10.37045/aslh-2011-0009 *Acta Silv. Lign. Hung., Vol. 7 (2011) 109–123*

The Riparian Alder Forests of the Sopron Hills

Ferenc SZMORAD*

Aggtelek National Park Directorate, Jósvafő, Hungary

Abstract – The present study demonstrates the classification of the riparian alder forests of the Alpokalja region through the analysis of their stands in the Sopron Hills. Besides the historical, ecological and floristic data collection, the differentiation of these forests was examined using 36 coenological relevés recorded according to the Braun-Blanquet method. Cluster analysis, principal component analysis and TWINSPAN analysis were applied in the process; the definition of diagnostic species for the resulting units was carried out by fidelity analysis using the Φ coefficient. The presence of three alder forest associations was verified by the research in the study area. In the vicinity of the lower and middle sections of the streams, characterized by stagnant water, small patches of swampy alder forests (*Angelico sylvestris – Alnetum glutinosae*) occur. In the fast-flowing stream sections alder woods rich in species of mesophilic deciduous forests (*Aegopodio – Alnetum glutinosae*) can be found, while along the middle and upper sections of the streams, at sites with seepage water, mixed ash-alder forests with montane herb species (*Carici remotae – Fraxinetum*) are typical. The investigations revealed that the *Carex brizoides* dominance-type alder groves were secondary forests that formed in former meadows and they belong to the 3 mentioned riparian alder forest types.

riparian alder forests / phytosociology / Sopron Hills

Kivonat – **A Soproni-hegység égerligetei.** Jelen tanulmány az Alpokalja égerligeteinek osztályozási problémáit a Soproni-hegység állományainak elemzésén keresztül mutatja be. A történeti, ökológiai és florisztikai adatgyűjtés mellett a szerző a ligeterdők differenciálódását Braun-Blanquet módszere szerinti 36 cönológiai felvétel felhasználásával vizsgálta. A feldolgozás során cluster-analízis, főkomponens-analízis és TWINSPAN-elemzés készült, az elkülönített egységekre a diagnosztikai fajok kimutatása a hűség-értékek Φ koefficiens szerinti számításával történt. Az elemzések alapján a hegység területén három égerliget-asszociáció jelenléte volt igazolható. Az alsó és középső patakszakaszok kiszélesedő, pangóvizes részein kis foltokban láposodó égerligetek (*Angelico sylvestris – Alnetum glutinosae*) fordulnak elő. Ugyanebben a fekvésben a patakok gyors folyású szakaszain üde lomberdei fajokban gazdag égerligetek (*Aegopodio – Alnetum glutinosae*), míg a középső-felső patakszakaszok szivárgó vizes termőhelyein montán elemekkel színezett, kőriselegyes égerligetek (*Carici remotae – Fraxinetum*) jellemzőek. A vizsgálatok feltárták, hogy a *Carex brizoides* dominancia-típusú égerligetek egykori rétek helyén kialakult, másodlagos jellegű erdők, s a fenti három égerliget-típushoz tartozó állományokat foglalnak magukba.

égerligetek / növénycönológia / Soproni-hegység

* uccuneki@yahoo.com; H-3758 JÓSVAFŐ, Tengerszem u. 1.

1 INTRODUCTION

The near-natural vegetation of the border region between the Alps and the Pannonian Basin has a strong transitional character due to the combined effects of the sub-Atlantic and sub-continental (and to a smaller extent sub-Mediterranean) climates. The montane influence and the occurrence of montane plant species is most remarkable in the regions of the Kőszeg and the Sopron Hills, which can primarily be explained with the direct biogeographical connections, and the orographical characteristics of the two regions (ridges exceeding the height of 800 and 600 m a.s.l., respectively).

The montane characteristics can be best detected in the riparian alder forests along the streams in both regions (see Szmorad 1994, Király – Szmorad 2004a) where the microclimatic conditions of the stands situated between beech forests allow the occurrence of numerous montane plant species. On the other hand, the alder forest sections of the foothills resemble more of the stands described in the inner basin, while secondary stands formed as a result of earlier anthropogenic impact are also possible to be found. This complexity of the situation makes it difficult to create a coenological classification of these alder forests; the different syntaxonomical systems of the two neighboring countries, Austria and Hungary (see Wallnöfer et al. 1993, Kevey – Borhidi 1996, Borhidi 2003, Willner 2007, Kevey 2008), and the different interpretations of the associations in the Austrian and Hungarian literatures further complicate this issue.

The classification issues are presented in this paper as a case study on the alder forests in the Sopron Hills region, divided by the Hungarian-Austrian border (see Szmorad 2010). There are only a few short descriptions of the alder woods of this area from the Hungarian side (Soó 1941, Csapody 1964), whereas no research has been carried out on the Austrian part. There are very few coenological relevés published that could be analyzed, and most of the riparian stands have never been subject to vegetation research. The coenological, ecological and phytogeographical characterization of the stands also considering historical aspects have not yet been carried out and the question of the montane riparian ash-alder forests has not yet been resolved (see Kevey 2008).

2 STUDY AREA

The Sopron Hills are the north-eastern subrange of the Alps reaching furthest into the Pannonian Basin together with the Kőszeg Hills. They are of medium height. To the west they are separated from the adjacent, nearly north-south running Rosalia Hills by a saddle above the village of Sieggraben. The area of the Sopron Hills is approx. 150 km^2 (Király 2004).

Concerning the area’s geology, the formations of two geological epochs play a major role: in the eastern part of the hills an island-like extrusion of a palaeozoic schist block (consisting of muscovite-gneiss, mica slate, quartzite and leucophyllite) can be observed (Vendl 1929) while the western part between that and the Rosalia Hills is covered with Miocene sandy, gravel–clay sediments (Vendl 1930, Küpper 1957). On the southern face of the hills (between Ritzing and Neckenmarkt, also south of Kalkgruben) there are intrusions of Leitha limestone, while acidic sandstones (between Neckenmarkt and Harka) add to the geological structure, as well (Draganits 1996). In the north-western part of the region, significant areas are covered with a Badenian clay sequence (Fuchs – Grill 1984).

The main ridge runs in West-East direction, its highest point is the Brenntenriegel (606 m a.s.l.) situated within Austrian territory. The surface structure is defined by wide and flat ridges and slopes of varying steepness. The valleys are usually deeply cut in the schists, thus they are narrow with an upper-course character, without alluvial valley floors (Kárpáti 1955).

On the other hand, the valleys that formed on the Miocene sediments show mostly middle-course characteristics, their streams often meander on the 30–50 m wide alluvial valley floors.

The hydrographic network of the area consists of small streams. Along their upper sections and in the vicinity of valley heads seeping springs are frequent, whereas smaller hallows with stagnant water appear along the middle and lower sections. The typical soil types of the valley floors are wet (in some cases affected by seeping or stagnant waters) alluvial and colluvial forest soils (Csapody – Neuwirth 1963). On wider valley floors the site conditions are more defined by the groundwater.

The climate of the region is basically cool with high precipitation. However, a definite macroclimatic gradient can be observed west-easterly; while the eastern hill front is warmer and dryer, the western, inner area is much cooler and has higher precipitation. The mean annual temperature varies between 8–9 ºC, and the annual precipitation usually between 650–900 mm (Király 2004).

From the phytogeographical point of view the Sopron Hills are situated in the border region of the Alpine (*Alpicum*) and the Pannonian (*Pannonicum*) floristic provinces. The phytogeographical classification of the area is difficult, since the detectable floristic gradients (Király – Szmorad 2004b) indicate a transitional nature and a dualistic character, which often appears in the forest vegetation as well.

3 FORMER RESEARCHES

The first references to the riparian alder forests of the Sopron Hills can be found at Gombocz (1906); later Soó (1941) studied the area. The latter mentions alder forests (*Alnetum glutinosae*) and ash-alder woods (*Fraxineto – Alnetum*) based on some coenological relevés recorded on a single site at the upper section of the Rák Stream. He distinguished several different types (for the former *Phragmites communis – Caltha palustris*, *Carex remota*, *Impatiens noli-tangere*, for the latter *Veratrum album*, *Carex brizoides*, *Chrysosplenium alternifolium*, *Petasites hybridus* types) and summarized his data in a synoptic table.

After World War 2 the reviving Hungarian botanical research was mostly confined to the eastern part of the hills due to the state border zone. The essay of Orlóci – Tuskó (1955), from this period mentions riparian forests dominated by black alder (*Alnetum incanae Alnus glutinosa* consociation) and mixed ash woods (*Cariceto remotae – Fraxinetum*). In his phytogeographical study using mainly earlier data Kárpáti (1956) describes alder woods under the name *Alnetum glutinosae-incanae* in the Sopron Hills region and ash woods (*Cariceto remotae – Fraxinetum*) in the Vadkan and Tacsi Valleys, the Fáber Meadow and the Nagyfüzes areas.

The riparian forests along the streams of the eastern half of the Sopron Hills were examined in detail by Csapody (1964). The montane alder forests that he named *Alnetum glutinosae-incanae* Br.-Bl. 1915 were characterized on the basis of 9 relevés and he also described the ash woods under the name *Carici remotae – Fraxinetum* Koch 1926 *orienti-alpinum* Knapp 1942, publishing a single relevé. The potential vegetation map of Csapody et al. (1964) can be considered an addition to this study; the authors indicated montane alder forests in some sections of the Zsilip Valley, Hidegvíz Valley and the valleys of the eastern rim of the hills, as well as small ash wood stands in the head part of the Kovács Valley and two spots in Nagyfüzes.

There was no significant research concerning the riparian alder forests of the Hungarian part of Sopron Hills following the previously mentioned ones; the botanical studies published until the early 2000’s only refer to earlier works and try to interpret these. Based on the floristic research of the region Király – Szmorad (2004a) provide a very short description of the riparian stands (*Aegopodio – Alnetum, Carici brizoidis – Alnetum*) whereas the historical aspects of the research on alder forests in the Alpokalja region are shortly summarized by Baranyai-Nagy – Baranyai (2008).

Publications about the Austrian side of the research area could not be found, and besides the general descriptions neither the work of Wallnöfer et al. (1993) nor that of Willner (2007) provides help concerning the coenological classification of the local riparian forests.

4 METHODS

I studied all the stream valleys of the Sopron Hills (ca 130 km) in the course of my research and tried to gather all relevant data and information concerning the site characteristics, structure, species composition, earlier management, naturalness and dynamics of the riparian alder forests. For the documentation and detailed examination of these stands I have recorded 30 relevés with the classical coenological method (Braun-Blanquet 1951). The size of the sample areas was either 20 × 20 or 10 × 40 meters (= 400 m^2). The plots were not permanent; data acquisition was carried out once in May or June.

When choosing the sampling plots I avoided disturbed and weedy stands (preferential sampling). Thus they were designated in middle-aged or old-growth stands with high naturalness and without conifers (in order to avoid the influence of such plantations, which had affected riparian sites, as well).

Besides my own ones I have included some (6) relevés by Csapody (1959–1966), surviving as manuscripts. These were also taken in the early summer and represented riparian forests with high naturalness. However, I have omitted some of Csapody's data (1964) since they were recorded in strongly disturbed stands as the high number and cover values of the species indicating disturbance would have strongly distorted the results of the comparative coenological analysis.

In the course of analysing the coenological data with multivariate methods I first used the SYN-TAX 2000 software package (Podani 2001). Before the analysis the cover values of the tree species in the canopy, shrub and herb layers were assembled by species and the A-D values were converted into percentages equal to the central values of the intervals. In case of binary data the Jaccard index was applied for the cluster analysis, while the data transformed using logarithmic standardization (base 2 and 10) were analyzed using the Beta-flexible method (value: –0.25) and the Bray-Curtis index. Principal component analysis (PCA) was applied for ordination.

I have also analysed the coenological data with the TWINSPAN method. This method of Hill (1979) is based on reciprocal averaging (correspondence analysis).The data have been processed with the 7.0 version of the JUICE software package (Tichý 2002, Tichý – Holt 2006). Before the analysis the cover values of the tree species in the shrub and herb layers were assembled by species and the A-D values converted to percentages equal to the central values of the intervals. I chose the level of pseudospecies as 3; their values are 0, 5 and 25%. The TWINSPAN analysis was run with the maximum number of divisions (6) and I interpreted the resulting classification according to the level of the divisions.

I have assigned the diagnostic species for the riparian alder forests for the finalized groups of relevés. Following the method of Chytrý et al. (2002) I defined these by calculating the fidelity values according to the Φ-coefficient. The table of synthetic data (fidelity, constancy) is published with Φ = 0.30, using Fischer's exact test (P <0.05) in order to emphasize species with high fidelity and to avoid bias due to small sample size.

The results from the analysis of the coenological relevés were evaluated (including the experiences of the field trips) and the vegetation types derived from classification were matched with the coenological units. Finally, I prepared the concise description of the region's alder associations, including a literature review. The letters in brackets signify the layers (A = canopy layer, BC = shrub and herb layer, C = herb layer, D= moss layer) in the descriptions. Constant and sub-constant species are represented above 60% constancy, dominant species above 60% cover (in the latter case the percentage values signify the frequency of the dominant occurrences).

I used the vascular plant names of the identification book edited by Király (2009) while moss names are based on the checklist of Erzberger – Papp (2004).

5 RESULTS

5.1 General results of the field research

As stand types associated with streams, alder woods can be found in any valley of the Sopron Hills. Besides the continuous, ribbon-like stands there are some occurrences limited to short valley sections in the north-western and south-eastern part of area on sand-gravel sediments with lower clay content. The latter phenomenon is most apparent south of Marz (in the valley between Gruskogel and Hochkogel), and above Neckenmarkt (in the valley of the Goldbach) mainly due to intermittent streams absorbed by the loose ground. Besides the riparian stands in some parts of the hills (e.g. around Asztalfő) alder woods of similar character appear on wet patches close to springs.

In the narrow valleys of the eastern part formed on schist, the alder stands are narrow, often only a single line wide. More extensive (with an extent of 20–50 m) alder woods which are more suitable for coenological analysis only occur in the valleys of the area covered with sedimentary rocks.

The original site conditions of these forests have been modified in many places by road and leat constructions, stream regulation works, drainage structures, buildings and artificial lakes (in the Austrian part nearly 30 ponds) during past centuries. Although such anthropogenic effects have influenced the sites of the alder stands (mainly the hydrological balance), most of them can still be considered quasi natural.

On the other hand, former land use practices have significantly reduced the extent of the alder stands. The forests on the floodplains of the lower and middle stream sections were cut down centuries ago and replaced by extensive meadows. Many of the meadows are still managed (especially on the Austrian side), however, a large-scale reforestation process started in the 1950's (see Baranyai-Nagy – Baranyai 2008). Non-native tree species were also introduced therefore many stands of *Picea abies*, *Pinus sylvestris* and *Populus* × *euramericana* can be seen on the valley floors. In the lower valley sections (near settlements and orchards) *Juglans regia* often occurs subspontaneously.

In the riparian alder woods *Alnus glutinosa* is the dominant tree species, but the stands are usually mixed. Of the accompanying species *Fraxinus excelsior* can play a major (even codominant) role (especially along the upper stream sections, in wet or seepage sites). *Alnus incana* is generally missing; there are only two records of this species in the area. The "Loipersbach – Herrentisch" occurrence is probably located in the Aubach valley, while the "NNW Deutschkreutz" in one of the alder woods at the south-eastern foot of Sopron Hills (see Király et al. 2004).

The quasi natural stands of the Sopron Hills alder woods are very diverse and also show significant variability in terms of structure and species composition. The differentiation of the wood types is mostly determined by their vertical location, the morphological characteristics of the valley floor, the depth of the stream bed and water availability but earlier land use practices (meadow management, forest usage, etc.) also seems to have a major influence.

Depending on the background variables the different types of riparian forests are often alternately positioned along the longitudinal axis of a valley.

The coenological characteristics of the riparian forests are defined by the species of mesophilic deciduous forests (*Fagetalia*) and riparian forests (*Alnion incanae*) but in sites with stagnant water some species of swamp forests (*Alnetea glutinosae*) and wet meadows (*Molinetalia*) also appear. According to the prior field studies the proportion of the coenological species groups within the stands (both with regard to species composition and cover) changes mainly depending on the water supply.

Alder woods have a considerable spring aspect, except for the stands nearing swamp state. The most frequent species include *Adoxa moschatellina, Anemone ranunculoides, Anemone nemorosa, Chrysosplenium alternifolium, Ranunculus ficaria, Lathraea squamaria* while *Allium ursinum, Corydalis cava, Dentaria enneaphyllos, Isopyrum thalictroides* occur less often.

The alder woods with an upper-course character are important sites of the montane plant species of Sopron Hills. *Pleurospermum austriacum* used to grow on the edge of a riparian alder wood and *Antriscus nitida, Doronicum austriacum, Equisetum sylvaticum, Gentiana asclepiadea, Lysimachia nemorum, Petasites albus* also partly or entirely occur in such woods (Király et al. 2004, Szmorad 2008). The occurrence of numerous montane moss species can also be linked to upper-course riparian alder forests; the mosses of the spruce zone (typical of the *Vaccinio-Piceetalia* order) occur in almost every case in these stands (see Szövényi et al. 2001).

The sites of these riparian alder stands provide favourable conditions for the spreading of several invasive species. The most notable ones are *Fallopia japonica* (mainly in Austrian valleys), *Telekia speciosa* (Hidegvíz-völgy), and *Impatiens glandulifera* (mainly at foothill stream sections) (see Király et al. 2004). The presence of invasive plants in the inner hill regions is mainly related to settlements and wildlife management facilities (feeding sites).

5.2 Results of the numerical analysis

The cluster analyses of the coenological data show 3 markedly different groups of samples. Here only the dendrogram made with log2 standardization is presented *(Figure 1.)* but the results were very similar when using binary data or log10 standardization.

The first group of the dendrogram (A) contains the relevés of the moderately swampy alder forests with the dominance of *Carex acutiformis* and *Caltha palustris* and the presence of *Cardamine amara*, *Crepis paludosa*, *Lycopus europaeus* and further species typical to sites with stagnant water.

The second group (B) includes relevés of the mixed ash-alder woods occurring in sites with seepage water and springs along upper and middle stream sections. In these samples (similarly to the previous group) *Fraxinus excelsior* sometimes plays a codominant role while *Caltha palustris, Carex brizoides, Carex pendula, Equisetum telmateia, Impatiens noli-tangere* and *Petasites albus* can reach significant cover in the herb layer.

The third group (C) is more distinct from the others, it is partly moderately disturbed, partly shows characteristics of mesophilic deciduous forests and is mixed with hornbeam. In the relevés assigned to this category (mainly at middle and lower stream sections) *Carpinus betulus, Salix fragilis* and *Tilia cordata* play a major role in the canopy layer, while *Sambucus nigra* and *Corylus avellana* do so in the shrub layer. The dominant species of the herb layer are *Aegopodium podagraria, Carex brizoides* and *Galeobdolon montanum.*

The scattergram of the PCA does not show spectacular groupings among the records due to the compositional variability of the alder forests. However if the 3 groups of the cluster analysis are projected unto the scattergram, the arrangement of the groups becomes apparent *(Figure 2).*

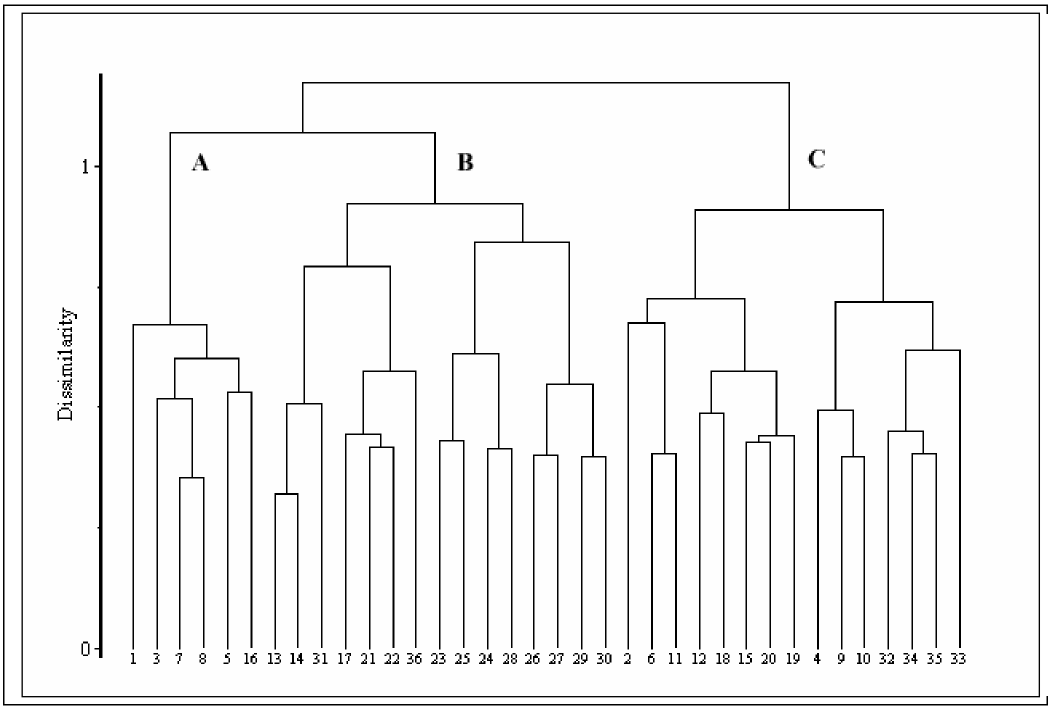

Figure 1. Dendrogram of the relevés (base data: logarithmic standardization, base 2, method: Beta-flexible, coefficient: Bray – Curtis index). (A) swampy alder forests, (B) riparian ash-alder forests, (C) riparian hornbeam-alder forests. Own relevés: 1–30, CSAPODY's (1959–1966) relevés: 31–36.

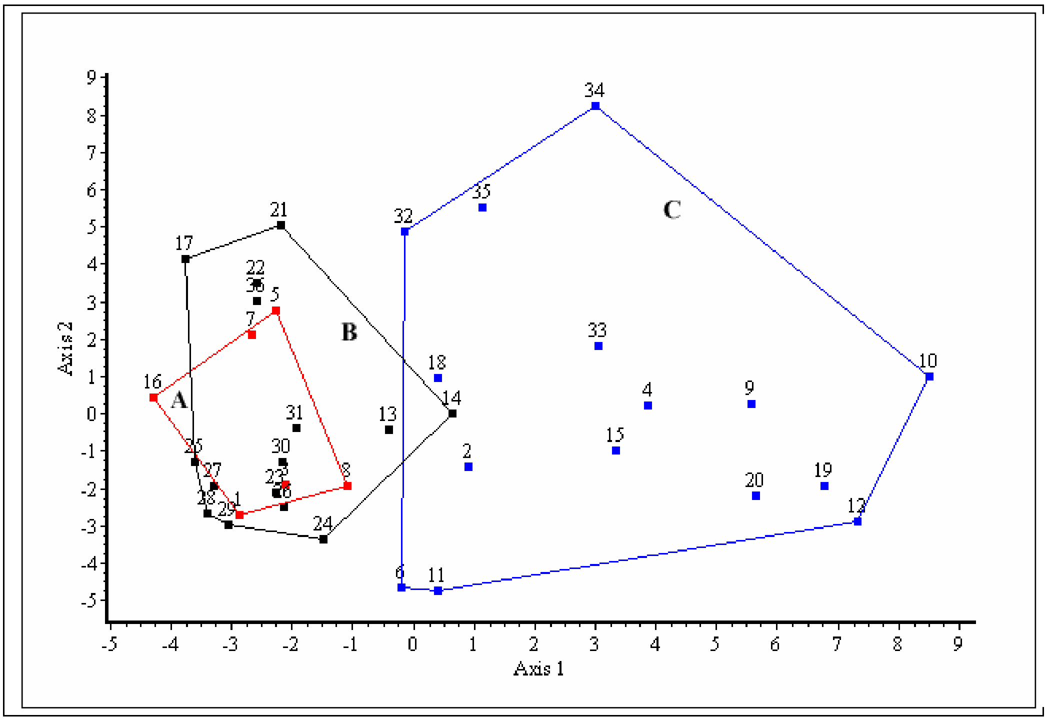

Figure 2. Scattergram of the relevés (centered principal components analysis, partitions according to Fig. 1). (A) swampy alder forests, (B) riparian ash-alder forests, (C) riparian hornbeam-alder forests. Own relevés: 1–30, CSAPODY's (1959–1966) relevés: 31–36

Group (C) (mixed with hornbeam) on the right side of the point cloud is relatively well separated from the other two groups, which are defined by stagnant or seeping waters, whereas the ordination diagram shows higher floristic similarity between groups (A) and (B).

In the TWINSPAN analysis the first division of the 36 relevés brought a differentiation of the types showing mesophilic characteristics (1) and those more defined by water (0). At the second division the difference between the two groups of hornbeam-mixed alder stands (1) was hardly detectable; in both units (11, 10) mainly the *Aegopodium podagraria*, *Carex brizoides*, *Galeobdolon montanum* és *Impatiens noli-tangere* dominance-type relevés were included (therefore the two groups should form a single coenological unit). The second division of the stands more defined by hydrological conditions (0) resulted in a further differentiation of slightly swampy alder stands characterized with stagnant water and the dominance of *Caltha palustris, Carex acutiformis, Carex brizoides* (01) and mixed ash-alder stands with seepage water occurring along upper-course streams, dominated by *Caltha palustris, Carex pendula, Impatiens noli-tangere* or *Petasites albus (00).*

As a conclusion of the analysis of the 36 coenological relevés, accepting the arrangement resulting from the TWINSPAN analysis, the final classification contains 3 categories: swampy alder forests (a), riparian ash-alder forests (b), riparian hornbeam-alder forests (c). The 3 groups can be identified as association-rank coenological units and related to forest associations described earlier. Their differentiation is presented with the list of diagnostic species, including fidelity and constancy values *(Table 1.).*

5.3 Description of the riparian alder forests

5.3.1 Swampy alder forests

(*Angelico sylvestris – Alnetum glutinosae* Borhidi in Borhidi & Kevey 1996)

Occurrence, site. This is a rare riparian alder forest type of the lower and middle stream sections. Its stands are small compared to the other two types and only appear in short sections between the mixed ash-alder woods and the mesophilic alder stands. It usually occurs where the valley floor widens, the stream bed is shallow and flow velocity is low. Water from temporary flooding usually remains longer, the site is characterized with shallow stagnant water patches (from ecological point of view the site is somewhere between riparian forests and swamp forests). The soils are colluvial forest soils showing swamp characteristics. Besides the primary forests some secondary stands also occur, mainly due to road constructions or blocked culverts.

Structure and species composition. Canopy is loose, and its dominant species is *Alnus glutinosa*. Other tree species are rare, only *Fraxinus excelsior* may reach a higher cover. The shrub layer is sparse; its only characteristic species is *Viburnum opulus*. The dominance of *Carex acutiformis* and *Carex brizoides* prevails in the herb layer but certain other taxa, typical of sites with stagnant water (*Caltha palustris, Cardamine amara, Carex paniculata, Crepis paludosa, Lycopus europaeus, Solanum dulcamara, Veronica beccabunga*), also influence the attributes of the stands. *Fagetalia* species only play a minor role but their presence emphasizes the transitional riparian-swamp forest coenological character typical of the region.

Constant-subconstant species: *Alnus glutinosa* [A] 100; *Acer pseudo-platanus* [BC] 86, *Euonymus europaeus* [BC] 86, *Fraxinus excelsior* [BC] 86, *Alnus glutinosa* [BC] 71, *Rubus fruticosus* agg. [BC] 71, *Viburnum opulus* [BC] 71; *Aegopodium podagraria* [C] 100, *Stachys sylvatica* [C] 100, *Dryopteris carthusiana* [C] 86, *Equisetum arvense* [C] 86, *Impatiens noli-tangere* [C] 86, *Urtica dioica* [C] 86, *Athyrium filix-femina* [C] 71, *Cardamine amara* [C] 71, *Carex remota* [C] 71, *Circaea lutetiana* [C] 71, *Ranunculus ficaria* [C] 71, *Galeobdolon montanum* [C] 71, *Ranunculus repens* [C] 71; *Hypnum cupressiforme* [D] 100, *Eurhynchium hians* [D] 71, *Plagiomnium undulatum* [D] 71

Table 1. *Synoptic table of fidelity and contancy based on 36 relevés from riparian alder forests. Determination of diagnostic species: with the use of Phi koefficient (Φ = 0.30) and Fischer's exact test (P < 0.05). Vegetation types: (a) swampy alder forests (Angelico sylvestris – Alnetum glutinosae Borhidi in Borhidi & Kevey 1996), (b) riparian ash-alder forests (Carici remotae – Fraxinetum Koch ex Faber 1936), (c) riparian hornbeam-alder forests (Aegopodio – Alnetum glutinosae V. Kárpáti & I. Kárpáti & Jurko ex Šomšák 1961). Layers: A = canopy layer, BC = shrub and herb layer, C = herb layer, D = moss layer. Asterisks (*) before species names indicate taxa with uncertain diagnostic value.*

Vegetation types		(a)	(b)	(c)	(a)	(b)	(c)
Number of relevés		7	11	18	7	11	18
Species	Layer	Phi coefficient (× 100)			Constancy (%)		
Filipendula ulmaria	C	92.2	---	---	100	0	11
Lycopus europaeus	C	89.9	---	---	100	9	6
Carex paniculata	C	79.1	---	---	71	0	0
Crepis paludosa	C	68.9	---	---	86	18	11
Lysimachia vulgaris	C	58.8	---	---	86	36	11
Dryopteris expansa	C	58.0	---	---	71	27	0
Cirsium rivulare	C	57.7	---	---	43	0	0
Plagiomnium ellipticum	D	57.7	---	---	43	0	0
Carex acutiformis	C	53.2	---	---	71	18	17
Veronica beccabunga	C	52.3	---	---	71	36	0
Brachythecium mildeanum	D	51.4	---	---	43	0	6
Equisetum sylvaticum	C	45.9	---	---	29	0	0
* *Glechoma hederacea*	C	45.8	---	---	43	0	11
Solanum dulcamara	C	44.0	---	---	71	45	6
Dryopteris dilatata	C	43.8	---	---	71	18	33
Caltha palustris	C	43.7	---	---	100	73	44
* *Fagus sylvatica*	BC	42.9	---	---	57	9	22
Juncus effusus	C	42.6	---	---	43	9	6
Valeriana dioica	C	42.6	---	---	43	9	6
Plagiothecium denticulatum	D	40.1	---	---	71	36	22
Rumex sanguineus	C	---	52.5	---	0	36	0
Senecio ovatus	C	---	52.5	---	0	36	0
Paris quadrifolia	C	---	48.0	---	29	82	33
Carex pendula	C	---	46.5	---	43	82	22
* *Carex pilosa*	C	---	45.7	---	0	36	6
* *Atrichum undulatum*	D	---	45.3	---	57	100	56
Petasites albus	C	---	44.6	---	14	55	11
* *Herzogiella seligeri*	D	---	42.4	---	57	82	17
* *Rubus fruticosus agg.*	BC	---	40.1	---	71	100	56
Tetraphis pellucida	D	---	38.7	---	29	55	6
* *Cardamine amara*	C	---	38.1	---	71	91	33
* *Carex sylvatica*	C	---	37.2	---	57	91	50
Circaea lutetiana	C	---	31.3	---	71	91	50
Stellaria holostea	C	---	---	67.1	29	18	94
Salix fragilis	A	---	---	63.2	0	0	50
Galium aparine	C	---	---	53.2	29	36	89
Amblystegium serpens	D	---	---	50.0	0	0	33
Knautia drymeia	C	---	---	49.1	0	9	44
Malus sylvestris	BC	---	---	45.2	0	0	28
Cardamine enneaphyllos	C	---	---	45.2	0	0	28
Corylus avellana	BC	---	---	43.4	29	73	94
Symphytum tuberosum	C	---	---	43.2	0	36	61
Mercurialis perennis	C	---	---	42.0	14	9	50
Sambucus nigra	BC	---	---	41.4	43	36	83
Carpinus betulus	BC	---	---	38.4	29	45	78
Geum urbanum	C	---	---	37.3	43	45	83
Moehringia trinervia	C	---	---	37.1	29	18	61
Brachythecium velutinum	D	---	---	35.0	14	27	56
Rubus caesius	BC	---	---	31.8	57	9	67

Dominant species: *Alnus glutinosa* [A] 86, *Fraxinus excelsior* [A] 14; *Carex acutiformis* [C] 29, *Carex brizoides* [C] 29

Syntaxonomy, nomenclature. Swampy alder forests appear in the Hungarian coenological literature as 'alder marsh forests', formerly under the name *Carici acutiformis – Alnetum* Soó 1963 then recently as *Angelico sylvestris – Alnetum glutinosae* Borhidi in Borhidi & Kevey 1996. Due to its transitional nature, the coenotaxonomical position of the association has changed; earlier Soó (1963) assigned them to the riparian forests, whereas recently Borhidi (1984), Borhidi – Kevey (1996) and Kevey (2008) to the swamp forests (*Alnetea glutinosae*). Austrian literature mentions similar stands also among alder swamp forests, however, the forests earlier described as *Carici acutiformis – Alnetum* Scamoni 1935 are more recently considered part of the disputably broad association *Carici elongatae – Alnetum glutinosae* Koch et Tx. 1931 s.l. (Willner 2007).

Phytogeographical relationships. The transitional swampy alder forests have been mainly reported from the widening stream valleys of the Transdanubian part of the Pannonian region so far, but similar stands also occur in the Szigetköz area (Kevey 2008). The association has been only known from a few uncertain hints (Soó 1963) in the Sopron area. This association becomes rare the closer we get to the Alps, further occurrences may be expected towards the Vienna and Graz Basins. Wallnöfer et al. (1993) mention similar riparian stands from Karinthia.

5.3.2 Riparian ash-alder forests

(*Carici remotae – Fraxinetum* Koch ex Faber 1936)

Occurrence, site. It is a forest type prevalent mainly in the inner Sopron Hills area, along the upper and middle sections of streams in the vicinity of springs and seepage water. The valley floor is usually narrow therefore the stands are usually only 15–20 m wide. The stream bed is shallow, the site is basically defined by the water seeping from the alluvial sediments, but smaller swamp-like patches can also be found (especially near adjacent spring vegetation). The valley floors are flooded for a short time several times a year (after spring thaw or heavy rainfalls). Poor, thoroughly wet alluvial (sometimes even gleyish) soils predominate consisting of rough debris and stilt.

Structure and species composition. In the canopy layer of the relatively closed stands *Alnus glutinosa* is the dominant species, but *Acer pseudoplatanus* and *Fraxinus excelsior* are also common (sometimes even codominant). The shrub layer cover is insignificant (no typical shrub species) whereas the diverse herb layer can be characterized mainly with meso- and hygrophilic species (*Caltha palustris, Carex pendula, Equisetum telmateia, Impatiens noli-tangere, Petasites albus*). The montane character of the stands is emphasized by the sporadic emergence of some montane species (*Doronicum austriacum, Gentiana asclepiadea, Lysimachia nemorum, Veronica montana, Stellaria alsine*) and the presence of the spruce-zone mosses.

Constant-subconstant species: *Alnus glutinosa* [A] 100; *Acer pseudo-platanus* [BC] 73, *Corylus avellana* [BC] 73, *Fraxinus excelsior* [BC] 73, *Alnus glutinosa* [BC] 64, *Euonymus europaeus* [BC] 64; *Stachys sylvatica* [C] 100, *Galeobdolon montanum* [C] 91, *Carex remota* [C] 82, *Dryopteris carthusiana* [C] 82, *Pulmonaria officinalis* agg. [C] 82, *Aegopodium podagraria* [C] 73, *Athyrium filix-femina* [C] 73, *Caltha palustris* [C] 73, *Dryopteris filix-mas* [C] 73, *Ranunculus repens* [C] 73, *Impatiens noli-tangere* [C] 64, *Milium effusum* [C] 64, *Oxalis acetosella* [C] 64, *Ranunculus lanuginosus* [C] 64; *Hypnum cupressiforme* [D] 100, *Rhizomnium punctatum* [D] 73, *Plagiomnium undulatum* [D] 64, *Brachythecium rivulare* [D] 64

Dominant species: *Alnus glutinosa* [A] 82; *Caltha palustris* [C] 9, *Impatiens noli-tangere* [C] 9, *Petasites albus* [C] 9

Syntaxonomy, nomenclature. The alder forests of the Sopron Hills that show montane characteristics were previously described under the name *Alnetum glutinosae – incanae* Br.-Bl. 1915 (Soó 1963, Soó et al. 1969) in Hungarian literature, later as *Carici brizoidis – Alnetum* I. Horvat 1938 em. Oberd. 1953 (Borhidi – Kevey 1996, Kevey 2008). The occurrences of the riparian ash-alder woods also showing montane characteristics (*Carici remotae – Fraxinetum* Koch ex Faber 1936) presented an unresolved issue (Kevey 2008). The similarly situated forests with alike floristic composition are uniformly classified as *Carici remotae – Fraxinetum* Koch ex Faber 1936 (see Wallnöfer et al. 1993, Willner et al. 2002, Willner 2007) in Austria. With regard to the Central European literature the latter name should be used in the case of the Sopron Hills stands.

Phytogeographical relationships. Similar riparian alder woods have been described in several places in the Alp-Pannonian border region. The coenological relevés representing the nearest similar stands were published from the Vienna Forest (see Wallnöfer et al. 1993) and the Leitha Hills (Hübl 1959, Karrer – Kilian 1990) but the riparian alder woods of the higher areas of the Kőszeg Hills (Szmorad 1994) and the neighbouring Rosalia Hills (Szmorad ined.) can also partly be assigned to this group. Besides the stands in the Sopron Hills, in Hungary this association type was only described in the Bakony area (Soó – Zólyomi 1951).

5.3.3 Riparian hornbeam-alder forests

(*Aegopodio – Alnetum glutinosae* V. Kárpáti & I. Kárpáti & Jurko ex Šomšák 1961)

Occurence, site. This riparian alder forest type is prevalent along the middle sections of the stream valleys and the lower sections reaching the outer rim of the hills, adjacent to the former pedunculate oak-hornbeam stands of the surrounding basins. The valley floor in these places is usually wider (up to 30–50 m), so more extensive stands can form (e.g. the lower section of the Aubach). The streams are fast and their bed deeply cut into the alluvium. Site conditions are less defined by the surface or sub-surface waters (either stagnant or flowing) rather by the groundwater in the alluvial sediments. Conditions can change only temporarily and to a small scale after thaw or rainfall. The soils are better developed and structured colluvial forest soils.

Structure and species composition. The stands are strongly structured vertically including both the canopy and the shrub layers. In the relatively closed canopy layer *Alnus glutinosa* predominates but there are several other species (*Acer psudoplatanus, Acer campestre, Carpinus betulus, Fraxinus excelsior, Tilia cordata, Salix fragilis, Ulmus glabra*) present, as well. In addition *Padus avium* sporadically appears in the lower canopy layer. The most important components of the shrub layer are *Cornus sanguinea, Corylus avellana, Euonymus europaeus, Sambucus nigra* but in some stands the role of *Rubus caesius* and *Rubus fruticosus* agg. can become more substantial. *Ribes rubrum* and *Viburnum opulus* also frequently appear in the lower shrub layer. Due to the moderate hydrological influence the species of the mesophilic deciduous forests (*Aegopodium podagraria, Galeobdolon montanum, Mercurialis perennis, Oxalis acetosella,* etc.) play a major role in the herb layer, while the importance of hygrophilic and meso-hygrophilic species decreases.

Constant-subconstant species: *Alnus glutinosa* [A] 100; *Euonymus europaeus* [BC] 83, *Acer pseudo-platanus* [BC] 78, *Alnus glutinosa* [BC] 67; *Aegopodium podagraria* [C] 89, *Galeobdolon montanum* [C] 83, *Urtica dioica* [C] 83, *Oxalis acetosella* [C] 78, *Pulmonaria officinalis* agg. [C] 72, *Athyrium filix-femina* [C] 67, *Ranunculus ficaria* [C] 67, *Impatiens noli-tangere* [C] 67, *Milium effusum* [C] 67, *Polygonatum multiflorum* [C] 67, *Dryopteris carthusiana* [C] 61; *Hypnum cupressiforme* [D] 78

Dominant species: *Alnus glutinosa* [A] 72; *Corylus avellana* [BC] 6; *Carex brizoides* [C] 22, *Aegopodium podagraria* [C] 17, *Allium ursinum* [C] 6, *Impatiens noli-tangere* [C] 6

Syntaxonomy, nomenclature. In the Hungarian syntaxonomical system (see Soó 1963, Borhidi – Kevey 1996) the riparian alder forests rich in mesophilic deciduous species ('mixed hornbeam-alder woods') can be identified with the association described under the name *Aegopodio – Alnetum glutinosae* V. Kárpáti & I. Kárpáti & Jurko ex Šomšák 1961. Of the forest associations described in Austria the *Pruno-Fraxinetum* Oberd. 1953, found in hilly or lowland regions, can be considered closest to these stands (Wallnöfer et al. 1993, Willner 2007) although these are doubtless a type showing a transition towards lowland riparian forests (*Ulmenion*) and as such are surely missing from the Sopron Hills. In order to specify the relationship between these types (*Aegopodio – Alnetum glutinosae* and *Pruno – Fraxinetum*) further investigations based on more extensive data (from larger areas) are needed.

Phytogeographical relationships. Similar stands can be found in the southern areas of Slovakia (Michalko 1987), and many regions of the Hungarian Mountains and Western Transdanubia. The similar stands with *Aremonio – Fagion* elements in Southern Transdanubia, are described under the name *Carici pendulae - Alnetum glutinosae* (Kevey 2008). In the vicinity of the study area such stands can be found in the Fertő hill regions (Kevey 2008) and the Kabold-Füles hill regions (Szmorad ined.) but the alder woods in the foothills of the Kőszeg Hills (see Szmorad 1994) can also be assigned to this type.

6 CONCLUSIONS

One of the most important results of the analysis is the presence of montane mixed ash-alder forests (*Carici remotae-Fraxinetum* Koch ex Faber 1936) showing the influence of the Alps is verified. These riparian forests related to springs and seepage water sites are described in the botanical literature from Western and Central Europe (Neuhäuslová-Novotná 1977, Douda 2008), and the edge of Northern Europe from Ireland (Kelly – Iremonger 1997) to Lithuania (Prieditis 1997). They always appear under Atlantic and sub-Atlantic climate influences and despite the similarities of the sites and the coenological characteristics they form differentiating and distinguishable associations within a large distribution area (Oberdorfer 1992).

Carici remotae – Fraxinetum forests (strictly speaking) were most intensively studied in Austria (Willner et al. 2002, Willner 2007), the Czech Republic (Neuhäuslová-Novotná 1977, Douda 2008) and Slovakia (Michalko 1987). The differential species (*Carex remota, Carex pendula, Chrysosplenium alternifolium, Equisetum telmateia, Lysimachia nemorum, Valeriana dioica, Veronica montana*) defined for the Austrian stands (see Willner 2007) are also characteristic of the mixed ash-alder stands of the Sopron Hills and the occurrences of some montane species in the region are also related to this type of riparian alder woods.

Most of the stands classified as mixed ash-alder forests have been described under the name *Carici brizoidis – Alnetum* I. Horvat 1938 em. Oberd. 1953 in the Hungarian literature. However, this name is not used for any alder wood associations in any coenological monographs published in Austria, the Czech Republic and Slovakia; therefore due to the great similarities (see Borhidi 2003) these two units mostly correspond in the Alpokalja region (the case of the higher-altitude alder woods of the Hungarian Mountains needs to be further investigated).

Concerning the riparian alder woods dominated by *Carex brizoides* it has to be noted that their stands are mostly secondary, formed by the reforestation of former meadows. All examined relevés from the Sopron Hills that could be assigned to this type came from sites of former meadows and similar cases were recorded in other Central European areas (Neuhäuslová-Novotná 1977). On the other hand, stands with *Carex brizoides* dominance cannot be uniformly assigned to any single alder wood type. Their floristic composition differs corresponding to their site; in most cases they can be classified as either swampy alder forests or mixed hornbeam-alder forests.

The two other associations are mainly typical to the Pannonian Basin; their role and extent diminishes towards the west. Narrow mountain valleys are not favourable for swampy alder forests while the mixed hornbeam-alder stands common in hills and lower mountains (described from Austria for the first time in this paper) are replaced by alder forests with *Alnus incana* dominance in higher grounds of the inner Alps (*Equiseto – Alnetum incanae* Moor 1958) (Willner 2007). This spatial pattern of the associations can also be observed in other regions of the Alpokalja area e.g. in the Kőszeg Hills.

The coenotaxonomical position of the studied riparian alder forest associations is similarly viewed in recent Austrian and Hungarian works (Willner 2007, Kevey 2008). The transitional swampy alder forests (*Angelico sylvestris – Alnetum glutinosae)* are assigned to the alder swamp woods (class: *Alnetea glutinosae*, order: *Alnetalia glutinosae,* alliance: *Alnion glutinosae*), while the mixed riparian ash-alder and hornbeam-alder forests to the riparian alder woods (class: *Querco-Fagetea*, order: *Fagetalia sylvaticae*, alliance: *Alnion incanae*). Although the interpretation of these syntaxa is slightly different in the two countries there are no open issues concerning the classification of the alder woods of the Alpokalja region.

Acknowledgements: The author thanks Dr. Dénes Bartha, Dr. Balázs Kevey and Dr. Gergely Király for their help in the research, in reviewing the literature and also for their valuable comments on the draft. Special thanks to Eszter Tanács and Zsuzsa Tolnay for the translation.

REFERENCES

BARANYAI-NAGY A. – BARANYAI ZS. (2008): Tájtörténeti kutatás a Soproni-hegység patakmenti területein a XVIII. század végétől napjainkig. [Landscape historical research along the streams of Sopron Hills from the end of the 18th century until nowadays.] Kitaibelia 13(1): 144. (in Hungarian)

BORHIDI A. (1984): A Zselic erdei. [The forests of Zselic.] Dunántúli Dolgozatok (A) Természettudományi Sorozat 4: 1–145. + 1 térkép (in Hungarian with English summary)

BORHIDI, A. – KEVEY, B. (1996): An annoted checklist of the Hungarian plant communities II. In: Borhidi A. (ed.): Critical revision of the Hungarian plant communities. Janus Pannonius University, Pécs. 95-138.

BRAUN-BLANQUET, J. (1951): Pflanzensoziologie (2. Aufl.). Springer Verlag, Wien. 631. p.

CHYTRÝ, M. – TICHÝ, L. – HOLT, J. – BOTTA-DUKÁT, Z. (2002): Determination of diagnostic species with statistical fidelity measures. Journal of Vegetation Sciences 13: 79-90.

CSAPODY I. (1959-1966): Kéziratos terepnaplók I-VIII. [Unpublished field notes I-VIII.] NYME Növénytani és Természetvédelmi Intézet, Sopron. (in Hungarian)

CSAPODY, I. (1964): Die Waldgesellschaften des Soproner Berglandes. Acta Botanica Hungarica 10: 43-85. + XI. Tabellen

CSAPODY I. – NEUWIRTH J. (1963): Soproni-hegyvidék. 47. sz. erdőgazdasági táj. [Sopron Hills. Forest region 47.] In: Danszky I. (szerk.): Magyarország erdőgazdasági tájainak erdőfelújítási, erdőtelepítési irányelvei és eljárásai I. [Principles and methods of regeneration and afforestation of forest regions of Hungary I.] Országos Erdészeti Főigazgatóság, Budapest. 519–577. (in Hungarian)

CSAPODY I. – GYETVAI GY. – PALLAY M. – TAKÁCS Z. (1964): A Soproni-hegység vegetációtérképe. [Vegetation map of the Sopron Hills.] – Erdőrendezőség, Szombathely. 2 térképlap (in Hungarian)

DOUDA, J. (2008): Formalized classification of the vegetation of alder carr and floodplain forests in Czech Rebuplic. Preslia 80: 199–224.

DRAGANITS, E. (1996): Kristallingeologische Neubearbeitung des südlichen Ödenburger Gebirges, Burgenland (Österreich). Diplomarbeit, Universität Wien. 151 p. + 3 Anhänge

ERZBERGER, P. – PAPP, B. (2004): Annotated checklist of Hungarian bryophytes. Studia Botanica Hungarica 35: 91–150.

FUCHS, W. – GRILL, R. (1984): Geologische Karte von Wien und Umgebung (1:200.000). Geologische Bundesanstalt, Wien. 1 Blatt

GOMBOCZ E. (1906): Sopron vármegye növényföldrajza és flórája. [The phytogeography and flora of Sopron county.] Mathematikai és Természettudományi Közlemények 28(4): 401–579. (in Hungarian)

HILL, M.O. (1979): TWINSPAN – a Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University, Ithaca, New York. 48 p.

HÜBL, E. (1959): Die Wälder des Leithagebirges. Eine vegetationkundliche Studie. Verhandlungen der Zoologisch-Botanishen Gesellschaft in Wien 98–99: 96–167.

KÁRPÁTI L. (1955): Adatok Sopron környékének geomorfológiájához. [Zur Geomorphologie der Umgebung von Sopron.] Földrajzi Értesítő 4: 21–40. (in Hungarian with German summary)

KÁRPÁTI, Z. (1956): Die Florengrenzen in der Umgebung von Sopron und Florendistrikt Laitaicum. Acta Botanica Hungarica 2: 281–307.

KARRER, G. – KILIAN, W. (1990): Standorte und Waldgesellschaften im Leithagebirge. Revier Sommerein. Mitteilungen der Forstliche Bundesversuchsanstalt 165: 1–224.

KELLY, D.L. – IREMONGER, S.F. (1997): Irish wetland woods: the plant communities and their ecology. Biology and Environment 97(1): 1–32.

KEVEY B. (2008): Magyarország erdőtársulásai. [Forest communities of Hungary.] Tilia 14: 1–488. (in Hungarian with English summary)

KIRÁLY G. (2004): Természetföldrajzi áttekintés. [Geographische Übersicht.] In: Király G. (szerk.): A Soproni-hegység edényes flórája. [Die Gefäßpflanzenflora des Ödenburger Gebirges.] Flora Pannonica 2(1): 7–12. (in Hungarian with German summary)

KIRÁLY G. – SZMORAD F. (2004a): A Soproni-hegység vegetációja. [Die Vegetation des Ödenburger Gebirges.] In: Király G. (szerk.): A Soproni-hegység edényes flórája. [Die Gefäßpflanzenflora des Ödenburger Gebirges.] Flora Pannonica 2(1): 13–17. (in Hungarian with German summary)

KIRÁLY G. – SZMORAD F. (2004b): A Soproni-hegység növényföldrajzi viszonyai. [Die pflanzengeographischen Verhältnisse des Ödenburger Gebirges.] In: Király G. (szerk.): A Soproni-hegység edényes flórája. [Die Gefäßpflanzenflora des Ödenburger Gebirges.] Flora Pannonica 2(1): 22–36. (in Hungarian with German summary)

KIRÁLY G. – CSAPODY I. – SZMORAD F. – TÍMÁR G. (2004): A Soproni-hegység edényes flórájának enumerációja. [Enumeration der Gefäßpflanzenflora des Ödenburger Gebirges.] In: Király G. (szerk.): A Soproni-hegység edényes flórája. [Die Gefäßpflanzenflora des Ödenburger Gebirges.] Flora Pannonica 2(1): 91–466. (in Hungarian with German summary)

KÜPPER, H. (Hrsg.) (1957): Erläuterungen zur geologischen Karte Mattersburg – Deutschkreutz (1:50000). Geologische Bundesanstalt, Wien. 80 p.

MICHALKO, J. (ed.) (1987): Geobotanical map of C.S.S.R. VEDA, Bratislava. 168 p. + 12 maps

NEUHÄUSLOVÁ-NOVOTNÁ, Z. (1977): Beitrag zur Kenntnis des *Carici remotae-Fraxinetum* in der Tschechischen Sozialistischen Republik. Folia Geobotanica et Phytotaxonomica 12(3): 225–243.

OBERDORFER, E. (Hrsg.) (1992): Süddeutsche Pflanzengesellschaften IV. A. Textband (2. Aufl.) Gustav Fischer Verlag, Jena, Stuttgart, New York. 282 p.

ORLÓCI L. – TUSKÓ J. (1955): A Soproni hegyvidék fenyvesítésének eredményeiből. [Die Ergebnisse der Aufforstung des Soproner Gerbirgsgeländes mit Nadelholzarten.] Erdőmérnöki Főiskola Közleményei 41–52. (in Hungarian with German summary)

PODANI, J. (2001): SYN-TAX 2000. Computer program for data analysis in ecology and systematics. User's manual. Scientia Publishing, Budapest. 53 p.

PRIEDITIS, N. (1997): Vegetation of wetland forests of Latvia: A synopsis. Annales Botanici Fennici 34: 91–108.

SOÓ R. (1941): Növényszövetkezetek Sopron környékéről. [Pflanzengesellschaften aus der Umgebung von Sopron.] Acta Geobotanica Hungarica 4: 3–34. (in Hungarian with German summary)

SOÓ, R. (1963): Systematische Übersicht der pannonischen Pfanzengesellschaften VI. Die Gebirgswälder II. Acta Botanica Academiae Scientiarum Hungaricae 9: 123–150.

SOÓ R. – ZÓLYOMI B. (1951): A magyarországi növénytársulások rendszeres áttekintése. [Systematic overview of the Hungarian plant communities.] In: Soó R. – Zólyomi B. (szerk.): Növényföldrajzi-térképezési tanfolyam jegyzete. [Handbook of the phytogeographical-mapping course.] OTTM Vácrátóti Botanikai Kutatóintézet és Növénytár, Budapest. 131–156. (in Hungarian)

SOÓ, R. – BORHIDI, A. – CSAPODY, I. – KOVÁCS, M. – PÓCS, T. (1963): Die Wälder und Wiesen West- und Südtransdanubiens und ihre Böden. Acta Botanica Academiae Scientiarum Hungaricae 15: 137–165.

SZMORAD F. (1994): A Kőszegi-hegység erdőtársulásai. [Forest communities of the Kőszeg Hills.] In: Bartha D. (szerk.): A Kőszegi-hegység vegetációja I–II. [The vegetation of the Kőszeg Hills I–II.] Saját kiadás, Kőszeg-Sopron. 106–132. +XI. tabella + 2 térkép (in Hungarian)

SZMORAD, F. (2008): Ergänzungen zur Gefäßpflanzenflora des Ödenburger Gebirges. Flora Pannonica 6: 89–115.

SZMORAD F. (2010): A Soproni-hegység erdeinek történeti, növényföldrajzi és cönológiai vizsgálata. [The historical, phytogeographical and coenological investigations on the forest of the Sopron Hills.] PhD dissertation in manuscript, Pécsi Tudományegyetem Biológia Doktori Iskola, Pécs. 128 pp. + 20 melléklet + V. tabella (in Hungarian with English summary)

SZÖVÉNYI P. – GALAMBOS I. – HOCK ZS. (2001): A Soproni-hegység mohaflórája. [The moss flora of the Sopron Hills.] Tilia 10: 5–180. (in Hungarian)

TICHÝ, L. (2002): JUICE, software for vegetation classification. Journal of Vegation Sciences 13: 451–453.

TICHÝ, L. – HOLT, J. (2006): JUICE program for management, analysis and classification of ecological data. Program manual. Masaryk University, Brno. 103 p.

VENDL, M. (1929): Die Geologie der Umgebung von Sopron I. Die kristallinen Schiefer. Bányamérnöki és Erdőmérnöki Főiskola Bányászati és Kohászati Osztályának Közleményei 225–291. + 1 Beilage

VENDL, M. (1930): Die Geologie der Umgebung von Sopron II. Die Sedimentsgesteine des Neogen und des Quartär. Erdészeti Kísérletek 32(1): 157–236., 32(2): 355–437. + 2 Beilagen

WALLNÖFER, S. – MUCINA, L. – GRASS, V. (1993): *Querco-Fagetea*. In: Mucina, L. – Grabherr, G. – Wallnöfer, S. (Hrsg.): Die Pflanzengesellschaften Österreichs III. Gustav Fischer Verlag, Jena, Stuttgart, New York. 85–236.

WILLNER, W. (2007): *Fagion sylvaticae* Luquet 1926. In: Willner, W. – Grabherr, G. (Hrsg.): Wälder und Gebüsche Österreichs. Spektrum Akademischer Verlag, München. 144–166.

WILLNER, W. – KARNER, P. – GRABHERR, K. (2002): Zur Syntaxonomie des eschenreichen Wälder in Österreich. In: Bericht über das 10. Österreiches Botanikentreffen, Irdning, 30. Mai – 1. Juni 2002. 99–102.