Forest site classification of forest ecosystems in Bohemian Karst (Czech Republic)

P. Šamonil, J. Viewegh

Faculty of Forestry and Environment, Czech University of Agriculture in Prague, Prague, Czech Republic

ABSTRACT: The study focuses on selected forest site units on water uninfluenced sites on limestone in Bohemian Karst. The species composition of phytocoenoses, their potential production and soil properties were assessed. Studied forest site complexes are correctly determined and they provide important information from the aspect of planning and practical nature conservation management. It is necessary to specify the criteria of *categoria calcaria* in detail, since it is often difficult to distinguish it from *categoria mesotrophica*. Water retention capacity of soils, a criterion often neglected so far, presents a useful view of forest site water budget and it is a suitable criterion in forest site classification.

Keywords: Bohemian Karst; limestone; forest site classification; soil; phytocoenose; oak; beech

Forest site classification of forest ecosystems is a significant background for qualified management of the natural conservation agency in highly protected areas. It is a framework for forest management planning and realization. Forest site classification reflects the expected potential of forest ecosystems and outlines the way to its accomplishment.

Forest site classification of the forest ecosystems in Bohemian Karst in the 1960's was based on a series of detailed geobotanical studies (e.g. Klika 1928, 1942, 1957) and on several soil studies (Najmr, Káš 1935; Mařan 1947; Smolíková 1960). The studies were mainly prepared by Samek (1960, 1964). A set of forest site maps Anonymus (1967) was made on the same basis. Průša (1974) discussed forest site classification units in Bohemian Karst. Forest site classification of Natural Forest Area (NFA) 8 (Anonymus 1996) was determined in Regional Plan of Forest Development (RPFD) and currently published (Zelenková in Trnčík et al. 2000). Podhorník (1998, 2000) prepared detailed forest site classification maps for Koda and Karlštejn National Nature Reserves. Differences between these maps and FDAP in some classification units show the need of further precise development of forest site classification.

This study aims to use present criteria for Czech forest site classification (Anonymus 1971/1976) and deeper specification of its units in the Bohemian Karst area. This study should help prepare precise definitions of disputed matters regarding the classification and open discussion about particular criteria. Results will be used to make conservation plans of small, highly protected areas in the Bohemian Karst Protected Landscape Area (PLA).

Forest Site Complexes (FSC) mentioned below were studied in detail:

1C – *Carpineto-Quercetum subxerothermicum,*
1W – (*Fagi-*) *Carpineto-Quercetum calcarium,*
2W – *Fageto-Quercetum calcarium,*
3W – *Querceto-Fagetum calcarium,*
2H – *Fageto-Quercetum illimerosum mesotrophicum.*

FSC studied for better understanding of possible connections:

1B – *Carpineto-Quercetum mesotrophicum,*
2B – *Fageto-Quercetum mesotrophicum,*
3B – *Querceto-Fagetum mesotrophicum,*

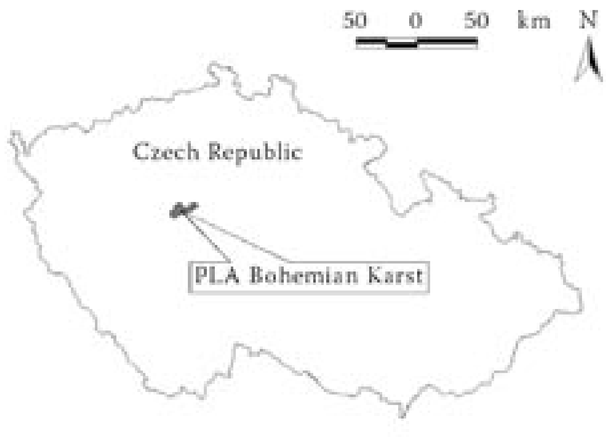

Fig. 1. PLA Bohemian Karst

3H – *Querceto-Fagetum illimerosum mesotrophicum,*
3J – *Tilieto-Aceretum saxatile,*
2A – *Aceri-Fageto-Quercetum lapidosum,*
1X – *Corneto-Quercetum xerothermicum.*

METHODS AND MATERIAL

A detailed forest site survey was carried out in the Bohemian Karst (Fig. 1) PLA in the period of 1997–2002. Fifty-seven water-uninfluenced sites on limestone of Silurian and Devonian ages were evaluated. Diabase and lime slates were also locally admixed. Sites were situated on plateaus, slope bases and slopes of exposures mostly not exceeding 20°.

Fig. 2 documents study plot positions in the terrain profile – exposure and slope gradient. Soils were classified according to FAO (Driessen et al. 2001) and humus forms according to Green et al. (1993). Horizon colours were assessed according to Munsell tables (Anonymus 1965). Water retention capacity (WRC) values were calculated for the physiological depth of the profile. WRC was determined by hydrolimits of the maximum capillary water capacity (MCWC) and temporary wilting point from pF curves. WRC of highly skeleton horizons was determined as a fraction content function < 0.01 mm (Benetin et al. 1987). Screening by Casagrande method helped to determine textural curves. Chemical analyses were done by methods of Zbíral (1995, 1996, 1997) and partly Anonymus (2003). General soil terminology was used according to Němeček et al. (1990) and Šustykevičová (1998).

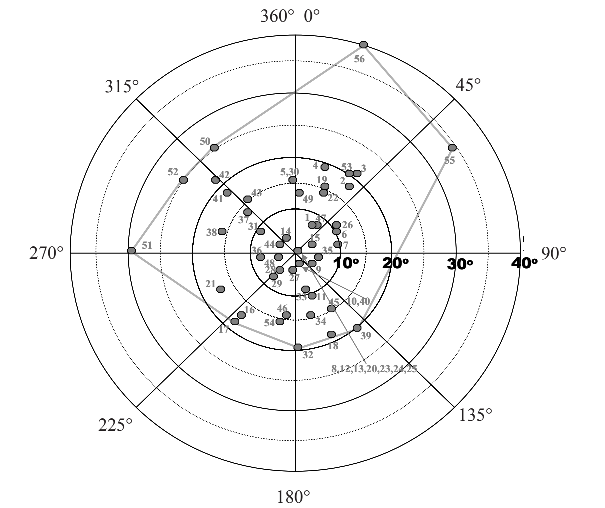

Fig. 2. Position of assessed sites according to the slope and exposition of hillside

Plant taxonomy corresponds with Kubát et al. (2002). The moss layer was not analyzed since its abundance did not exceed 5%. (*Hypnum cupressiforme* reached the highest frequency and abundance.) The size of vegetation survey plots was 400–450 m^2. Last spring aspect was evaluated. Vegetation survey was published by Šamonil (2004). Phytocoenoses were classified by floristic approach (Braun-Blanquet 1921), according to Moravec et al. (2000). Braun-Blanquet scale, modified by Zlatník (1953 in Zlatník 1975), was used. Fidelity was evaluated by "Φ" coefficient (sensu Chytrý et al. 2002), Ellenberg's average indication values by Ellenberg et al. (1992). Ordinations were made in conformance with ter Braak and Šmilauer (2002).

Forest mensurations were carried according to Korf (1972). Mensurational tables, developed by Černý et al. (1996), were used. Absolute height yield class (AHYC) was the basic criterion for stand production potential assessment.

Forest site classification units were distinguished according to Viewegh et al. (2003).

RESULTS AND DISCUSSION

Forest site classification units in terrain profile

According to a macroclimatic characteristic Bohemian Karst belongs to the 2nd altitudinal forest zone (AFZ). With regard to the geological base, *Fageto-Quercetum calcarium* (2W) is a pivotal forest site complex (FSC) that occurs on undulating plateaus and moderate slopes. Conditions for 1st AFZ are found mostly on southern slopes. The 3rd AFZ is also mesoclimatically conditioned. It belongs to northern slopes and narrow valleys (FSC: 3W – *Querceto-Fagetum calcarium*, 3B – *Querceto-Fagetum mesotrophicum* and 3D – *Querceto-Fagetum acerosum deluvium*; and also 3H – *Querceto-Fagetum illimerosum mesotrophicum* that is lined behind

Table 1. Pedological characteristics of chosen Forest Site Complexes

FCS	Matrix	Genetic depth (cm)	WRC (mm)	Subsurface horizons	Soil classification (FAO-ISSS-ISRIC 1998)
1X	limestone (sporadically with slate)	0–30	0–20	surface organomineral horizons always convert to parent rock	Lithic Leptosol (Rendzic and Eutric) Hyperskeletic Leptosol (Rendzic, Calcaric and Eutric) Rendzic Leptosol (Humic and Eutric)
1C (for sites on limestone)	limestone (if there are relict soils – allochthonous material also)	to 50 (65)	around 20 mm (if there is Cambic horizon – then WRC > 20 mm)	strongly skeletal surface organomineral horizons usually directly convert to substrate horizons	Hyperskeletic Leptosol (Rendzic, Calcaric and Eutric) Rendzic Leptosol (Humic and Eutric) Eutric Cambisol (Chromic)* Calcaric Cambisol (Eutric and Chromic)*
1W, 2W, 3W	limestone, in some cases (particularly relict soils) eolic or solifluction materials are important also !!!). Always without siliceous soil sceleton	30–75	(20) 35–90	Cambic horizon is usually presented (not so much frequent in FCS 1W). It has usually atributes of rubification or illuviation also. Albic horizon (thickness to 10 cm) is not so frequent !!!	Endoleptic Cambisol (Calcaric, Eutric and Chromic) Eutric Cambisol (Chromic) Calcaric Cambisol (Eutric and Chromic) Calcaric Cambisol (Endoskeletic, Eutric and Chromic) Calcaric Cambisol (Episkeletic, Eutric and Chromic) Leptic Cambisol (Calcaric, Episkeletic, Eutric and Chromic) Endoskeletic Cambisol (Eutric and Chromic) Endoleptic Cambisol (Calcaric, Episkeletic, Eutric and Chromic) Rendzic Leptosol (Humic, Calcaric and Eutric) Hyperskeletic Leptosol (Rendzic, Calcaric and Eutric)*
2H, 3H	eolic material, slate, limestone, solifluction material !!!	> 70	> 80	Albic horizon is always presented over Argic (or Cambic horizon with attributes of illuviation and rubification) horizon. Both horizons are almost without skeleton.	Eutric Cambisols (Chromic) Calcaric Cambisols (Eutric and Chromic) Vertic Luvisols (Calcaric, Albic and Cutanic) Haplic Albeluvisols

WRC – Water Retention Capacity; *marginal soils

northern slopes). Climate inversion of the altitudinal forest zones is often common there as well. Edatope and subsequently the edaphic category partly change due to terrain properties. These transitions are expressive especially on southern slopes where FSC 1X (*Corneto-Quercetum xerothermicum*), 1C (*Carpineto-Quercetum subxerothermicum*), 1W ((*Fagi-) Carpineto-Quercetum calcarium*) and 1B (*Carpineto-Quercetum mesotrophicum*) change in a sharp ecological gradient. Sites of FSC 1C (*Carpineto-Quercetum subxerothermicum*) very often form a kind of collar around sites belonging to the xerothermic category (*categoria xerothermica*). In other cases they make smaller compact sites mainly on southern slopes (often on slopes around 20°). Sites of FSC 1B (*Carpineto-Quercetum mesotrophicum*) and 1W ((*Fagi-) Carpineto-Quercetum calcarium*) are situated in similar locations with different substrate. They are located again on exposed slopes and slightly declined slopes. Soil conditions of edaphic category H (*categoria illimerosa mesotrophica*) FSC 2H (*Fageto-Quercetum illimerosum mesotrophicum*) are mostly found on plateaus and scarcely on wide ridges. In similar locations FSC 2W (*Fageto-Quercetum calcarium*) could also be found that form the largest and most compact units in the area. Sites of edaphic categories A (*categoria acerosa lapidosa*), J (*categoria acerosa saxatile*) and D (*categoria acerosa deluvia*) are situated on steep slopes and deluvia.

Forest site classification units from the aspect of soil types*

Categoria subxerothermica

Carpineto-Quercetum subxerothermicum – FSC 1C (for sites on limestone, Table 1): Soils could mostly be classified as Hyperskeletic Leptosol (Rendzic, Calcaric and Eutric) or Rendzic Leptosol (Humic and Eutric). The humus form, Rhizomull or Vermimull, depends on the herb layer composition. Surface anhydromorphic humic horizon (not "mellanic" as it is classified in Němeček et al. 2001) transits to parent material detritus horizon or directly neighbours with parent rocks on sites FSC 1C. Surface (organo-mineral) horizon (very rarely without carbonates) reacts with HCl weakly, while lower horizons always react strongly. Lime clastics make the soil profile highly skeletal (> 50%). Surface (organo-mineral) horizon has colour No. 7.5 YR 4/4, 3/4, 4/2 (Anonymus 1965), it is loose and in full depth distinctively rooted through. Soil is clay-loam with crumb or polyhedral structure. Physiological depth often exceeds the genetic one. Soil is fully saturated (> 90%) by Ca and Mg cations in whole thickness. Soil reaction (pH_{KCl}) varies between neutral (6.1–7.0) and slightly acid (5.6–6.5).

Developed cambic horizon is present on gently sloping, southern exposed sites, especially where the recent profile does not respect the inner relief (cf. Šály 1978). Transition from about 10 cm thick organo-mineral horizon is sharp. Cambic horizon has signs of rubification (colour 5 YR 5/6, 5 YR 5/4) and sometimes narrow clay incrustations are visible on aggregates. Cambic horizon can be free of carbonates. It highly contrasts with the rich carbonate detritus of parent soil to which the horizon sharply transits. Profiles were classified as Eutric Cambisol (Chromic) and Calcaric Cambisol (Eutric and Chromic). Genetic depth usually never exceeds 65 cm. Cambic horizon can be completely (but not necessarily) free of skeleton. This horizon is less rooted through than the surface (organo-mineral) horizon. The rooting still reaches substrate horizon. Transition between horizons is sharp. In cambic horizon, soil is compacted clay and it does not react with HCl. Its structure is polyhedral. In comparison with the above-mentioned soil types of Reference Soil Group Leptosols, these soils have minimum air capacity (also below 5%). There could be expected lower values of soil reaction (in cambic horizon $pH_{KCl} < 6$) and soil complex saturation by basic cations. Cambic horizon is still fully saturated (> 90%).

Groundwater is always unavailable in the profiles. WRC of the profile usually does not exceed 20 mm. Soil profiles with wider cambic horizon incline to FSC 1W (*Fagi-*) *Carpineto-Quercetum calcarium*). On the contrary, there are not found Lithic Leptosols (Rendzic and Eutric) on these sites and soils usually correspond with more exposed sites as X – category (*categoria xerothermica* – X).

Categoria calcaria

Limestone is the parent rock and the only skeleton source in the soil profile. Being pedogenic, it takes significant part in soil genesis. The relation between AFZ and soil profiles is mostly based on the site position in the terrain relief, which is a significant factor influencing soil genesis and at the same time it represents certain mesoclimatic conditions important for distinguishing AFZs. Soils on southward oriented slopes classified as 1st AFZ are generally shallow and have a higher skeleton content than soils of other terrain profiles (except steep slopes). This statement corresponds with that of Šály (1986) declaring that in long-term genesis the soils on southward oriented slopes defrosted deeper than those on northward slopes and the material was removed by solifluction or otherwise. The soil profile character of southward situated slopes then cooperates in the formation of extreme ecological conditions regarding vegetation growth. On the other hand, it is not a rare phenomenon that the soil profiles belonging to

FSC 1W ((*Fagi-*) *Carpineto-Quercetum calcarium*) form better soil conditions for plant growth than the profiles belonging to FSCs 2W (*Fageto-Quercetum calcarium*) and 3W (*Querceto-Fagetum calcarium*), although it is the opposite way in general (Samek 1960; Šály 1986).

In Bohemian Karst, all three FSCs belonging to this edaphic category are formed by different proportions of soils belonging to Leptosols and Cambisols Reference Soil Group. Soils were classified as Rendzic Leptosol (Humic, Calcaric and Eutric) and Hyperskeletic Leptosol (Rendzic, Calcaric and Eutric). The last mentioned soil types particularly incline to *categoria saxatilis acerosa* – J, and *categoria acerosa lapidosa* – A. Carbonates could be partly leached out of the surface, about 10 cm thick, organo-mineral horizon. In comparison with FSC 1C (*Carpineto-Quercetum subxerothermicum*) the soil is deeper, has lower skeleton content and higher WRC values, which do not decrease below 20 mm. WRC of soil profiles ranges between 22 mm ((*Fagi-) Carpineto-Quercetum calcarium*) and 86 mm (*Fageto-Quercetum calcarium*). The parent rock is lower than 30 cm in *Carpineto-Quercetum subxerothermicum*. There are known soil profiles that developed on soil sediments.

Soils belonging to Cambisols Reference Soil Group were classified as Calcaric Cambisol (Eutric and Chromic), Calcaric Cambisol (Endoskeletic, Eutric and Chromic), Calcaric Cambisol (Episkeletic, Eutric and Chromic), Leptic Cambisol (Calcaric, Episkeletic, Eutric and Chromic), Endoskeletic Cambisol (Eutric and Chromic), Endoleptic Cambisol (Calcaric, Episkeletic, Eutric and Chromic), Endoleptic Cambisol (Calcaric, Eutric and Chromic), Eutric Cambisol (Chromic). Cambic horizon often has visible loam films on soil aggregates. In such cases the albic horizon is usually only little developed. Its richness exceeds 10 cm only on plateaus. This horizon differentiation is frequently based on lithologic heterogeneity – eolic deposition or solifluctional movement down the slope. The coefficient of texture differentiation mostly varies around 1.45. Albic horizon combined with cambic horizon and with clear rubification characteristics was present in most studied soils. Parent material disintegration horizon or pure parent rock (both horizons have a high carbonate content) begin 50–75 cm from the organo-mineral horizon surface. Skeleton is almost always present in B-horizon. Soil of cambic horizon does not react with HCl or it reacts weakly. This part of profile has a carbonate content usually below 0.5% rarely exceeding 2%. Soil is fully saturated by Ca and Mg cations in the whole profile with the exception of thin albic horizon. In eluvial horizon the sorption complex saturation can decline to 50%. This part of soil profile has pH_{KCl} value ranging between 3.5 and 4. Lower in the profile – cambic horizon, substrate horizons – the soil reaction is almost always neutral (6.1–7.0) or slightly alkaline (> 7.0). Humic organo-mineral horizon is strongly rooted through and dark (7.7 YR 3/2–4, 4/2–4, 5/3), it is below 10 cm thick with crumb or polyhedral structure, it almost lacks carbonates (values up to 0.1%) and its pH_{KCl} is around 6. The content of plant accessible nutrients is fully sufficient. Especially cambic horizon is texturally very heavy. Fraction content of < 0.01 mm is to 75%. Fraction < 0.001 mm can reach 50%. The soil texture allows estimation of low air capacity and high plant inaccessible water proportion. Organo-mineral and eluvial horizons are usually texturally more airy, often containing 0.05–0.01 mm fractions in over 30% (max. 42.4%). WRC values for the physiologic depth of soil profiles are ranging between 35 and 90 mm.

Depending on phytocoenosis content the humus forms are Vermimull or Mullmoder.

(*Fagi-*) *Carpineto-Quercetum calcarium* – FSC 1W: Reference Soil Group Leptosol is more frequent in comparison with FSCs 2W (*Fageto-Quercetum calcarium*) and 3W (*Querceto-Fagetum calcarium*). Cambisols are also common; they often display albic horizon indication and weak films in cambic horizon.

(*Fagi-*) *Carpineto-Quercetum calcarium* and *Fageto-Quercetum calcarium* – FSCs 2W and 3W: Reference Soil Group Cambisols dominate. Frequent albic horizon indication and clay film forming lower in the profile. Formation of clay films is not essential for development of rubified cambic horizon (cf. Werner 1958; Šály 1986). Eolian or deluvium additions are very frequent in the surface part of profile.

Categoria illimerosa mesotrophica

Fageto-Quercetum illimerosum mesotrophicum and *Querceto-Fagetum illimerosum mesotrophicum* – FSCs 2H and 3H: All studied soils had signs of undergoing illimerization. Albic horizon has been slightly to distinctly developed. Cambic horizon has transparent rubification attributes and clay films are often present on pedologic aggregates. Soils have been classified as Eutric Cambisols (Chromic), Calcaric Cambisols (Eutric and Chromic), Vertic Luvisols (Calcaric, Albic and Cutanic) and Haplic Albeluvisols. The last listed soils develop on loess overlaps. The substrate horizon of crumbled solid rock material with high carbonate content is below the depth of 75 cm. In comparison with soils of *categoria calcaria* all above-mentioned soil types contain hardly any skeleton in cambic or argic horizons. Transition between horizons is more visible and sharp. The illimerization process taking place together with profile decarbonization is more distinctive in comparison with *categoria calcaria* soils. The argic horizon structure changes from polyhedral to prismatic, with compact consistency. Content of fraction < 0.01 mm reaches nearly 80%, content of fraction < 0.001 mm can exceed 50%. Due to the mentioned soil texture in profile gleyfication caused by precipitation could be observed. In spite of the distinctive physiological depth exceeding 100 cm, profiles form only about 80 mm WRC. Minimum air capacity reaches the possible lowest values in the middle part of the profile. Surface profile parts (organo-mineral and eluvial horizons) even there often contain a higher proportion of 0.05–0.01 fraction (about 44.6%). The profile soil reaction (pH_{KCl}) is generally lower than in *categoria calcaria* – W (*categoria subxerothermica* – C, *categoria mesotrophica* – B). It can be medium acid (4.1–5.0) in cambic or argic horizons. It reaches even lower values in albic horizon, where it is < 4.0. Substrate horizons show neutral to slightly alkaline soil reaction.

Surface humus forms are classified as Vermimull.

Other edaphic categories

Study plots belonging to edaphic category B (*categoria mesotrophica*) were classified only marginally. They contained sites that could not be classified as category W (*categoria calcaria*). Soil profiles form transition between the two categories; they resemble W-category profiles with the exception of the silicate rock material being always present. Described profiles are not obviously model examples of B-category. A more objective conception could be made by studying the wider spectrum of substrates accepted in B-category.

In soil profiles belonging to xerothermic edaphic category – X (FSC 1X – *Corneto-Quercetum xerothermicum*) the organo-mineral horizon was always followed by substrate horizon. The soils were classified as Lithic Leptosol (Rendzic and Eutric) and/or as Hyperskeletic Leptosol (Rendzic, Calcaric and Eutric) or Rendzic Leptosol (Humic and Eutric).

Cambic or argillic horizons were not present in any profile on sites belonging to J and A categories (FSCs 3J – *Tilieto-Aceretum saxatile* and 2A – *Aceri-Fageto-Quercetum lapidosum*) that were also influenced by sharp sloping (> 20°) and gravitation mixing of material. The organo-mineral surface horizon of these sites was usually thick, aired, and rich in humus with a good C/N ratio. Skeleton was present in the whole profile, mostly formed by limestone. Soils were classified as Hyperskeletic Leptosol (Rendzic, Humic, Calcaric and Eutric) and in some cases as Lithic Leptosol (Rendzic and Eutric). The soil was mostly developed on the soil sediment.

Site classification units from the dendrometry aspect

The biomass production potential of studied sites could be simply described as: FVC (1X) < 1C < 1W (= 1B) < 2W (= 2B) ≤ 2H ≤ 3W (= 3B).

Absolute height yield class (AHYC) for *Quercus petraea* was estimated as 12–14 m on FSC 1C (*Carpineto-Quercetum subxerothermicum*). *Fagus sylvatica* was not present on these sites. It was only present individually in FSCs 1W ((*Fagi-) Carpineto-Quercetum calcarium*) and 1B (*Carpineto-Quercetum mesotrophicum*) and its AHYC values (16 and 18 m) have only informational character. *Quercus petraea* and *Tilia cordata* reached the same AHYC values. AHYC values for *Carpinus betulus* ranged between (10) 12 and 14 m. Production potential is higher in FSCs 2W (*Fageto-Quercetum calcarium*) and 2B (*Fageto-Quercetum mesotrophicum*), where *Quercus petraea* reaches AHYC = (18) 20–24 (26) m. *Fagus sylvatica* and *Tilia cordata* attained similar values. AHYC for *Carpinus betulus* were estimated as (14) 16–18 (20) m.

Similar values could be expected on sites belonging to FSC 2H (*Fageto-Quercetum illimerosum mesotrophicum*), only with a higher minimum height of *Quercus petraea* (AHYC = 22 m). Tree species on FSCs 3W (*Querceto-Fagetum calcarium*) and 3H (*Querceto-Fagetum illimerosum mesotrophicum*) also reach higher AHYC: *Fagus sylvatica* (24) 26–28 m, *Quercus petraea* 26 m, *Carpinus betulus* (16) 18–20 m and *Tilia cordata* 24–28 m.

This survey corresponds with mensurational assessment prepared for Plot No. 8 by Zelenková (in Trnčík et al. 2000). Conversely to this study, a lower value of AHYC was accepted there (*Quercus petraea* 16 m). The regional plan of forest development gives AHYC = 26 m for *Fagus sylvatica* and 22 m for *Quercus petraea* on the studied sites. Within edaphic categories W, H (D and B) in the area Zelenková (in Trnčík et al. 2000) did not use the 3rd AFZ. The author of this study found higher AHYCs (up to 28 m for *Fagus sylvatica*, and up to 26 m for *Quercus petraea*).

Site classification units from the aspect of phytocoenoses

Vegetation surveys of sites belonging to FSC 1C (*Carpineto-Quercetum subxerothermicum*) corresponded in all cases with *Quercion pubescenti-petraeae* alliance, mostly with *Corno-Quercetum* association (Table 2). *Lathyro versicoloris-Quercetum pubescentis* association also appeared in several cases, but it also inclined to FSC 1X (*Corneto-Quercetum xerothermicum*). On sites belonging to FSC 1W ((*Fagi-) Carpineto-Quercetum calcarium*) (respectively to 1B – *Carpineto-Quercetum mesotrophicum*) several vegetation surveys were classified as *Corno-Quercetum* association as well. This association slowly fades away on those sites and a majority of evaluated vegetation surveys was classified as the association *Melampyro nemorosi-Carpinetum*, subassociation *M.n.-C. primuletosum veris*. From the aspect of phytocoenoses FSC 2W (*Fageto-Quercetum calcarium*) and 2B (*Fageto-Quercetum mesotrophicum*) were relatively heterogeneous. Stands most frequently correspond with association *M.n.-C.* (*M.n.-C. typicum* or *M.n.-C. festucetosum heterophyllae*; subass. *M.n.-C. primuletosum veris* clearly disappears), and in a few cases with ass. *Cephalanthero-Fagetum*. Vegetation of FSC 2H (*Fageto-Quercetum illimerosum mesotrophicum*) usually corresponds with subass. *M.n.-C. festucetosum heterophyllae* or it could be also classified in the framework of ass. *Potentillo albae-Quercetum*. Phytocoenoses belonging to FSC 3W (*Querceto-Fagetum calcarium*) or 3B (*Querceto-Fagetum mesotrophicum*) can usually be classified as ass. *Cephalanthero-Fagetum*, where there often appear transitions to subass. *M.n.-C typicum* and *M.n.-C. festucetosum heterophyllae*. A similar situation is in FSC 3H (*Querceto-Fagetum illimerosum mesotrophicum*).

Differential species of FSC 3W (*Querceto-Fagetum calcarium*) in principle copy the significant and differential elements of *Fagion* alliance and ass. *Cephalanthero-Fagetum*. From this point of view the highest values were found in *Actaea spicata* and *Cephalanthera rubra*. The abundance of species *Viola reichenbachiana, Scrophularia nodosa* and *Oxalis acetosella* is less significant. Against expectations, species *Lilium martagon, Sanicula europaea, Dentaria bulbifera* or *Cephalanthera damasonium* nearly lack the diagnostic value in studied localities. These plants occur with similar frequency and fidelity even on sites of FSC 2W (*Fageto-Quercetum calcarium*), in the case of species *Cephalamthera damasonium* also on FSCs 1W ((*Fagi-) Carpineto-Quercetum calcarium*) and 1C (*Carpineto-Quercetum subxerothermicum*). The shrub layer is formed by *Fagus sylvatica* as well as *Acer platanoides, A. pseudoplatanus, Daphne mezereum* and *Cornus sanguinea*.

Highly significant species of ass. *Potentillo albae-Quercetum* and subass. *Melampyro nemorosi-Carpinetum festucetosum heterophyllae* are a combination of differential species for FSC 2H (*Fageto-Quercetum illimerosum mesotrophicum*), namely acidophilous species and species of heavy, periodically drought and gleyed soils lower in the profile. Such species are *Potentilla alba, Serratula tinctoria, Ajuga reptans, Melampyrum nemorosum, Lysimachia nummularia, Aegopodium podagraria, Maianthemum bifolium,*

Table 2. Units of floristic classification (Braun-Blanquet 1921) in chosen Forest Site Complexes

FSC	Units of floristic classification (Braun-Blanquet 1921; Moravec et al. 2000)
1C	as. *Corno-Quercetum* as. *Lathyro versicoloris-Quercetum pubescentis**
1W	subas. *Melampyro nemorosi-Carpinetum primuletosum veris* as. *Corno-Quercetum**
2W (2B)	subas. *M.n.-C. typicum* subas. *M.n.-C. festucetosum heterophyllae* subas. *M.n.-C. primuletosum veris** as. *Cephalanthero-Fagetum**
3W (3B)	as. *Cephalanthero-Fagetum* subas. *M.n.-C. typicum** subas. *M.n.-C. festucetosum heterophyllae**
2H, 3H	subas. *M.n.-C. festucetosum heterophyllae* as. *Potentillo albae-Quercetum* as. *Cephalanthero-Fagetum*

*marginal unit

Impatiens parviflora and in the case of higher acidification there can appear also *Vaccinium myrtillus*.

From the aspect of phytocoenosis composition the FSC 2W (*Fageto-Quercetum calcarium*) is very variable. There dominate mesophylous species (*Hepatica nobilis, Lathyrus vernus, L. niger, Galium odoratum, Mercurialis perennis,* etc.). They are also present in other assessed FSCs, although with lower dominancy. In comparison with FSC 1W ((*Fagi-*) *Carpineto-Quercetum calcarium*), there fade out the thermophilous species differential for subass. *M.n.-C. primuletosum veris* (*Primula veris, Viola mirabilis*). Frequent are also species commonly present in FSC 2H (*Convallaria majalis, Maianthemum bifolium, Festuca heterophylla*, *Stellaria holostea*). In comparison with other FSCs, there is a higher fidelity of *Milium effusum, Lathyrus niger* and *Polygonatum multiflorum*. Regularly present are species commonly classified as "beech species" – *Dentaria bulbifera, Hordelymus europaeus*. *Lonicera xylosteum* appears more frequently in the shrub layer.

Sharp differentiation of the 1st AFZ from the others due to understorey composition is visible. There are many common species for FSCs 1W and 1C. In connection with other units, they have character of differential species. There are significant common species: *Anthericum ramosum* (also on sites with slightly decarbonized surface part of soil profile), *Bupleurum falcatum, Campanula persicifolia, Festuca rupicola, Betonica officinalis, Polygonatum odoratum, Dictamnus albus* and *Clinopodium vulgare*. The last species is together with *Astragalus glycyphyllos* and *Galium mollugo* related rather to FSC 1W. *Torilis japonica* also shows higher fidelity to FSC 1W. *Poa angustifolia, Trifolium alpestre, Betonica officinalis* and *Silene nutans* occur on sites of SFC 1C. In opposition to FSC 1W the determining species for this FSC are *Euphorbia cyparissias, Carex humilis, Teucrium chamaedrys, Asperula cynanchica* and *A. tinctoria*. Floristic similarity with FSC 1X (*Corneto-Quercetum xerothermicum*) was not assessed where it is possible to expect the same species.

The presence of *Fagus sylvatica, Quercus pubescens, Berberis vulgaris, Cotoneaster integerrimus, Sorbus aria, C. sanguinea* (*Cornus mas*) is significant for determining forest sites. The presence of juvenile development stages is also an important attribute.

A majority of the above-mentioned species was described by Viewegh et al. (2003), who denotes presented survey as significant (respectively dominant) species. His survey, elaborated for the whole territory of this country on FSC level is more extensive, although some species are not present in the studied area (e.g. *Carex pilosa, Pulmonaria officinalis* and *Galium schultesii* on FSC 2H), others do not appear as either as diagnostic or dominant species in processed surveys (e.g. *Galium odoratum* and *Melittis melissophyllum* for FSC 2H and *Lathyrus vernus* for FSC 1C). Within the studied area, some species listed by him are connected with other site types and they are not present in these vegetation surveys (e.g. *Adonis vernalis* and *Helianthemum nummularium* for FSC 1W).

For NFA No. 8 survey of differential species on forest site (FS) level is created by Zelenková (in Trnčík et al. 2000). Established results correspond with this survey. There are only small exceptions (e.g. on FSC 1C *Viola collina* rather than *V. hirta* is present). Only Zelenková (in Trnčík et al. 2000) did not determine FSC 3W. In Anonymus (1971/1976), Plíva (1980) and Randuška et al. (1986), the survey of plant species was prepared only as reference on the level of edaphic categories. It also lacks differentiation of W-category or relevant FSC. The last mentioned relates to work of Průša (2001) as well.

Table 3. Ellenberg's average indication values for vegetation surveys grouped by relation to forest site units. Table presents average values. In brackets are min. and max. values. Number of vegetation surveys used for calculating average values is noted in brackets at the first column

FSC	Light	Temperature	Continentality	Moisture	Soil reaction	Soil nitrogen
1C (7)	5.6 (5.2–6.0)	5.8 (5.7–5.8)	4.0 (3.9–4.2)	4.2 (3.9–4.5)	6.9 (6.7–7.2)	4.2 (3.9–4.7)
1W (8)	5.3 (5.1–5.5)	5.7 (5.6–5.9)	3.9 (3.7–4.2)	4.3 (4.2–4.5)	6.7 (6.5–6.9)	4.3 (3.8–4.8)
1B (3)	5.1 (4.9–5.5)	5.8 (5.8–5.9)	3.9 (3.8–4.0)	4.3 (4.3–4.4)	6.7 (6.6–6.8)	4.2 (4.1–4.3)
2W (11)	4.6 (4.3–4.7)	5.7 (5.6–5.8)	3.8 (3.7–3.9)	4.7 (4.5–4.8)	6.5 (6.3–6.9)	4.9 (4.4–5.2)
2B (1)	4.5	5.8	3.8	4.8	6.6	5.3
2H (4)	4.7 (4.5–4.8)	5.7 (5.7)	3.8 (3.8–3.9)	4.8 (4.7–4.8)	6.1 (5.9–6.3)	4.9 (4.8–5.1)
3W (10)	4.2 (3.9–4.5)	5.5 (5.4–5.6)	3.7 (3.6–4.0)	4.8 (4.6–5.0)	6.7 (5.9–6.9)	5.3 (5.0–5.7)
3B (1)	3.8	5.5	3.8	4.9	6.4	5.2
3H (2)	4.1 (4.0–4.2)	5.5 (5.5–5.6)	3.8 (3.8)	4.9 (4.9)	6.8 (6.8)	5.5 (5.5)

Table 3 shows computed Ellenberg's indication values for vegetation surveys of studied sites.

CONCLUSIONS

Studied FSCs are fully relevant, including recently newly described FSC 1W ((*Fagi-*) *Carpineto-Quercetum calcarium*) and often discussed FSC 3W (*Querceto-Fagetum calcarium*). All FSCs have clear distinguishing characteristics from the planning and management realization aspects. Pattern of stands would also be suitable if included on the site type level to "general guidelines".

Categoria calcaria and its boundary to *categoria mesotrophica* appear problematic due to correct differentiation. There is a need for better definition of differences between those categories. The only criterion should not be just the description of geological base as there appear very frequent eolic or soliflucion depositions and common visible decarbonization of the part of soil profiles. Ambiguity was caused by accepting of *Fagus sylvatica* in 1st altitudinal forest zone (FSC 1W) in basic publications. Water retention capacity (WRC) makes a good picture regarding the important factor of stand water balance and is suitable as a classifying criterion for classification of Czech forest sites. It was very suitable for separation *categoria subxerothermica* from *categoria calcaria*.

* neither term of qualifier Mollic nor mollic horizon is used in individual Reference Soil Groups. The reason is different approach to this horizon by FAO (FAO-ISSS-ISRIC 1998; Driessen et al. 2001) and Němeček et al. (2001).

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Typologické hodnocení lesních ekosystémů Českého krasu (Česká republika)

P. Šamonil, J. Viewegh

Fakulta lesnická a environmentální, Česká zemědělská univerzita v Praze, Praha, Česká republika

ABSTRAKT: Článek předkládá podrobnou charakteristiku typologických jednotek na vodou neovlivněných stanovištích na vápenci Českého krasu. Bylo posouzeno druhové složení fytocenóz, jejich produkční potenciál a vlastnosti půdního prostředí. Studované soubory lesních typů jsou svou náplní plně opodstatněné a i z pohledu plánování a praktické realizace managementu ochrany přírody vykazují důležitá specifika. Dořešit je třeba kritéria klasifikace zejména u edafické kategorie W – *categoria calcaria*. Její rozlišení proti edafické kategorii B – *categoria mesotrophica* je často obtížné. Retenční vodní kapacita půd, kritérium dosud opomíjené, dává dobrou představu o důležité složce vodní bilance porostů a je vhodná jako klasifikační kritérium pro typologické hodnocení.

Klíčová slova: Český kras; vápenec; lesnická typologie; půda; fytocenóza; dub; buk

V Národních přírodních rezervacích Koda, Karlštejn a v přírodní rezervaci Radotínské údolí byly hodnoceny stanovištní poměry, produkční potenciál a složení lesních fytocenóz. Výzkum se zaměřil zejména na posouzení gradientu stanovištních podmínek a porostních poměrů v rámci těchto souborů lesních typů (SLT): 1C – suchá habrová doubrava (*Carpineto-Quercetum subxerothermicum*), 1W – vápencová habrová doubrava ((*Fagi-) Carpineto-Quercetum calcarium*), 2W – vápencová buková doubrava (*Fageto-Quercetum calcarium*), 3W – vápencová dubová bučina (*Querceto-Fagetum calcarium*), 2H – hlinitá (a sprašová) buková doubrava (*Fageto-Quercetum illimerosum mesotrophicum*). Obsahová náplň a vymezení těchto typologických jednotek byly podrobně diskutovány. Ostatní SLT byly studovány pouze okrajově. Byla navržena některá doplňková kritéria.

Studované SLT jsou v oblasti plně opodstatněné, a to včetně nedávno nově zavedeného SLT 1W i často diskutovaného SLT 3W. Třetí lesní vegetační stupeň je v Českém krasu mezoklimaticky podmíněný na výrazných severních partiích svahů (u souboru lesních typů 3H – *Querceto-Fagetum illimerosum trophicum* v zákrytu těchto svahů), je na spodní hranici svého výskytu a není typicky vyvinutý. Porosty s dominancí *Fagus sylvatica* v těchto polohách jsou trvalými společenstvy. SLT mají i z pohledu plánování a praktické realizace managementu zřejmá specifika.

Půdy vykazovaly značnou diverzitu. Půdotvorným substrátem byl materiál *in situ* i soliflukčně, eolicky a fluviálně transportovaný. Část profilů se vyvíjela polygeneticky a polycyklicky. Půdy byly klasifikovány jako litozem modální varieta karbonátová, rendzina litická, suťová, melanická, modální, pararendzina modální, suťová, kambizem rubifikovaná, luvická, vyluhovaná, modální, arenická, hnědozem pelická, oglejená. Podle fyzikálně-chemických vlastností byly půdy označeny jako eubazické. Humusovou formou byl Rhizomull, Vermimull či Mullmoder. Těsná byla závislost charakteristik porostů a stanovišť na reliéfu terénu. Na svazích se sklonem > 20° se nacházely půdy se stratigrafií Ah_k-C_k, Am_k-C_k, $Am_{(k)}$-Cr_k-R_k. Tyto půdy byly výrazně zastoupeny i na J exponovaných svazích sklonů < 20°, kde byly popsány i půdy stratigrafie Ah-$Br_{(k)}$-Cr_k-R_k, Ah-Ev-$Brt_{(k)}$-Cr_k-R_k. Na svazích ostatních expozic sklonů < 20°, na plošinách a úpatních površích převládaly půdy s vyvinutým B (Br, Brt, Bt, Bv) horizontem a často i s horizontem eluviálním (Ev).

Obecné představy o vztahu půdního typu k reliéfu terénu ale neplatily vždy. Profily v obdobné poloze někdy vykazovaly značně odlišné vlastnosti. Ty se odrazily v hodnotách retenční vodní kapacity půd („RVK“). Voda je primární limitující faktor zdejších ekosystémů. RVK se pohybovala mezi 12,1 mm a 123,7 mm (pro fyziologickou hloubku půd). Díky vysokému obsahu frakce < 0,001 mm (i přes 50 %) byl značný podíl vody v půdě pro rostliny těžko dostupný. V argilickém Bt či rubifikovaném argilickém Brt horizontu nabývala limitních hodnot i minimální vzdušná kapacita.

Rostlinná společenstva byla podle školy curyšsko-montpellierské zařazena do asociací: *Lathyro versicoloris-Quercetum pubescentis*, *Corno-Quercetum* (subas. *C.-Q. euonymetosum europaeae*), *Melampyro nemorosi-Carpinetum* (subas. *M.n.-C. primuletosum veris, M.n.-C. festucetosum heterophyllae, M.n.-C. typicum), Cephalanthero-Fagetum*.

V porostech na ekologicky extrémních stanovištích J expozic dosahoval *Quercus* spp. absolutní výškové bonity („AVB“) = 12. *Fagus sylvatica* zde nebyl zastoupen. Nejvyšší produkční potenciál (*Quercus petraea* AVB = 26, *Fagus sylvatica* AVB = 28) byl zjištěn na úpatních površích a severně exponovaných svazích.

Jako problematická se jeví obsahová náplň *categoria calcaria* – W a její hranice proti *categoria mesotrophica* – B. Hranici obou je třeba lépe definovat. Při velmi časté a vysoké účasti eolického či soliflukčního (s.l.) materiálu a při zjevné dekarbonizaci části půdních profilů nemůže jako jediné kritérium sloužit charakter geologického podkladu. Nedostatečné je i vymezení obou těchto kategorií vůči *categoria illimerosa mesotrophica* – H. Nejasnosti způsobuje přijímaná účast *Fagus sylvatica* v 1 LVS (SLT 1W) v podkladových materiálech lesnické typologie. Retenční vodní kapacita půd dává dobrou představu o důležité složce vodní bilance porostů a je vhodná jako klasifikační kritérium pro typologické hodnocení. Velmi platná byla při separaci *categoria subxerothermica* od *categoria calcaria*.

Corresponding author:

Ing. Pavel Šamonil, Ph.D., Česká zemědělská univerzita v Praze, Fakulta lesnická a environmentální, 165 21 Praha 6-Suchdol, Česká republika
tel.: + 420 224 383 401, fax: + 420 234 381 860, e-mail: samonil@fle.czu.cz