrients to become more intense, particularly in stands of age up to 20 years (Ranger, Bonneau 1986). A specific effect on the soil environment is the frequent disturbance of the soil due to timber harvest and skidding (Ranger, Nys 1996). Specific consequences of pro-active coppicing particularly involve the negative relationship of nutrient concentrations and pH, as well as a negative balance of the propor-

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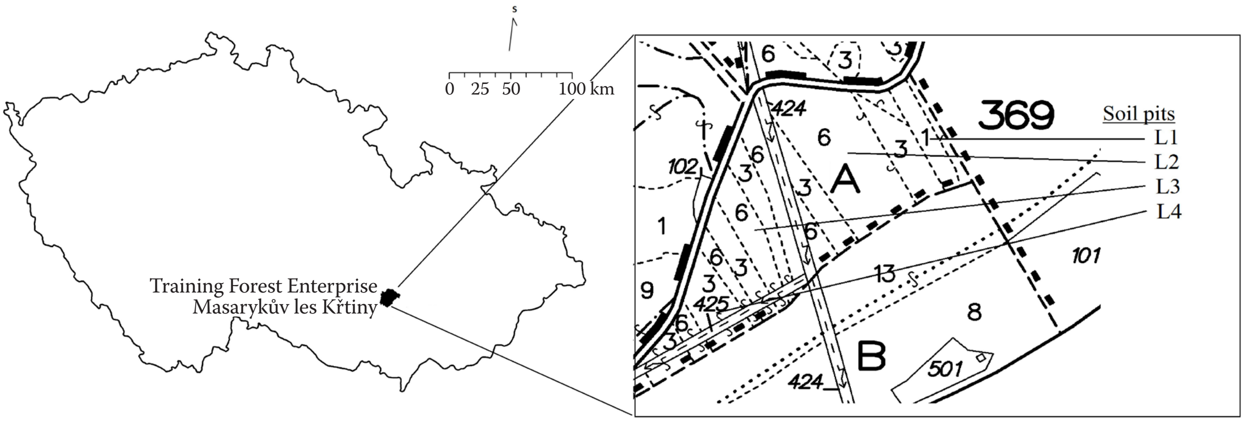

Fig. 1. Location of the studied area and soil pits (L1–L4) in a forest map

tion of nutrients in soil and in biomass. In coppice stands on calcareous soils there is a risk of deficiency in magnesium nutrition, while base saturation may be in a positive correlation with N, K and Ca in the case of intensely cultivated coppice. A threat of nutrient leaching was also reported for such stands (ADAMSON et al. 1992).

However, some reports have presented indifferent or positive effects of coppicing on soil conditions (RANGER, NYS 1996; HÖLSCHER et al. 2001; PIGNATARO et al. 2011). Non-decreasing pH or nutrient availability as well as burning of post-harvest biomass and incorporation of organic matter into the soil surface are attributed to the unintentional cultivation of soil, and were also highlighted as the main positive consequences of coppicing. Furthermore, plants colonizing forest clearings (e.g. the family *Fabaceae*) can contribute to nitrogen fixation also in the case of coppicing. Despite the short rotation and intense erosion of phytomass, coppice stands do not reduce the availability of nutrients.

Soil properties were analysed at a nutrient-rich site at the Training Forest Enterprise "Masarykův les" Křtiny (Czech Republic) to assess the soil degradation and changes in the condition of forest stands that had been managed as a coppice in the past and, approximately for the last 110 years, they have been converted to high forest. The purpose of the study was to compare the current condition of forest stands and the soil environment with those of 1959 (MACHARÁČEK 1961) and to evaluate the response of soil properties to management conversion from coppice to high forest.

The main hypotheses were as follows: (1) coppice management reduces (or decreased in the past) the fertility of forest soils at nutrient-rich sites; (2) a change in management and an associated change in the woody species composition resulting from converting the coppice to high forest significantly affected the soil fertility (the amount of nutrients in the upper layer) at the nutrient-rich site.

MATERIAL AND METHODS

Stand description and history. The four analysed stands (L1–L4) are located at the Training Forest Enterprise "Masarykův les" Křtiny, a special-purpose facility of Mendel University in Brno, Czech Republic (Fig. 1). The average annual temperature in the area is about 7.5°C and the average annual rainfall ranges from 550 to 650 mm. Soils are classified as mesobasic, mesotrophic Haplic Luvisol ruptic, with mesomull as humus form. The soil material alone is a substrate of aeolian sediments (loess loam) with a thickness of 60–90 cm, mixed with basal clastic strata of the Moravian Karst with sparse admixture of limestone in the form of small skeleton. The surrounding soil material of limestone fragments does not contain available $CaCO_3$. Illimerization is the leading soil-forming process. The textural differentiation is significant in all profiles (up to 4.2), but is highlighted by the lithological discontinuity. There is a fast humification on the soil surface, which is delayed in the case of a higher portion of coniferous litter.

By 1898, the entire area of the site analysed (9.99 ha) had been covered exclusively by coppice. Its species composition was dominated by hornbeam (70%), plus there was an occurrence of oak (30%), as well as an admixture of birch and linden. The age of stems was 25 years and their standing volume was 33 $m^3 \cdot ha^{-1}$. During the past 110 years approximately, conversion of the stands to different methods of high forest was underway. At present, there is a mixed high forest. In the analysed stands, four soil pits of 1959 (MACHARÁČEK 1961) were located and re-excavated, to which the following stand conditions relate with regard to the type of conversion:

- Direct conversion (L1): the stand being the result of a direct conversion of the initial coppice to high forest, with conifers (mainly spruce) accounting for a substantial proportion in the woody species composition over the past 110 years of conversion, approximately. Conditions of the stands are as follows: deciduous vegetation at the age of 15 years with a dominant proportion of oak (50%), hornbeam (40%), and linden (10%). Oak was planted here in the past, while hornbeam and linden are clearly of coppice origin (Table 1).

- Indirect conversion variant 1 (L2, L3): the stand was constituted via an indirect conversion of coppice, which specifically involved underplanting the open initial coppice by target woody species of the seed origin that were subsequently felled; today, it is a mixture of woody species of largely seed origin, of which conifers form a substantial part. Conditions of the stands are as follows: stands of 68 years consisting of a mixture of woody species, where larch clearly prevails (48%), linden is significantly represented (22%), followed by beech (9%) and other species. The volume of the stand ranges from 497 $m^3 \cdot ha^{-1}$ (L2) to 528 $m^3 \cdot ha^{-1}$ (L3) – see Table 1.
- Indirect conversion variant 2 (L4): the current stand is a result of an indirect conversion by maintaining the former coppice over a planned rotation period to obtain so called "quasi high forest", with sessile oak clearly prevailing at the stand age of 100 years; 40 years ago, indirect conversion (var. 1) was applied within the plot. Conditions of the stands are as follows: stand of 33 years consisting of a mixture of pine (23%), linden (21%), oak (17%), larch (16%), and other species. The stand reaches the level of stock of 184 $m^3 \cdot ha^{-1}$ (Table 1).

Currently, the analysed stands are managed as high forest with a rotation period of 100 years and a regeneration period of 20 years. They are two-storeyed stands (except the youngest plot on which there is a single-storeyed stand – Site L1) and of full stocking. All locations are classified as nutrient-rich sites of a group of forest types 2B (Rich beech-oak forest) (Viewegh et al. 2003). With the exception of the youngest stand (direct conversion, L1), coniferous woody plants are now a prevailing component of these stands (Table 1).

Field survey. A survey was carried out in the analysed stands in June 2011, aiming at assessing the current dendrometric characteristics and the nature of the soils.

In each stand, the soil pit dug in 1959 was found which was used as a centre of research plot. A rectangular plot of approximately 0.15 ha was selected for the stand above the pit on L1 with regard to the shape of the stand. In the stands above the pits on L2, L3 and L4, circular plots were used, the size being 0.3 ha per plot. A number of trees, the species and dbh of each tree were recorded on each plot. DBH was determined for all trees with a diameter greater than 7 cm using the Haglöf MANTAX calliper (Sweden AB) to the nearest 1 mm. Tree height was measured with the VERTEX III hypsometer (Sweden AB) to the nearest 0.1 m. The number of measured heights was determined proportionally to the frequency of trees in 4 cm diameter classes as per species so that at least three heights were measured per diameter class. Using volume equations (Petráš, Pajtík 1991), tree volume was computed in diameter classes, the volume for the entire stand being calculated by summarising. The representation of woody species in the stand was established by percentage of the species in total stand volume.

Soil properties were investigated with particular regard to those described in the original comparative study (Macharáček 1961). Sampling soil pits were excavated at the site of the excavation of the original pits of 1959, with the soil pit forehead moved by about 50 cm against the original location, into undisturbed soil. Three randomly placed shallow pits were excavated in the vicinity of the pit within a radius of 5 m. The sampling pit was described and sampled for each soil horizon, with A horizon samples being taken from each of the shallow pits. The soils were classified according to the FAO system (Michéli et al. 2006), while humus forms were classified according to the French classification (Jabiol et al. 1994).

Laboratory analysis. The texture was found out according to Kopecký (Kopecký 1928; Rejšek 1999) and also a sedimentation method was used for determining colloidal clay (Rejšek 1999; Walmsley, Godbold 2009). Undisturbed soil samples were analysed to determine the soil

Table 1. Basic characteristics of the analysed stands by conversion type and soil pit (2011)

Type of conversion (site)	Soil pit co-ordinates N	E	Elevation (m a.s.l.)	Aspect	Slope (%)	Prevailing species (%)	Age (yr)	Standing volume ($m^3 \cdot ha^{-1}$)
Direct (L1)	49°13'51.6"	16°41'50.7"	395	NW	32	sessile oak 50	15	–
Indirect var. 1 (L2)	49°13'50.0"	16°41'46.7"	401	NW	20	larch 44	68	497
Indirect var. 1 (L3)	49°13'47.4"	16°41'41.9"	398	NW	14	larch 51	68	550
Indirect var. 2 (L4)	49°13'45.1"	16°41'40.4"	412	W-NW	10	pine 23	33	184

moisture (w), bulk density (ρ_d), soil hydrolimits, porosity (P), aeration (A), minimal aeration capacity (A_{MCC}), wilting point (WP) and pore saturation (PS). pH was measured as active (pH_{H_2O}) and exchangeable (pH_{CaCl_2}). Cation exchange capacity (CEC) was assessed according to Kappen (Kappen 1939; Klečkovskij, Peterburskij 1964; Zbíral 2002): hydrolytic acidity H_a in the extraction of 1M sodium acetate (CH_3COONa), the content of base cations in 0.1M hydrochloric acid (HCl). Nutrients were determined in the extraction of 1% citric acid solution. Soil carbon (C_{ox}) was also established using oxidation in chromosulphuric acid with the end-point titration by ammonium iron (II) sulphate; total nitrogen (TN) was established according to Kjeldahl (Zbíral et al. 2004), humic substances were determined as follows: concentration of humic acids (C-HA), concentration of fulvic acids (C-FA) expressed as C-HA/FA in the extraction of sodium pyrophosphate according to Kononova and Bělčikova (1961). Humus stability index was established according to Hock (k_1/k_2) (Hock 1937) as the extinction coefficient k_1/k_2, where k_1 is the value of absorbance of the soil sample eluate in 1% Na oxalate and k_2 is the value of absorbance of the soil sample eluate in 0.5% NaOH, as measured at a wavelength of 619 nm after previous suspension shaking for 15 min and standing time of 24 h (the soil to extractant ratio was 1:5 w/v).

Data processing. To determine whether there has been a change in soil properties due to the different conversion methods between 1959 and 2011, several statistical procedures were employed. The comparability of methods applied in 1959 and 2011was tested by the test of significance of coefficients of linear regression (Meloun, Militký 2002) on data sample with $n = 13$, with pH values, K_2O content and k_1/k_2 index used for comparison. This unfortunately revealed that with 95% probability, the methods used in 1959 and in 2011 were not comparable. In the case of K_2O, both the intercept and the slope were significantly different from 0 and 1, respectively. It was found that K_2O values in 2011 correlated with those of 1959 using the K_2O content units of mg/100 g. In the case of humus stability index according to Hock (k_1/k_2), sufficient data from 1959 ($n = 4$) were not available for executing the test of comparability for the methods of 1959 and 2011.

Testing the significance of the difference between the two soil parameters (K_2O content and Hock's humus stability index) between 1959 and 2011 employed one-sample Student's t-test on the true mean value. The mean values of the current K_2O content and Hock's humus stability index of four sites were computed as the arithmetic average of values of the given parameter of three shallow pits and the upper horizon of the soil pit. The normality of the data was tested by the one-sample Shapiro-Wilk normality test. Using the t-test, it was assessed whether the value given for 1959 falls within the confidence interval of the mean value of the given parameter of 2011 or beyond that. Comparing differences in the values of hydrophysical, physicochemical and chemical properties of organomineral horizons grouped in $n = 4$ (1 from soil pit, 3 from shallow pits) of the four tested stands in 2011 employed a single-factor analysis of variance (ANOVA) with $\alpha = 0.05$. Multiple comparisons were made using Fisher's LSD test.

RESULTS

Status of soils

Actual results of soil analysis are shown in Table 2. In organomineral horizons, compared with mineral ones, the soils are mostly highly and weakly to moderately porous; with moderate and low aeration potential; with strong and moderate water holding capacity, respectively. The most unfavourable aeration conditions were detected at L4, where the aeration is low also in the organomineral horizon. The soil reaction prevails as moderately acid and the values are quite well-balanced within the soil profile. Nutrient content is supraoptimal, especially in organomineral horizons, as well as cation exchange capacity (CEC) and base saturation (BS). The C-HA/FA ratio shows dominance of low-molecular humic acids which can indicate a tendency to acidification from the aspect of humic substance quality. The soils were evaluated as well-drained with no stagnation of water, well aerated, with high nutrition status.

Compared to raw data from Tables 2–4 show the results of ANOVA and multiple comparisons for selected soil parameters. The soils are specific in terms of both physical and chemical properties. L1 is characterised by the highest values of water retention (MCC). The nutrient content in mg of nutrient per kg of soil (Table 2) was not found by the test to be a habitat-specific parameter. But recalculation per 1-ha area into the depth of the soil occupied by the organomineral horizon and taking into account the bulk density (ρ_d) demonstrated a significant difference between the individual plots (Table 3).

Table 2. Observed soil properties on study plots

Soil pit	Horizon	Downer boundary/ thickness (cm)	Clay < 0.002 (%)	w (%)	ρ_d (g/cm)	MCC	P	A_{MCC}	pH		Ca	Mg	K	CEC (meq·kg^{-1})	BS	TN	C/N	C-HA/FA
							(%)		H_2O	$CaCl_2$		(mg·kg^{-1})			(%)			
L1	Ah	9/8	11.6	22.9	1.06	38.80	59.9	21.1	5.51	4.90	1,872.5	125.8	97.5	23.1	77.0	0.35	13.8	0.82
	Ev	31	17.6	12.9	1.38	30.29	48.0	17.7	5.05	3.68	794.0	95.0	36.6	7.5	53.3	0.08	11.0	0.57
	Btr	61	10.4	11.1	1.89	27.36	28.4	1.0	5.21	3.82	942.0	97.0	32.4	13.7	81.8	0.04	17.0	0.43
	Bt/C	90	7.5	8.2	2.04	22.89	24.2	1.3	4.31	3.64	161.0	23.0	38.4	7.6	21.1	0.07	29.0	0.64
	C	105	19.0	7.2	2.15	20.24	20.4	0.1	4.16	3.63	54.0	10.0	20.9	6.8	2.9	0.06	33.0	0.41
L2	Ah	5.5/3.5	11.0	14.7	0.94	35.10	60.4	25.3	5.30	4.68	1491	115.3	105.6	20.60	72.3	0.31	20.0	0.93
	Ev	43	24.0	6.4	1.39	34.98	46.8	11.8	4.32	3.56	211	22.0	31.4	7.20	13.9	0.08	23.0	0.47
	Btr	66	22.4	10.0	1.88	28.11	29.8	1.7	4.70	3.68	710	77.0	42.7	12.10	74.4	0.03	27.0	1.00
	Bt/C	86.5	4.3	6.8	1.99	25.94	26.3	0.4	5.26	4.73	1,404	116.0	109.0	19.10	72.3	0.34	16.0	0.89
	C	105	27.0	8.1	1.97	26.21	26.9	0.7	4.64	3.76	490	151.0	37.7	10.20	68.6	0.04	22.0	1.00
L3	Ah	9/7	21.2	11.7	0.95	33.15	64.3	31.1	5.56	4.94	1857	136.8	116.1	25.75	75.5	0.36	19.5	0.85
	Ev	32	8.1	7.1	1.27	34.03	51.8	17.7	5.15	4.13	939	82.0	36.4	10.70	89.7	0.03	37.0	1.00
	Bt	62.5	21.1	9.9	1.69	31.37	36.4	5.0	4.30	3.47	313	71.0	40.3	13.40	28.4	0.07	15.0	0.57
	Cd	105	5.5	3.3	2.02	18.08	25.8	7.7	4.90	3.86	972	67.0	32.8	9.20	80.4	0.05	21.0	0.50
L4	Am	21.5/19.5	7.5	12.2	1.16	38.66	49.1	10.5	5.50	4.82	1,519.8	123.5	94.4	20.13	72.6	0.32	16.3	0.89
	Ev	38.5	6.0	5.9	1.61	28.00	39.7	11.7	5.56	5.06	1,327.0	105.0	71.4	21.80	73.4	0.32	16.0	0.91
	Bt	62	25.3	10.7	1.87	28.58	30.1	1.5	5.55	4.36	1,035.0	68.0	37.4	10.50	87.6	0.05	17.0	0.50
	BC	89.5	4.6	8.1	1.92	27.82	28.0	0.2	5.23	4.75	1,137.0	104.0	55.0	12.00	76.7	0.18	16.0	0.68
	C	105	9.8	6.7	2.05	22.93	26.5	0.6	5.38	4.38	723	69.0	25.0	5.60	78.6	0.07	19.0	0.30

w – moisture; ρ_d – bulk density; MCC – maximum capillary capacity; P – porosity; A_{MCC} – minimal aeration; pH_{H_2O} and pH_{CaCl_2} – active and exchangeable soil reaction, respectively; Ca, Mg and K – nutrient content; CEC – cation exchange capacity; BS – base saturation; TN – total nitrogen content; C/N – carbon-nitrogen ratio; C-HA/FA – humic acid-fulvic acid ratio

Table 3. ANOVA results for selected soil properties in upper horizons of 4 pits per plot

Soil property	*F*	*P*
WRC	7.49	*0.0044*
WP	5.60	*0.0123*
P	5.13	*0.0164*
A_{MCC}	5.09	*0.0168*
Ca	11.90	*0.0007*
Mg	17.86	*0.0001*
K	20.15	*0.0001*
N	11.20	*0.0009*
Total nutrients	13.42	*0.0004*
k_1/k_2 index	4.33	*0.0275*

WRC – water retention capacity (%); WP – wilting point (%); P – porosity (%); A_{MCC} – minimum aeration capacity (%); Ca, Mg, K, N and Total nutrients – nutrient content (kg·ha^{-1}); ANOVA was determined for α = 0.05, in italics – statistically significant at $P < 0.05$

Table 4. Multiple comparisons of selected soil properties in upper horizons of 4 pits per plot using Fisher's LSD test α = 0.05 (see Table 3 for captions)

Soil property	Locality	L2	L3	L4
WRC	L1	*0.00066*	*0.00509*	*0.02055*
	L2		0.27857	0.08348
	L3			0.46610
WP	L1	*0.00164*	0.17652	0.07821
	L2		*0.02306*	0.05606
	L3			0.63350
P	L1	0.05344	0.12442	0.19800
	L2		0.63333	*0.00435*
	L3			*0.01077*
A_{MKK}	L1	*0.01538*	0.10092	0.52956
	L2		0.31617	*0.00463*
	L3			*0.03207*
Ca	L1	*0.04505*	0.46867	*0.00426*
	L2		0.16241	*0.00009*
	L3			*0.00110*
Mg	L1	0.06143	0.63140	*0.00039*
	L2		0.14219	*0.00002*
	L3			*0.00017*
K	L1	0.06199	0.81903	*0.00018*
	L2		0.09312	*0.00001*
	L3			*0.00013*
Total nutrients	L1	0.05652	0.56501	*0.00188*
	L2		0.15482	*0.00006*
	L3			*0.00066*
k_1/k_2 index	L1	0.71750	0.54666	*0.00722*
	L2		0.80692	*0.01436*
	L3			*0.02280*

in italics – statistically significant at $P < 0.05$

Comparison of soil conditions in 1959 and 2011 and soil conditions of particular sampling sites and for methods of conversion of the silvicultural system

Results of the test on the mean value for K_2O parameters and the k1/k2 index are shown in Table 5.

As for K_2O, a decrease of its content can be observed on L1 and L4 (slight extent on L4); on L2 and L3, the content of the substance remains more or less unchanged. On all the four plots, there were statistically insignificant changes in the content of K_2O. Overall, the potassium content is low to medium, which was true of 1959 as well. Comparing the K_2O content in various types of conversion found the unchanged K_2O content in the method of conversion by re-shaping.

The stability of humic substances was assessed using the ratio of humic to fulvic acids (C-HA/FA) and index k_1/k_2. The C-HA/FA ratio is < 1 for all locations (Table 2) and is neither site-specific nor conversion type-specific. The predominance of FA over HA may suggest the reduced (but yet not tending to be decreasing) quality of humus, which is confirmed through the k_1/k_2 ratio. Optimal values for "brown earth" (Hock 1937) are reported to be at least 1.5–4.5 (1–10). Values < 1.0 may assume degradation processes. The k_1/k_2 index shows a significant decrease on L3. L2 and L4 are unchanged, while for L1 the index increased. Given that the overall values are balanced between locations and do not show specific binding to the ways of the silvicultural system conversion, we can deduce a general pedogenetic trend under the influence of forest stand.

DISCUSSION

As follows from the results, some of the soil parameters are site-specific. Specific of the physical properties is MCC, which may be caused by the long-term presence of spruce in the tree species composition. The tree contributes by its litter to the accumulation of organic matter along the soil surface and the subsequent increase of water retention. Significant differences also exist in soil chemistry, when L4 was found to have a higher total nutrient content, although their concentrations, CEC and BS are comparable at all sites. This results from the generally greater thickness of the Ame horizon compared with Ah horizons. As the potential vegetation within many areas of southern Moravia is suggested to be steppes (Neuhäuselová et al. 1998; Müller et al. 2000; Adam et al. 2012), it can be considered as a reason for the evolution of the

Table 5. Results of the *t*-test on the mean value for the k1/k2 index and soil content of K_2O parameters

Parameter	Locality	Mean		$P_{S\text{-}W}$	2011		*t*	df	*P*
		1959	2011		c.i. – low	c.i. – up			
K_2O (mg·100g^{-1})	L1	16	11.70	0.8791	2.39	21.02	−1.4678	3	0.2385
	L2	13	12.70	0.6713	3.52	21.82	−0.1151	3	0.9156
	L3	13	13.93	0.2847	3.66	24.20	0.2879	3	0.7922
	L4	14	11.32	0.0970	7.71	14.93	−2.3608	3	0.0993
k_1/k_2 index	L1	0.66	0.82	0.7843	0.78	0.86	12.1215	3	*0.0012*
	L2	0.92	0.92	0.5179	0.79	1.06	0.1178	3	0.9136
	L3	1.31	0.85	0.4625	0.51	1.19	−4.2690	3	*0.0236*
	L4	0.89	0.88	0.9289	0.82	0.94	−0.3368	3	0.7584

S-W – Shapiro-Wilk test of normality; c.i. – low and up is the lower and upper boundary of confidence interval, respectively; *t* – stands for *t*-test criteria; df – stands for degrees of freedom; in italics – statistically significant at $P < 0.05$

topsoil morphology, rather than tree species composition and forest management. In order to monitor the soil response to changes in silvicultural systems, soil parameters being established in the study of 1959 were monitored. Of these, some proved to be unusable for statistical analysis, either because of too small samples or lack of correlation between historical and current methods used. While it is analytically easier to determine the pH, this parameter proved to be uncorrelated. This may result from the fact that the K_2O content in the soil is a more stable value, whereas the pH has a higher variability within the time and depth of the soil profile.

Several authors (e.g. Pelíšek 1957; Switzer, Nelson 1973; Hansen, Baker 1979; Ranger, Bonneau 1986; Le Goaster et al. 1990; Adamson et al. 1992; Ranger, Nys, 1996) are linking coppicing or other types of intense management of the risks of the soil environment degradation as well as reduced soil fertility and production potential with increased use of nutrients, loss of fertility, and loss of organic matter. The rate of potential degradation depends on the mineral strength of the site and duration of coppicing, with long-term reduction of soil fertility and thus the production and stability of the forest ecosystem being the consequence. In the case of the studied localities, which involve nutrient-rich sites, the degradation effects mentioned above were not stated.

Changes in soil parameters correspond to the change in woody species composition rather than to that in the silvicultural system: the proportion of spruce was reduced on L1 and the species is not currently present there, while the percentage of conifers on L2 and L3 has increased, which particularly applies to larch, its litter having an acidifying effect and accelerating the degradation of humic substances.

The condition and possible degradation of organic matter can be deduced from the nature of humic substances: the narrowest C-HA/FA ratio in the A horizon was detected within L1, but it is < 1 even at the remainder of locations. This indicates the degradation of organic matter and the transition from high to low molecular weight substances as also reported by Ranger and Nys (1996). The k_1/k_2 index is < 1 as well at all the localities. When compared to 1959, it could be observed to rise on L1 and reduce on L3, while maintaining its status on L2 and L4. In general, the index has been balanced within all sites. The very fact that the same method of conversion was used for L2 and L3 makes it possible to attribute the change in the nature of organic matter to the influence of woody species litter on the soil chemistry rather than to the cultivation method as such (i.e. the silvicultural system). As early as in 1959, the index of humus stability was below the limit of the optimum at all localities, which would have been assumed to be degradation of organic matter.

Within the monitored time scale, the change in management does not represent, in the case of a nutrient-rich site, a source of the risk of the reduced fertility of soil in the form of increased utilization of nutrients. The given site is assumed to have had a balanced level of nutrients over time, although high forest provides a lower consumption of nutrients from the soil, as shown for example by Ranger and Bonneau (1986) or Hölscher et al. (2001). In the event of significant degradation effects of coppicing on the soil, however, one would predict a more striking return of soil chemistry into the optimal condition as a result of sudden interruption of degradation effects. This finding is all the more important considering the fact that on the studied localities coppicing was approximately the prevailing form of management prior to 1945 and was evidenced to be for at least 200 years before that (Macharáček 1961).

In terms of soil degradation (soil genesis), illimerization processes were recorded in the soil profile. These, however, are a predicted pedogenetic phenomenon under the given circumstances of climate, soil-forming substrate and vegetation type, and at the level of soil body morphology they are even highlighted by the polygenesis of the soil-forming substrate and intra-soil weathering.

CONCLUSION

When monitoring changes in soil parameters, statistically insignificant changes were found as to the content of K_2O. As regards the k_1/k_2 index, there was an increase on L1 and a reduction on L3, while it remained unchanged on L2 and L4. These changes are not definitely related to changes in the silvicultural system. Coppicing cannot be confirmed to constitute a silvicultural system showing degradation effects on the soil. Soil fertility was not significantly influenced before 1959 when converting the silvicultural system to high forest was underway, preceded by intense coppicing for at least 200 years, and even after 1959, when the management went as part of the high forest system. From the forestry aspect, the soil was not immediately threatened by degradation in the medium term under the circumstances studied in this paper involving (to some extent) extensive coppicing system. The conclusion above is formulated for the example of a nutrient-rich site at a lower altitude, where a clearly degradation effect of the selected silvicultural system in relation to a change in forest management was not stated. The development of soils does not have attributes of degradation processes beyond normal pedogenesis.

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