Specification of the beechwood soil environment based on chosen soil properties, aiming at the *Fageta paupera* habitat

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ABSTRACT: This paper deals with a specific type of homogeneous beechwood called *Fageta paupera*. The aim is to acquire information about the heterogeneity of soil environment. As a material we used 20 research plots of semi-natural European beech stands, where the sampling of soil profile and the observation of floristic conditions were realized. Laboratory assessment of soil samples was focused on physicochemical and chemical properties of soil: pH/$CaCl_2$, K^+, Ca^{2+}, Mg^{2+}, *CEC* (T, S, V), C_{ox}, N_t, C/N, C-FA, C-HA, C-CHL, C-HA/FA. Data processing was done with the aim to discover a variability of soils, observing soil genetic horizons individually (H, A, B, C). Research plots were divided into biotopes with the cover of understory vegetation < 15% and > 15% (in accordance with the definition of *Fageta paupera*) and the variability of soil properties in each horizon for the two above-mentioned biotopes and furthermore for all plots together was investigated. Results show the highest variability of soil properties in the biotope of *Fageta paupera*, especially in its holorganic (H) and organomineral (A) horizons. Furthermore, regression analysis showed the strongest dependence of the variability of soil properties in the biotope of *Fageta paupera*.

Keywords: *Fageta paupera*; soil; variability of soil properties

European beech (*Fagus sylvatica* L.) belongs to tree species with the complicated creation of forest communities. One of several factors causing this fact is the wide ecological valence of conditions in which beech is able to grow and a high aptitude of competition. Naturally, it is not dominating vert over all forest area of its widespread. Despite of that, in conditions of Central Europe, it is an abundant species with a high ecological potential and it exceeds other autochthonous species. Furthermore, in supraoptimal conditions it creates homogeneous ecosystems, wherein it represents almost 100% species and in many cases, ecosystems of *Fageta paupera* (Buček, Lacina 2002) or also *Fagetum nudum (*Ellenberg 1996; Chytrý et al. 2001*)* communities. These forest coenoses are defined as beechwood, where the understory vegetation does not cover more than 15% of the soil surface. Causes of the formation of such communities are presently better known in theories than in facts based on original data of research (Kučera 2009), especially results of soil investigations are relatively scarce.

This article disserts on the European beech in relation to a forest habitat, which on the one hand means natural conditions and, on the other hand, the habitat is highly influenced by present vegetation.

In comparison with many deciduous species the beech influences humic conditions less positively (Godefroid, Massant 2005) but along with other species it can preserve and ameliorate the good quality of forest floor. So although beech litter represents the material with a high amount of nutrients, beech alone tends to degrade humus forms from mull towards moder. Another study (Fabiánek et al. 2009) reported a significant influence of management and species composition on

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the forest floor, when the quality of observed soil properties (humus reserves and forms, pH, C_{ox}, N_t and C/N) increased from spruce to beech forest.

Vegetation by itself is a significant eco-indicator of edaphic conditions. Based on the observation of phytocoenoses, the soil environment can be described. As a typical example we can cite the specification of groups of types of geobiocoenoses using soil acidity, base saturation and C/N ratio. The relationship between vegetation and soil characteristics, and/or humus forms, can be defined by observing the process of decomposition, pedochemical properties and presence of plant communities (Klinka et al. 1990). Another question is when the understory vegetation is absent, like in the case of *Fageta paupera.*

Using a single soil property, the description of *Fageta paupera* is very complicated. To describe soils of *Fageta paupera*, in this study soil properties are used as the indicator of stability or variability of soil environment from two aspects: firstly, for a comparison of soils with herb cover densities < 15% and > 15%; secondly, for a comparison of present soil horizons in each type of biotope.

Changes of soil properties with depth are typical of the soil environment in general (Brady, Weil 2002; White 2006). Although the beech belongs to the species of scientists' interest, the variability of the soil profile environment in natural conditions is not assessed so much and furthermore it is little known (Cienciala et al. 2006; Vanwalleghem et al. 2010), especially when we talk about a concrete stand type.

In this contribution, the soil environment is solved from a more complex point of view, using soil properties such as pH/$CaCl_2$, exchangeable macro-bioelement (K^+, Ca^{2+}, Mg^{2+}) content, soil adsorption characteristics (T, S, V), soil carbon (C_{ox}) and nitrogen (N_t) and C/N ratio and characteristics of humic substances (C-HK, F-FK, C-CHL, C-HK/FK). Such soil conditions are used to express a measure of invariability of soil properties, along the soil profile, for the stands of homogeneous beech forests (*BF*), more narrowly specified as a beechwood with the understory vegetation cover < 15% (*FP*) and a beechwood with the understory vegetation cover > 15% (*BV*).

Concrete aims of this study are: based on field observations, laboratory and statistical analyses of 20 research plots (1) to determinate the variability of soil properties in each soil genetic horizon for all 20 plots; (2) these plots are divided into biotopes of (a) *FP* (9 plots of 20) and (b) *BV* (11 plots of 20) – so the general specifications of point (1) apply to biotopes (a) and (b) to describe the stability and variability of soil properties in the observed soil genetic horizons.

MATERIAL AND METHODS

For the assessment, 20 research plots were selected in all homogeneous beech stands at the stage of mature stands. Basic characteristics are shown in Table 1. These habitats were classified on the basis of the geobiocoenological classification system, which defines *Fageta paupera inferiora* 3 AB-B(BC) 3 and *Fageta paupera superiora* 4 AB-B(BC) 3. These semi-natural European beech stands are situated in small-scale preserved areas, i.e. in the areas with a special statute of protection (Simon et al. 2004) as a part of Natura 2000 Network (Chytrý et al. 2001).

On each research plot, a soil pit was dug to describe the soil profile and to determine the soil unit (Němeček et al. 2001), classified also in accordance with the World Reference Base (WRB 2006), used also in Table 1. Samples were taken from each soil genetic horizon. In accordance with the classification of Domin scale (Moravec et al. 1994), the density of understory vegetation cover was classified.

Haplic Cambisols are the most abundant soil type while Luvisols, Podzosols and Leptosols are less frequent; as forest floor, humus types of typical moder and mull moder are the most abundant.

Laboratory analyses were focused on the assessment of physicochemical and chemical properties of soil: pH/$CaCl_2$ was assessed in 0.01M solution of $CaCl_2$ at the soil to solution ratio 1:2.5; nutrient (K^+, Ca^{2+}, Mg^{2+}) content in Mehlich 3 solution (Zbíral 2002); H^+ ion content by the method of double measuring (Adams, Evans 1962); cation exchange capacity (*CEC*) was computed by the accumulative method; C_{ox} was assessed by the oxidation of organic substances by chromsulphuric acid in wet medium (Walkley, Black 1934) by the oxidative-volumetric method; N_t was assessed by the method ISE (with ion-selective electrodes using a calibration curve in accordance with ISO 11 261 (Rejšek 1999)); content of humus substances was assessed in accordance with Kononova and Bělčikova (1961).

Data processing was done with the accent on assessing the variability of soil properties in each soil horizon to be able to deduce the heterogeneity of environments of selected stand types. To achieve the aims, data were organized (a) according to soil horizons: holorganic H horizon; organomineral A

Table 1. Research plots where the research was realised

Name of research plot	PLO	Groups of types of geobiocoenoses	Soil unit	Humus form	Type of habitat
Bučina pod Františkovou myslivnou	27	6 AB 3 (*Abieti-Fageta piceae*)	haplic Cambisols	moder	*BV*
Bukoveček I	37	3 BC 3 (*Qureci-Fageta aceris*)	luvic Cambisols	moder	*BV*
Bukoveček II	37	3 AB-B(BC) 3 (*Fageta paupera inferiora*)	haplic Luvisols	moder	*FP*
Býčí skála	30	4 AB-B(BC) 3 (*Fageta paupera superiora*)	rubic Luvisols	moder	*FP*
Čantoria	40	5 BC 3 (*Abieti-Fageta aceria inferiora*)	lithic entic Podzols	moder	*BV*
Čerňavina	40	6 A-AB 2v (*Abieti-Fageta piceae humilis*)	haplic Podzols	mor	*BV*
Dvorčák	37	3 BC 3 (*Qureci-Fageta aceris*)	stagnic Luvisols	moder	*BV*
Habrůvecká bučina	30	4 AB-B(BC) 3 (*Fageta paupera superiora*)	luvic Cambisols	moder	*FP*
Javorový	40	4 AB 3 (*Fageta abietino-quercina*)	haplic Cambisols	moder	*BV*
Jelení bučina	27	5 BC 3 (*Abieti-Fageta aceria inferiora*)	lithic Cambisols	moder	*BV*
Mazázký Grůnik	40	4 AB-B(BC) 3 (*Fageta paupera superiora*)	luvic cambisols	moder	*FP*
Mrhatina	16	4 AB-B(BC) 3 (*Fageta paupera superiora*)	dystric Cambisols	moder	*FP*
Rakovec	30	4 AB-B(BC) 3 (*Fageta paupera superiora*)	luvic Cambisols	moder	*FP*
Razula	41	5 B 3 (*Abieti-Fageta typica*)	haplic Cambisols	moder	*BV*
Salajka	40	4 AB-B(BC) 3 (*Fageta paupera superiora*)	haplic Cambisols	moder	*FP*
Sidonie	38	4 AB-B(BC) 3 (*Fageta paupera superiora*)	stagnic Cambisols	moder	*FP*
Skalka	40	4 AB-B(BC) 3 (*Fageta paupera superiora*)	lithic Cambisols	moder	*FP*
Smrk	40	5 B 3 (*Abieti-Fageta typica*)	entic Podzols	moder	*BV*
Vývěry Punkvy	30	3 BD 3 (*Querci-Fageta Tiliae*)	cambic rendzic Leptosols	moder	*BV*
Žákova hora	16	5 B 3 (*Abieti-Fageta typica*)	dystric Cambisols	moder	*BV*

FP – *Fageta paupera*; *BV* – beechwood with understory vegetation

horizon; metamorphic B horizon; parent weathering material – C horizon; (b) according to observed stand types (Beech Forest – *BF*; *Fageta paupera* – *FP*; Beechwood with understory vegetation – *BV*).

Because statistical data have a character of multivariate values, measured data were autoscaled using the formula $y_j = (x_j - \overline{x}_j)/s_j$, where x_j = measured value in statistical sample; $\overline{x}_j$ = arithmetic mean of original statistical sample; s_j = standard deviation. Partial task (1) (heterogeneity of soils in beechwood ‑ *BF*) was assessed by one-way ANOVA in Statistica 9.0. This analysis provides information about the limits of confidence intervals ± 95% (significance level $\alpha = 0.05$) for each soil property in each considered soil horizon. For each soil horizon, sizes of confidence intervals of all assessed soil properties were grouped and these data were used for a new ANOVA. Results from the analysis provide information about the variability of the analogue composition of soil properties in each soil horizon, it means one arithmetical mean and limits of confidence interval for each horizon.

Partial task (2) (heterogeneity of soils in *FP* and in *BV*) was realized in the same way but a different analysis was used. For the assessment of confidence intervals for each property in each horizon, data set has a small size of statistical samples (9 values in *FP* and 11 values in *BV*). In this case, a robust methodology for the estimation of reference intervals for data sets with small numbers of observations (so called Horn analysis) (Horn et al. 1998) was used. The second part of assessment was analogical with task (1): for each soil horizon, sizes of confidence intervals of all assessed soil properties were grouped and these data were used for ANOVA, which renders information about the variability of the analogue composition of soil properties in each soil horizon, it means one arithmetical mean and limits of confidence interval for each horizon in *FP* and in *BV*.

To acquire information about a significant distinction of variability among soil horizons, all three statistical samples (*BF*, *FP*, *BV*) were tested by Tukey's range test of multiple comparisons. To complete the information about the dependence of soil properties on soil depth, each stand type was tested by a regression analysis in MS Excel 2003 to get the R^2 value.

RESULTS

Confidence intervals of ANOVA for the entire statistical sample of 20 plots (*BF*) are shown in Table 2. Results from the second part of the analysis of *BF* are documented in Fig. 1. It shows the variability of soil properties in each soil horizon, where *X*-axis represents variability and *Y*-axis compared soil horizons. From the graph (Fig. 1) and from Table 3 it is evident that ANOVA rejects the null hypothesis and the sets are significantly different. Variability is the highest in H horizon and the lowest in B horizon, multiple comparisons show the agreement of variability just between horizons A and C, where the null hypothesis is closely non-rejected.

Table 2. Confidence intervals of ANOVA for the entire statistical sample of 20 plots (*BF*). Results in this table show variability of soil properties in each soil horizon

Soil property	Soil horizons			
	H	A	B	C
pH/KCl	1.2679	1.1690	0.9708	1.0901
K^+	0.9869	0.9099	0.7556	0.8485
Ca^{2+}	0.9869	0.9099	0.7556	0.8485
Mg^{2+}	0.9869	0.9099	0.7556	0.8485
H^+	1.0312	0.9507	0.7895	0.8866
CEC	1.1591	1.0686	0.8874	0.9965
S	0.9869	0.9099	0.7556	0.8485
V	1.0085	0.9298	0.7722	0.8670
C_{ox}	0.9869	0.9099	0.7556	0.8485
N_t	0.9869	0.9099	0.7556	0.8485
C/N	0.9869	0.9099	0.7556	0.8485
C-HK	0.9869	0.9099	0.7556	0.8485
C-FA	0.9869	0.9099	0.7556	0.8485
C-CHL	0.9869	0.9099	0.7556	0.8485
C-HA/FA	0.9869	0.9099	0.7556	0.8485

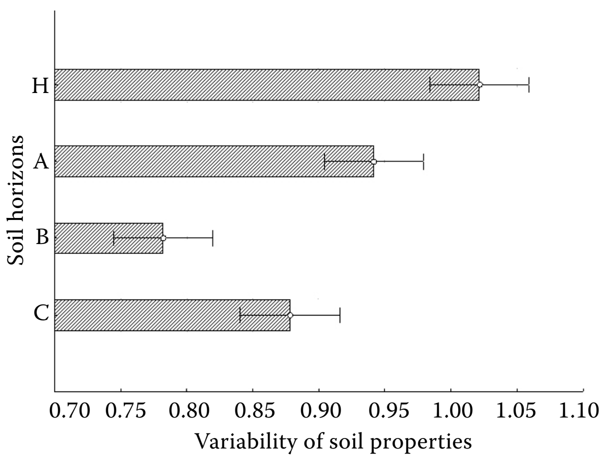

Fig. 1. Results of ANOVA with 0.95 confidence intervals for entire statistical sample of 20 plots (*BF*)

Table 3. Multiple comparisons (Tukey's HSD test) for the statistical sample *BF* (beech forest) (P = 0.05)

	H	A	B	C
H		0.020227	0.000159	0.000164
A	0.020227		0.000159	0.089639
B	0.000159	0.000159		0.003533
C	0.000164	0.089639	0.003533	

For *FP* and *BV*, confidence intervals of Horn analysis are shown in Table 4. ANOVA testing the groups of properties for each horizon and stand type shows significant variability in horizons H and A in *FP*; horizons do not reject the null hypothesis. Results show facilitation of research plot diversification in *FP* and *BV* to determine that the soils of *Fageta paupera* are mostly the cause of large differences and that they are characterized by high heterogeneity of the soil environment, especially in top soil.

Table 5 shows the highest dependence of variability of soil properties with depth in the case of *FP*; the statistical sample *BV* is the most indifferent among the tested sets. Its separation seems to enable to show the extremity of the depth gradient in *Fageta paupera*; the statistical sample *BF* is logically situated by its value of R^2 between the two specified stand types.

DISCUSSION

The first point is a different method of statistical assessment of *BF* contrary to *FP* and *BV*. The reason is a small size of *FP* and *BV* sets and slight invalidation of normality contrary to an optimal size of *BF*, when ANOVA can be used. Furthermore, the data are valuable for the observation of trends in the soil profile and those tendencies are comparably shown in the regression results.

One of the important points is also that in the spectrum of used soil properties physical properties are absent. The reason is that for H horizon, the analysis of physical ring or texture is not possible,

Table 4. Confidence intervals of Horn analysis for the statistical samples *FP* and *BV*. Results in this table show variability of soil properties in each soil horizon of each type of biotope

Soil property	Type of biotope/Soil horizons							
	FP/H	*BV*/H	*FP*/A	*BV*/A	*FP*/B	*BV*/B	*FP*/C	*BV*/C
pH/$CaCl_2$	4.7581	0.8496	3.6167	0.5434	0.6527	0.6046	4.8226	0.3982
K^+	3.1038	1.1966	1.5131	0.9475	1.1854	1.1756	2.1235	1.6771
Ca^{2+}	3.7239	0.5647	2.6562	0.5561	0.4077	0.2279	1.1930	0.2630
Mg^{2+}	3.8796	2.7105	3.9874	2.2564	1.5768	1.0731	2.5288	0.6756
H^+	5.0735	3.2639	3.6577	2.1752	1.0477	2.1519	2.3854	2.5214
CEC	10.1499	3.9841	3.9130	1.0402	1.7731	0.7083	1.1996	0.6485
S	4.4000	0.5744	2.7847	0.6762	0.2815	0.3232	1.2591	0.4424
V	5.8764	2.1240	4.2299	1.1760	1.0466	0.8078	2.4106	1.1862
C_{ox}	4.1084	1.1405	4.7628	1.7383	1.4793	0.9407	2.2527	1.9911
N_t	3.7950	2.4899	3.8726	1.3598	1.0228	1.1275	1.7343	1.4104
C/N	3.4284	0.9781	4.0234	2.3415	0.6327	1.7878	1.9131	2.0654
C-HA	3.3791	2.2201	4.6223	0.7711	0.6069	1.4157	1.7469	1.9377
C-FA	2.0334	2.9402	2.7347	1.9762	0.8872	1.6246	1.4493	2.0059
C-CHL	1.9908	2.5634	3.1209	1.2448	0.6896	1.4444	1.5296	2.0904
C-HA/FA	4.1115	2.0776	4.1406	1.0118	1.4150	1.0545	1.5420	1.7241

FP – *Fageta paupera*; *BV* – beechwood with understory vegetation

so for the equivalent number of compared properties in each horizon we used properties observable in the entire soil profile.

Results show that in the zones of subsoil, beechwood soils are generally uniform in the soil properties while in the rhizosphere the diversification of soil properties can be observed.

The unanswered question is if the difference in top soil between *FP* and *BV* is caused by understory vegetation and the rest of phytocoenosis contributing to the formation of the soil environment or on the contrary, the absence or presence of herbs on the soil surface is primarily caused by the specificity of the soil environment.

After summarization of the computed values it is evident that the soils of *Fageta paupera* in the entire profile are more variable in soil properties than *BV* – in *FP*: H_0 is non-rejected relatively "closely" in comparison with B and C horizons ($P = 0.0939$) while in *BV* the *P*-value in Table 6 are higher in most cases than the critical value ($P = 0.05$).

Table 5. Results of regression analysis

Type of biotope	R^2
BF	0.395
FP	0.600
BV	0.258

BF – entire statistical sample of beech forest; *FP* – *Fageta paupera*; *BV* – beechwood with understory vegetation

A significant gradient of variability in soil properties within the soil profile is also evident from the regression analysis (Table 5). ANOVA also shows a significant variability in all three assessed cases. Variability is strictly dependent on soil depth and it decreases towards the base of regolith. Comparing with literature, the influence of soil depth as a prediction factor for the constancy of soil environment was assessed in the permeability of soil for rain water (Janík, Pichler 2008). Contrary to this study, the soil depth was not found to be a significant factor.

On the contrary, the character of the ecosystem aboveground part of soil was observed for the comparison with physicochemical properties of forest floor (Podrázský 2006) in beech forests with closed canopy, compared with the character of forest floor under canopy gaps. Their conclusion showed an acceleration of decomposition (reduction of humus layer thickness, increase of pH, V and *CEC* and number of nutrients), consequently amelioration of conditions for seedlings. Such a situation could

Table 6. Multiple comparisons (Tukey's HSD test) of variability of soil properties for the statistical samples *FP* and *BV* (P = 0.05)

Type of biotope/ Soil horizons	Type of biotope/Soil horizons							
	FP/H	*BV*/H	*FP*/A	*BV*/A	*FP*/B	*BV*/B	*FP*/C	*BV*/C
FP/H		0.0001	0.5651	0.0001	0.0001	0.0001	0.0001	0.0001
BV/H	0.0001		0.0007	0.6043	0.1130	0.2306	1.0000	0.7498
FP/A	0.5651	0.0007		0.0001	0.0001	0.0001	0.0008	0.0001
BV/A	0.0001	0.6043	0.0001		0.9808	0.9986	0.5526	1.0000
FP/B	0.0001	0.1130	0.0001	0.9808		1.0000	0.0939	0.9382
BV/B	0.0001	0.2306	0.0001	0.9986	1.0000		0.1974	0.9900
FP/C	0.0001	1.0000	0.0008	0.5526	0.0939	0.1974		0.7028
BV/C	0.0001	0.7498	0.0001	1.0000	0.9382	0.9900	0.7028	

FP – *Fageta paupera*; BV – beechwood with understory vegetation

lead to the conclusion that the soil environment is non-changeable when the aboveground soil is homogeneous. These results demonstrate that vegetation can be absent in more cases of the soil specificity than it can be present. On the basis of this work project we can conclude that the causation does not lie in the presence of a concrete soil property, but in the heterogeneity of soils in general.

CONCLUSION

This contribution deals with a topic of the soil environment in beech forest stands, focused on the specific biotope *Fageta paupera*. As a feature for soil assessment, soil conditions are used to explain the stability of soil environment or the measure of homogeneity of soil conditions within the entire soil profile. Results of this study show a high variability of soils in the specific beechwood ecosystem *Fageta paupera*, compared with a beechwood with understory vegetation cover > 15%.

This study does not provide any information about the specific causation defining soils of *Fageta paupera*, on the contrary, the contribution to the knowledge of this ecosystem is in the determination of complicated soil environment, compared with the monotonously and "uncomplicatedly" looking forest aboveground part of soil.

Further activities should lead to the assessment of nearly holorganic and organomineral horizons, to determination of soil properties which are "responsible" for high variability or of stable properties conditioning the creation of the *Fageta paupera* ecosystem.

References

Adams F., Evans C.E. (1962): A rapid method for measuring lime requirement of red-yellow podzolic soils. Soil Science Society of America Journal: 355–357.

Brady N.,Weil R. (2002): The Nature and Properties of Soil. Upper Saddle River, Prentice Hall: 960.

Buček A., Lacina J. (2002): Gebiocenology II. [Textbook.] Brno, MZLU: 249. (in Czech)

Cienciala E., Exnerová Z.,Macků J., Henžlík V. (2006): Forest topsoil organic carbon content in Southwest Bohemia region. Journal of Forest Science, ***52***: 387–398.

Ellenberg H. (1996): Vegetation Mitteleuropas mit den Alpen in Ökologischer, Dynamischer und Historischer Sicht. Stuttgart, Ulmer: 623.

Fabiánek T., Menšík L., Tomášková I., Kulhavý J. (2009): Effects of spruce, beech and mixed commercial stand on humus conditions of forest soils. Systems Biology, ***32***: 119–126.

Godefroid S., Massant W., Koedam N. (2005): Variation in the herb species response and the humus quality across a 200-year chronosequence of beech and oak plantations in Belgium. Ecography, ***28***: 223–235.

Horn P.S., Pesce A.J., Copeland B.E. (1998): A robust approach to reference interval estimation and evaluation. Clinical Chemistry, ***44***: 622–631.

Chytrý M., Kučera T., Kočí M. 2001: Catalogue of Biotopes of the Czech Republic. Praha, AOPK ČR: 307. (in Czech)

Janík R., Pichler J. (2008): Amounts of throughfall and lysimetric water in a sub-mountain beech forest in the Kremnické vrchy Mts. (West Carpathian Mts., Slovakia). Sciences-New York, ***54***: 207–211.

Klinka K.,Wang Q.,Carter R.E. (1990): Relationships among humus forms, forest floor nutrient properties, and understory vegetation. Forest Science, ***36***: 564–581.

Kononova M.M., Bělčikova N.P. (1961): Rapid methods for obtaining of humus content in mineral soils. Počvovedĕnie, ***10***: 75–87. (in Russian)

Kučera A. (2009): Case study, assessing the type of forest ecosystem *Fageta paupera*, realised on the part of study area of Alois Zlatník n. 6 in research area group Javornik. In: Hrubá V., Štykar J. (eds): Geobiocenology and its Application in the Landscape. Papers of Geobiocenology. Vol. 13. Brno, MZLU: 70–77.

Moravec J. (1994): Phytocenology. Praha, Academia: 403. (in Czech)

Němeček J.E. (2001): Taxonomical Classifical System of Soil of the Czech Republic. Praha, ČZU: 78. (in Czech)

Podrázský V.V. (2006): Changes in humus forms in gaps of the canopy of semi-natural beech stand. Journal of Forest Science, ***52***: 243–248.

Rejšek K. (1999): Forest Pedology-Practice. Brno, MZLU: 152. (in Czech)

Simon J., Vacek S., Buček A. (2004): Rating of Risk Resulting from Assertion of the Production Function of the Forest in Specially Protected Areas (Methods.) Brno, MZLU: 60. (in Czech)

Vanwalleghem T., Poesen J., McBratney A., Deckers J. (2010): Spatial variability of soil horizon depth in natural loess-derived soils. Geoderma, ***157***: 37–45.

Walkley A., Black I.A. (1934): An examination of the Detjareff method for determinating soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, ***37***: 29–38.

White R.E. (2006): Principles and Practice of Soil Science: the Soil as a Natural Resource. Oxford, Blackwell: 363.

WRB (2006): World Reference Base for Soil Resources. A Framework for International Classification, Corelation and Communcation. Roma, FAO/ISRIC/ISSS: 128.

Zbíral J. (2002): Soil Analysis I. Method Operations. Brno, ÚKZÚZ: 197. (in Czech)

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