

## ***Festuco-Brometea* communities of the Transylvanian Plateau (Romania) – a preliminary overview on syntaxonomy, ecology, and biodiversity**

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### **Abstract**

The Transylvanian Plateau in Romania is well known to host large areas of a variety of dry grassland types, still traditionally managed by low-intensity mowing or grazing. While this natural heritage is now under threat from changes in agricultural practices, the diversity of Transylvanian dry grasslands is still little understood. There is a lack of both field data sampled with standardised methods and a syntaxonomic treatment with modern statistical methods and supra-regional perspective. Therefore, the *European Dry Grassland Group* (EDGG) carried out its first international Research Expedition in Transylvania 2009 to study syntaxonomy, vegetation-environment relationships, and biodiversity patterns of these communities. In various locations across Transylvania, we sampled 10-m<sup>2</sup> vegetation plots ( $n = 82$ ) and nested-plot series from 0.0001 m<sup>2</sup> to 100 m<sup>2</sup> ( $n = 20$ ), including all vascular plant, bryophyte, and lichen species, as well as structural and soil data. The vegetation classification was carried out with modified TWINSpan, followed by determination of diagnostic species with phi values and a small-scale re-assignment of relevés with the aim of crispness maximisation. Both TWINSpan and ordination revealed three major groups of syntaxa, which were matched to three orders from the class of basiphilous dry grasslands, *Festuco-Brometea*, represented by one alliance each: rocky dry grasslands (*Stipo pulcherrimae-Festucetalia pallentis: Seslerion rigidae*); xeric grasslands on deep soils (*Festucetalia valesiacae: Stipion lessingianae*) and meso-xeric grasslands on deep soils (*Brachypodietalia pinnati: Cirsio-Brachypodion pinnati*). We accepted nine association-level units plus two that potentially merit association status but were only represented by one relevé each. Most of the units could be identified with one or several previously described associations. To support nomenclatural stability, we provide a nomenclatural revision and designate nomenclatural types where previously there were none. Further, we used DCA ordination and analysis of variance to determine the main environmental drivers of floristic differentiation and to determine ecological and structural differences between the vegetation types. The strongest differentiation occurred along the aridity gradient with the dense, particularly diverse stands on more or less level sites on the one hand (*Brachypodietalia pinnati*) and the more open, less diverse stands on steep south-facing slopes on the other end of the gradient (*Stipo pulcherrimae-Festucetalia pallentis, Festucetalia valesiacae*). The two xeric orders were then separated along the second DCA axis, with the *Stipo pulcherrimae-Festucetalia pallentis* inhabiting the stone-rich sites at higher altitudes while the *Festucetalia valesiacae* occur on soft, deep substrata at lower altitudes. The analysed dry grassland communities have extraordinarily high  $\alpha$ -diversity at all spatial scales for all plants and for vascular plants, but are relatively poor in bryophytes and lichens. Some formerly mown stands of the *Festuco sulcatae-Brachypodietum pinnati* (*Brachypodietalia pinnati*) are even richer in vascular plant species than any other recorded vegetation type worldwide on the spatial scales of 0.1 m<sup>2</sup> (43) and 10 m<sup>2</sup> (98); the respective relevés are documented here for the first time. Also, the  $\beta$ -diversity of the grasslands was unexpectedly high, with a mean  $z$ -value of 0.275. Despite its limited extent, the methodological thoroughness of this study allows us to shed new light on the syntaxonomy of dry grasslands in Romania and to raise the awareness that Transylvania still hosts High Nature Value grasslands that are biodiversity hotspots at a global scale but at the same time are highly endangered through changes in agricultural practices.

### **Zusammenfassung: *Festuco-Brometea*-Gesellschaften im Siebenbürgischen Becken (Rumänien) – eine vorläufige Übersicht zu Syntaxonomie, Ökologie und Biodiversität**

Das Siebenbürgische Becken ist bekannt als Heimat verschiedener Typen von Trockenrasen, die eine große Fläche einnehmen. Diese Grasländer werden zum großen Teil noch sehr traditionell durch extensive Beweidung oder Mahd genutzt. Während dieses Naturerbe derzeit durch gravierende Landnutzungs-

änderungen gefährdet ist, ist wenig über die Vielfalt der Siebenbürgischen Trockenrasen bekannt. Es fehlten standardisiert erhobene Daten sowie syntaxonomische Auswertungen mit modernen statistischen Methoden aus einem überregionalen Blickwinkel. All diese Tatsachen zusammen motivierten die *European Dry Grassland Group* (EDGG) dazu, ihre erste internationale Forschungsexpedition im Jahre 2009 nach Siebenbürgen durchzuführen, um die Syntaxonomie, Ökologie und Biodiversitätsmuster der Siebenbürgischen Trockenrasengesellschaften zu untersuchen. In verschiedenen Gebieten Siebenbürgens fertigten wir sowohl Vegetationsaufnahmen auf 10 m<sup>2</sup>-Flächen ( $n = 82$ ) als auch geschachtelte Aufnahmeserien auf Flächen von von 0,0001 m<sup>2</sup> bis 100 m<sup>2</sup> Größe ( $n = 20$ ) an. In den Aufnahmenflächen wurden Gefäßpflanzen, Moose und Flechten erhoben sowie Untersuchungen der Vegetationsstruktur und Bodeneigenschaften durchgeführt. Die Vegetationsklassifikation erfolgte mit Hilfe einer modifizierten TWINSpan-Analyse. Diagnostische Arten wurden durch Phi-Werte nach einer Neuordnung weniger Aufnahmen mit dem Ziel der Maximierung der Trennschärfe ermittelt. Sowohl durch TWINSpan als auch durch die Ordinationanalyse wurden drei Hauptgruppen von Syntaxa ermittelt, die je einer Einheit innerhalb von drei Vegetationsordnungen der Klasse der basiphilen Trockenrasen (*Festuco-Brometea*) zugeordnet wurden: Felstrockenrasen (*Stipo pulcherrimae-Festucetalia pallentis: Seslerion rigidae*); Trockenrasen auf tiefgründigem Boden (*Festucetalia valesiacae: Stipion lessingianae*) und Halbtrockenrasen auf tiefgründigen Böden (*Brachypodietalia pinnati: Cirsio-Brachypodion pinnati*). Wir akzeptierten neun Vegetationseinheiten auf der Ebene von Assoziationen sowie zwei weitere mögliche Assoziationen, die aber nur durch jeweils eine Vegetationsaufnahme repräsentiert waren. Die meisten Einheiten konnten einer oder mehreren bereits beschriebenen Assoziationen zugeordnet werden. Um nomenklatorische Stabilität zu erreichen, führten wir eine nomenklatorische Revision der Gesellschaften durch und benannten neue nomenklatorische Einheiten. Weiterhin führten wir eine Gradientenanalyse (DCA) und Varianzanalysen durch, um den Zusammenhang zwischen Umweltfaktoren und Vegetationsunterschieden zu ermitteln sowie ökologische und strukturelle Unterschiede zwischen den Vegetationstypen zu analysieren. Die stärksten floristischen Unterschiede wurden entlang eines Trockheitsgradienten mit dichter, besonders artenreicher Vegetation auf weniger stark geneigten Flächen auf der einen (*Brachypodietalia pinnati*) und offener, weniger artenreicher Vegetation an steilen Südhängen auf der anderen Seite des Gradienten (*Stipo pulcherrimae-Festucetalia pallentis, Festucetalia valesiacae*) ermittelt. Diese zwei Ordnungen differenzierten entlang der zweiten DCA-Achse, wobei die *Stipo pulcherrimae-Festucetalia pallentis*-Gesellschaften auf gesteinsreichen Flächen in höheren Lagen und die *Festucetalia valesiacae*-Gesellschaften auf tiefgründigen Böden in niedrigeren Lagen vorkommen. Die untersuchten Trockenrasengesellschaften besaßen über alle räumlichen Skalen hinweg eine außergewöhnlich hohe  $\alpha$ -Diversität, bezogen auf die Gesamtartenzahl und die Gefäßpflanzen, aber sie waren arm an Moosen und Flechten. Für einige der früher gemähten Flächen der *Festuco sulcatae-Brachypodietum pinnati*-Gesellschaft (*Brachypodietalia pinnati*) wurde sogar die höchste Gefäßpflanzenvielfalt weltweit auf den Skalen 0,1 m<sup>2</sup> (43 Arten) und 10 m<sup>2</sup> (98 Arten) gemessen; die jeweiligen Vegetationsaufnahmen werden hier zum ersten Mal präsentiert. Auch die  $\beta$ -Diversität des Graslandes war unerwartet hoch mit einem mittleren  $z$ -Wert von 0.275. Zusammenfassend lässt sich sagen, dass unsere Studie durch die methodische Gründlichkeit trotz ihres begrenzten Ausmaßes ein neues Licht auf die Syntaxonomie der rumänischen Trockenrasen wirft. Weiterhin stärkt sie das Bewusstsein, dass Siebenbürgen immer noch Grasland von sehr hohem Schutzwert besitzt, das global betrachtet einen Hotspot der Biodiversität bildet, aber durch Landnutzungsänderungen stark gefährdet ist.

**Keywords:** bryophyte; conservation; dry grassland; High Nature Value grassland; lichen; nomenclatural revision; species richness; vascular plant; vegetation classification; vegetation-environment relationship.

**Abbreviations:** Art. = Article (of the ICPN); BP = before present; DCA = detrended correspondence analysis; EDGG = *European Dry Grassland Group*; EIV = Ellenberg indicator value; GPS = global positioning system; ICPN = International Code of Phytosociological Nomenclature 3rd ed. (WEBER et al. 2000); rel. = relevé; SAR = species-area relationship; SCI = Site of Community Interest (i.e. part of the Natura 2000 network); TWINSpan = Two-Way Indicator Species Analysis (HILL 1979).

**With 2 supplements.**

## Introduction

The Transylvanian region of Romania still harbours large areas of extensively managed High Nature Value grasslands (CREMENE et al. 2005, BRINKMANN et al. 2009, JONES et al. 2010, AKEROYD & PAGE 2011, CSERGÖ & DEMETER 2011a). Here, traditional agricultural

practices that have mostly been lost in Western Europe, such as common grazing and hand scything of meadows, are still part of everyday farming life (e.g. AKEROYD 2006, BAŞNOU et al. 2009, BRINKMANN et al. 2009). However, these valuable historic landscapes are currently facing substantial land-use changes in the form of intensification and abandonment, which threaten their rich biodiversity (e.g. CREMENE et al. 2005, KUEMMERLE et al. 2009, RUPRECHT et al. 2009, CSERGŐ & DEMETER 2011b). The combination of these factors was the motivation for the *European Dry Grassland Group* (EDGG; www.edgg.org) to direct its first international research expedition in 2009 to Transylvania, with the aim to sample high quality data on various aspects of phytodiversity in a standardised manner (DENGLER et al. 2009). Many of the studied dry grasslands turned out to be exceptionally rich in vascular plants when compared to other dry grasslands in Europe (DENGLER et al. 2009). In a recent review, WILSON et al. (in press) found that the richness values recorded in one particular site close to Cluj-Napoca were the highest ever recorded at two spatial scales (0.1 m<sup>2</sup> and 10 m<sup>2</sup>) in any vegetation type worldwide. This review generally found that below 100 m<sup>2</sup>, extensively managed nutrient poor grasslands of the temperate zone (subcontinental Europe and Argentina) show higher maximum plant species richness than tropical rainforests. The unexpected results were widely picked up by the press, from major science journals (e.g. ANON. 2012b, MOSHER 2012), through online platforms (e.g. ANON. 2012a), to normal newspapers.

Despite this long known and now confirmed extraordinary position and value of Transylvanian dry grasslands, the knowledge about their distribution, diversity, ecology, and phytosociology is still limited. Current knowledge is based on several fundamental phytosociological monographs published in the early 20<sup>th</sup> century on dry grassland communities in the surroundings of Cluj-Napoca (SOÓ 1927, 1947, 1949) and those inhabiting rocky habitats (ZÓLYOMI 1939). These were followed by a variety of mostly local studies by various authors up to now, typically dealing with only one or a few associations. Supraregional syntheses such as the comparative study of the alliance *Stipion lessingianae* across Romania by SCHNEIDER-BINDER (1977) remained a rare exception. At first glance, Romania seems to be well studied in phytosociological terms as evidenced by voluminous overview of syntaxa by SANDA et al. (2008), whose long reference list demonstrates that a huge amount of phytosociological raw data have been sampled. However, a lack of synthesis and critical evaluation makes interpretation and comparison of the data difficult. For example, the Romanian literature rarely considers multiple syntaxa in the same vegetation table (but see POP 1991, RUPRECHT et al. 2009), and determination of diagnostic species with statistical methods is practically unknown. Both aspects led to an “inflation” of associations whose floristic separation and ecological meaning remains doubtful. Moreover, the rules of phytosociological nomenclature (WEBER et al. 2000) are not normally adhered to. Many authors resort to using association names described from unrelated areas if only one or two dominant species (which often have Eurasian distribution ranges) match (e.g. *Stipetum capillatae* (Hueck 1931) Krausch 1961 nom. illeg. described from NE Germany). Finally, few available studies on Transylvanian dry grasslands contain measurements of environmental variables and, with the exception of some of the older papers, non-vascular plants are usually not recorded. With this in mind, we use the data sampled during the EDGG expedition to address four aims:

- Delimitation of the major plant community types for dry grasslands and determination of their diagnostic species with modern statistical methods.
- Placement of these community types in a supraregional classification scheme, including the search for correct syntaxon names.
- Understanding the environmental factors that shape community composition.
- Documentation of the plant diversity patterns of vascular plants, bryophytes, and lichens in these vegetation types on various spatial scales.

While our data are clearly limited in terms of plots sampled, their quality as well as our methodological approaches go beyond usual studies in the area, and thus we hope that our results will contribute to a better knowledge about and valuation of these plant communities.

## 2. Study area

### 2.1. Location and climate

The study was conducted in the Transylvanian Plateau, sometimes referred to as the Transylvanian Basin (45°40'–47°50' N and 23°00'–25°40' E), a hilly area in the centre of Romania (Fig. 1). It is almost entirely surrounded by the Eastern, Southern and Western Romanian Carpathians (maximum altitude 2544 m a.s.l.), and its elevation ranges from approximately 200 to 700 m a.s.l. We also included some relevés from the adjacent Turda Gorge at similar altitudes, which geographically belongs to the Trascău Mountains, a part of the Western Romanian Carpathians. The climate is subcontinental, with mean annual temperatures from 8 to 10 °C, while mean annual precipitation ranges from 520 to 700 mm, the higher values usually found on the more elevated areas in East (POP 2001, KUN et al. 2004).

### 2.2. Geomorphology and soils

The Transylvanian Plateau is fragmented by numerous valleys, which generally flow from East to West. Different Eocene and Oligocene bedrock types prevail: clays, marls, sands, and sandstones, while reef limestones are rare (TUFESCU 1974). The steeper, mostly south-facing flanks of the monoclines, the dominant relief features in the area composed of strata inclined in the same direction, support the majority of the dry grasslands of the region (Fig. 2).

Occasionally, clusters of “slumping hills”, locally called *movile*, *glimee*, or *copârsaie*, have developed here, providing specifically favourable conditions for these types of communities (e.g. MEUSEL 1940, SCHNEIDER 1996). The “slumping hills” are approx. 10–40 m in

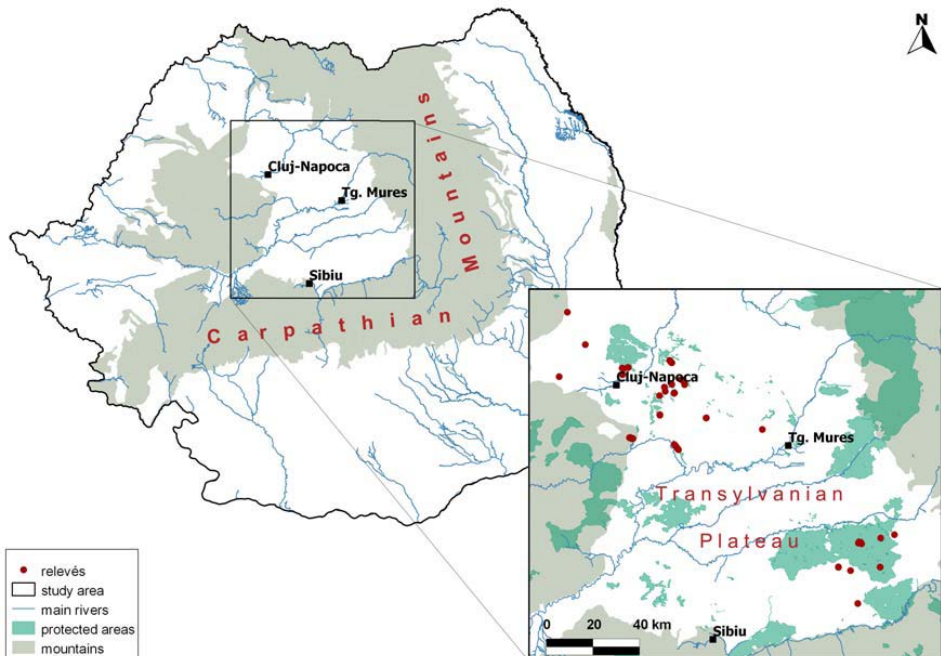


Fig. 1: Location of the Transylvanian Plateau within Romania and distribution of the analysed 82 relevés within the study region (note that due to geographic proximity not all relevés are visible as separate symbols).

Abb. 1: Lage des Siebenbürgischen Beckens in Rumänien und der 82 Aufnahmeflächen im Untersuchungsgebiet (man beachte, dass wegen der geografischen Nähe nicht alle Aufnahmen einzeln sichtbar sind).

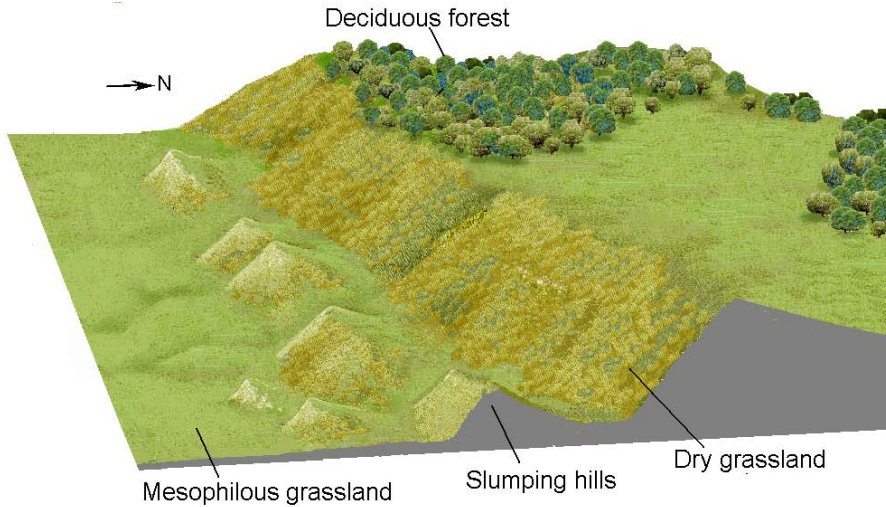


Fig. 2: Schematic representation of two typical and widespread landscape features of the Transylvanian Plateau that host dry grasslands. Monoclines (mostly stretching east-west), whose steep sides are facing in southward directions, and slumping hills, which in some places occur in large clusters (illustration by C. Azeri, Manisa).

Abb. 2: Schematische Darstellung von zwei Landschaftsformen mit Trockenrasen, die für Siebenbürgen typisch und dort weit verbreitet sind: Südexponierte Steilhangstufen und alleinstehende Rutschhügel (*slumping hills = movile*), die oft in größeren Gruppen vorkommen (Zeichnung von C. Azeri, Manisa).

height, with the form of elongated crests or cones and very steep slopes (Fig. 2). Most of them probably originated under periglacial conditions in late Pleistocene and early Holocene (PENDEA 2005, GRECU & COMĂNESCU 2010). They were formed by the slippage of a permeable layer of substrate over an impermeable layer of marl or clay (BACIU 2006). The slumping hills often contain unusual plant assemblages, which may represent relicts of past climatic conditions i.e. of extensive steppes which covered Eastern Europe during the Pleistocene period (LANG 1994, AKEROYD & PAGE 2011). *Glimée* formations are not unique to Romania, but they are particularly characteristic for the Transylvanian Plateau, where they are unusually frequent (MALOS 2011).

The soil types of the region are mainly Luvisols and, to a lower extent, degraded Chernozems on the western side of the Transylvanian Plateau (POP 2001; BUNESCU et al. 2005).

### 2.3. Landscape and vegetation

Today, the landscape is characterised by a mosaic of arable fields, old-fields of different ages, several hundred year-old secondary grasslands, ancient dry, steppe-like grasslands, and deciduous forests. Recent palaeoecological studies show that most of the Carpathian Basin was dominated by temperate deciduous wooded steppe throughout most of the Holocene (MAGYARI et al. 2010). Some “forest species” occurring nowadays in more mesic grasslands of the region can be seen as indicators of the capacity of the substrates to support woodlands (e.g. *Mercurialis ovata*, *Anemone sylvestris*, *Campanula persicifolia*). In contrast, steppe-like grasslands were originally restricted to edaphically poor areas (MAGYARI et al. 2010). According to MAGYARI et al. (2010), after c. 3100 cal. yr BP anthropogenic activities led to the development of a “cultural steppe”, especially in the Great Hungarian Plain, which probably displayed similar ecological conditions to the Transylvanian Plateau. By the beginning of the 18th century only fragments of the once almost complete forest cover remained (ANON. 1769–1773), leading to the present-day highly fragmented and small forest remnants. It is thus likely that some of the dry grasslands in Transylvania have a very long history, dating back hundreds or even thousands of years.



The map of the potential natural vegetation of BOHN et al. (2004) displays unit G3 as the most extensive in the study area, which is characterized by the Transylvanian mixed Tatarian maple-oak forests (*Quercus robur*, *Q. petraea* and *Acer tataricum* with *Helleborus purpurascens* and *Melampyrum bibariense* in the understorey) and steppe grasslands (*Stipa* spp. and *Carex humilis*). Less represented in the natural vegetation are the Southeast Carpathian hornbeam-beech forests (*Fagus sylvatica*, *Carpinus betulus*) with *Melampyrum bibariense* (unit F60). In a more detailed analysis on the potential vegetation based on climatic characteristics of the region, especially distribution of precipitation between and within years, KUN et al. (2004) have found that there are three main climate types in the study area, which determine different “vegetation zones”: forest (northern and eastern parts), a transitional type between forest and forest-steppe (western and south-central parts), and forest-steppe (south-western part).

## 2.4 Phytogeography

Chorologically, Transylvania is considered as part of the Pontic-South Siberian Floristic Region, with the Transylvanian Plateau forming the Transylvanian Sub-province of the Pannonian Province (MEUSEL & JÄGER 1992). There are both similarities with and differences from the core of this province in the Great Hungarian Plain. The Transylvanian dry grasslands differ from the Pannonian s.str. by several Pontic (-South-Siberian) (e.g. *Allium albidum*, *Centaurea trinervia*, *Cephalaria uralensis*, *Nepeta ucranica*, *Peucedanum tauricum*, *Stipa lessingiana*), as well as some Balkanic (e.g. *Carduus candicans*, *Centaurea atropurpurea*, *Seseli gracile*) and endemic taxa (e.g. *Cephalaria radiata*, *Jurinea mollis* subsp. *transylvanica*, *Onosma pseudoarenaria*, *Salvia transylvanica*) (compare TUTIN et al. 1968–1993). SCHNEIDER-BINDER (1975, 1977) published detailed distribution maps of most of these endemic and Pontic species, which demonstrate that within Romania they are restricted to the Transylvanian Plateau, except *Stipa lessingiana*, which also occurs in the regions of Moldova and Dobrogea. The rocky dry grassland have also several Carpathian endemics (e.g. *Sesleria heuflerana*) and eastern Carpathian endemics (e.g. *Helictotrichon decorum*; distribution maps in ZÓLYOMI 1939).

## 2.5. Land use and conservation

Transylvanian dry grasslands are currently faced by two threats. On the one hand, land use change through afforestation with non-native pines (RUPRECHT et al. 2009) or conversion into arable fields is occurring in more productive areas. On the other, traditional usage as pastures or hay meadows is ceasing due to changes in the socioeconomic situation, so that litter accumulation and shrub encroachment takes place, leading to diversity losses and changes in vegetation structure (ENYEDI et al. 2008; RUPRECHT et al. 2009). A significant part of the remaining high quality dry grasslands is now part of the Natura 2000 network of protected areas (SCIs = Sites of Community Interest; see Fig. 1 and Appendix 2) and/or are eligible for grassland Agri-Environment payments that promote non-intensive management. However being included in an SCI or an Agri-Environment Scheme does not necessarily mean good conservation status. In some regions, NGOs are active in order to maintain the historic cultural landscape, for example in the Natura 2000 site “ROSCI0227 Sighişoara – Târnava Mare” (AKERROYD 2006), and “ROSCI0295 Dealurile Clujului de Est” (PAULINI et al. 2011).

## 3. Methods

### 3.1. Vegetation sampling

The field sampling was carried out from the second half of July to the end of August 2009 (by E.R., A.S., J.D., E.U., M.B., P.D.T.) and supplemented by some additional relevés made in late July 2011 (by T.B., U.B.). We tried to cover the whole range of *Festuco-Brometea* communities in various sites within the counties of Sălaj, Cluj, Mureş, and Braşov, mostly located in various categories of protected areas (Fig. 1, Appendix 2).

We applied two complimentary sampling schemes: (i) nested-plot series ( $n = 20$ ) with plots of the sizes of 0.0001, 0.001, 0.01, 0.1, 10, and 100 m<sup>2</sup>, where all plot sizes except the largest were replicated in two opposite corners (DENGLER 2009b), and (ii) additional 10-m<sup>2</sup> plots ( $n = 42$ ). In both cases, all plots were square-shaped and placed in visually homogeneous stands in terms of topography, physiognomy, and composition. We recorded all terricolous vascular plants, bryophytes and lichens that were superficially present (i.e. shoot presence = any-part system; DENGLER 2008); for the 10-m<sup>2</sup> plots additionally percentage cover values were estimated.

To verify the determination of lichens, extracts of some specimens were analyzed by thin-layer chromatography using solvent A (CULBERSON & AMMANN 1979). The taxonomy of vascular plants follows *Flora Europaea* (TUTIN et al. 1968–1993) or *Atlas Florae Europaeae* (JALAS & SUOMINEN 1994, JALAS et al. 1996, 1999, KURTTO et al. 2004–2010), depending on which of the treatments in the two series was the more recent. For mosses we followed HILL et al. (2006), for liverworts GROLLE & LONG (2000), and for lichens SANTESSON et al. (2006). In a few cases, additions to and deviations from these checklists were necessary as documented in Tables 1 and 2.

All relevés and nested plots used in this article are stored in and available from the *Database Species-Area Relationships in Palaeartic Grasslands* (see DENGLER et al. in press), which is registered as EU-00-003 in the *Global Index of Vegetation-Plot Databases* (GIVD; www.givd.info; see DENGLER et al. 2011).

Table 1: Supraspecific taxa of vascular plants used in the paper in addition to those defined in the given checklists.

Tab. 1: Supraspezifische Taxa der Gefäßpflanzen, die in dieser Publikation zusätzlich zu den in den angegebenen Referenzlisten definierten Aggregaten genutzt werden.

Taxon	Reference	Included species
<i>Centaurea jacea</i> agg.	EHRENDORFER (1973)	<i>C. haynaldii</i> , <i>C. bracteata</i> , <i>C. weldeniana</i> , <i>C. rocheliana</i> , <i>C. pannonica</i> , <i>C. vinyalsii</i> , <i>C. dracunculifolia</i> , <i>C. jacea</i> , <i>C. decipiens</i> , <i>C. subjacea</i> , <i>C. macroptilon</i> , <i>C. microptilon</i>
<i>Centaurea phrygia</i> agg.	EHRENDORFER (1973)	<i>C. phrygia</i> , <i>C. stenolepis</i>
<i>Centaurea scabiosa</i> agg.	TUTIN et al. (1976) [as <i>C. sect. Lopholoma</i> ]	<i>C. scabiosa</i> , <i>C. cephalariifolia</i> , <i>C. alpestris</i> , <i>C. sadlerana</i> , <i>C. badensis</i> , <i>C. grinensis</i> , <i>C. spiculata</i> , <i>C. stereophylla</i>
<i>Festuca</i> ser. <i>Valesiaca</i>	PAWLUS (1985), DENGLER (1996)	<i>F. pseudovina</i> , <i>F. illyrica</i> , <i>F. wagneri</i> , <i>F. makutrensis</i> , <i>F. valesiaca</i> , <i>F. carnuntina</i> , <i>F. rupicola</i> , <i>F. taurica</i> , <i>F. dalmatica</i> , <i>F. pseudodalmatica</i>
<i>Ornithogalum</i> subgen. <i>Ornithogalum</i>	TUTIN & al. (1980)	<i>O. comosum</i> , <i>O. umbellatum</i> , <i>O. orthophyllum</i> , <i>O. armeniacum</i> , <i>O. refractum</i> , <i>O. divergens</i> , <i>O. exaratum</i>
<i>Ranunculus polyanthemos</i> agg.	WIBKIRCHEN & HAEUPLER (1998)	<i>R. polyanthemos</i> , <i>R. serpens</i>
<i>Salvia pratensis</i> agg.	ad-hoc taxon	<i>S. pratensis</i> , <i>S. dumetorum</i> , <i>S. teddii</i> , <i>S. transsylvanica</i>
<i>Thymus pannonicus</i> agg.	WIBKIRCHEN & HAEUPLER (1998)	<i>T. glabrescens</i> , <i>T. pannonicus</i>

Table 2: Additional taxa used in this publication that are not listed in the given checklists.

Tab. 2: Zusätzliche Taxa die in dieser Publikation Verwendung finden, aber in den angeführten taxonomischen Referenzlisten nicht enthalten sind.

Group	Taxon	Author citation	Reference
Lichens	<i>Caloplaca raesaenenii</i>	Bredkina	VONDRAK et al. (2012)
Lichens	<i>Cladonia magyarica</i>	Vain.	SEAWARD et al. (2008)
Lichens	<i>Xanthoparmelia perrugata</i>	(Nyl.) Blanco et al.	SEAWARD et al. (2008)
Vascular plants	<i>Dactylis glomerata</i> subsp. <i>glomerata</i>		TUTIN et al. (1980) ["vide"-taxon]
Vascular plants	<i>Medicago sativa</i> nothosp. <i>varia</i>	(Martyn) Arcang.	= <i>M. sativa</i> subsp. <i>nigra</i> × <i>M. sativa</i> subsp. <i>sativa</i>
Vascular plants	<i>Pimpinella saxifraga</i> subsp. <i>nigra</i>	(Mill.) Gaudin	MOSSBERG & STENBERG (2003)
Vascular plants	<i>Solidago virgaurea</i> subsp. <i>virgaurea</i>		TUTIN et al. (1976) ["vide"-taxon]

### 3.2. Environmental parameters

In all 10-m<sup>2</sup> plots, we estimated the cover of the shrub, herb, and moss layers as well as that of litter, open soil, and superficially visible stones + rocks. Maximum height of the herbaceous vegetation was measured with a folding rule. We determined geographic coordinates and altitude with a GPS, aspect with a compass, and slope with an inclinometer. The latter two parameters were used to calculate the heat load index according to OLSSON et al. (2009), which is a relative measure that takes the highest positive values on steep southwest facing slopes, zero in level areas, and negative values on northeast facing slopes. Microrelief was measured as maximum vertical deviation from an imaginary plane through the plot. We classified present land use roughly into the categories “mown”, “grazed”, and “not used” based on our knowledge of the sites and/or visible signs in the plots.

In order to determine relevant soil parameters, we took a mixed soil sample of the uppermost 10 cm and dried it for lab analysis. All analyses followed standard protocols in SCHLICHTING et al. (1995). Chemical analyses were conducted on the < 2 mm fraction of the air-dried soil. We performed analyses of soil pH (determined in a solution of 10 g soil in 25 ml distilled water and in 25 ml CaCl<sub>2</sub> solution with a standard glass electrode) and soil organic content (by loss on ignition at 550 °C for 2 hours), estimated CaCO<sub>3</sub> content semi-quantitatively (testing acoustic and optical soil reaction of a 10% HCl dropping on the soil). Additionally, we determined soil texture class by haptic tests (AD-HOC-AG BODEN 2005).

As proxies for not easily measurable complex environmental variables, we calculated mean un-weighted Ellenberg indicator values (EIVs) for temperature (T), nutrients (N), moisture (M), and soil reaction (R). The calculations were based on the classification of the Hungarian vascular plant flora by BORHIDI (1995) for vascular plants (including nearly all species except the few mentioned in Subsection 2.4) and ELLENBERG et al. (2001) for bryophytes and lichens. To assess the conservation relevance of different dry grassland types, we calculated the mean constancy of vascular plant species with conservation concern per relevé, based on the combined assignments as rare, vulnerable, and/or endemic in the Red Lists by DIHORU & DIHORU (1994) and OLTEAN et al. (1994).

### 3.3. Vegetation classification

Vegetation classification was performed on the 82 relevés of 10-m<sup>2</sup> plots (40 from the nested-plot series, 42 additional ones). To get an initial idea of the data structure, we conducted the modified version of TWINSpan (Two-Way Indicator Species Analysis; HILL 1979) proposed by ROLEČEK et al. (2009) and implemented in JUICE (TICHÝ 2002). Prior to this numerical classification we standardised our relevé data (see JANSEN & DENGLER 2010): (i) occurrences of species in shrub and herb layer were combined; (ii) taxa determined only on genus level or coarser were removed except for *Nostoc* sp. and *Taraxacum* sp. (which were never determined at species level but have a clear diagnostic value even at genus level); (iii) taxa that were recorded with different taxonomic precision were joined at the aggregate level (*Centaurea jacea* agg., *C. scabiosa* agg., *Salvia pratensis* agg.); (iv) records of the type “Genus cf. species” were joined with “Genus species”; (v) some cover values not applicable in JUICE were changed to the nearest allowed values. We used the default settings of JUICE (pseudospecies cut levels: 0%, 2%, 5% and 10%; minimum group size: 5) and tried cluster numbers up to 12.

As the TWINSpan analysis showed that the three-cluster resolution corresponded very closely to phytosociological orders known from the literature (“ordinal clusters”), and the nine-cluster resolution was the lowest resolution with floristically well-defined units (“association-level clusters”), we used these two TWINSpan resolutions as starting point for further refinement. We calculated phi coefficients of association (CHYTRÝ et al. 2002) for the TWINSpan units at the two-, three-, and nine-cluster resolution. While at the two higher levels we used the raw phi values, we standardised them at the lowest resolution to equal cluster size to avoid undue effects of widely differing numbers of included relevés (see TICHÝ & CHYTRÝ 2006). This table was first sorted according to decreasing phi-values in the units derived from TWINSpan. In the next step, we then identified relevés in which diagnostic species of another cluster than their own prevailed and reassigned them when this overall led to an increase of the phi values of highly diagnostic species as proposed and applied, *inter alia*, by LUTHER-MOSEBACH et al. (in press) and BECKER et al. (2012). Then the same procedure (calculation of phi values, sorting of species blocks, checking for and reassigning of outlying relevés) was repeated iteratively until no further improvement in the crispness of the classification could be achieved.

We considered species as highly diagnostic when  $\phi > 0.50$  and as diagnostic when  $\phi > 0.25$  (see CHYTRÝ 2007), provided the concentration was significant according to Fisher’s exact test at  $\alpha = 0.05$ . According to this definition, species can be diagnostic for several nested syntaxa. Such so-called “trans-



gressive” diagnostic species were only accepted additionally at higher hierarchical level when the species had positive phi-values in more than half of the included associations. When a species was diagnostic for more than one association of a higher unit, it was accepted only on the higher level. Note that the term “diagnostic species” is meant in the regional context and contains both differential and character species. As each of the three orders accepted contained one alliance only, it was also not possible to distinguish directly between diagnostic species of the order and of the alliance; this could only be done by comparison with literature data.

In the association descriptions (Subsection 4.4), we characterised the communities within the context of this work, using standardised terminology in relation to the mean value found in all our stands, e.g. we classified species richness on 10 m<sup>2</sup> (where the overall mean was 53) as follows: < 33: extremely species poor; 33–43 species: very species poor; 43–53: moderately species poor; 53–63: moderately species rich; 63–73: very species rich; > 73: extremely species rich.

Finally, we tried to assign our units to phytosociological associations, alliances, and orders described in the literature. This phytosociological classification involved an extensive search for original literature and check for validity and legitimacy of names in use according to the *International Code of Phytosociological Nomenclature* (WEBER et al. 2000; further ICPN). As a contribution to nomenclatural stability, we define nomenclatural types for some syntaxa that seemingly had not been typified before (in Appendix 1).

### 3.4. Other statistical analyses

To display the floristic interrelationships between the relevés along the first three floristic gradients, we carried out a detrended correspondence analysis (DCA) with log-transformed percent cover values in CANOCO 4.5 using down-weighting of rare species (TER BRAAK & ŠMILAUER 2002). In the ordination diagram the relevés were coded according to the refined vegetation units after application of phi-value maximisation according to the procedure described in Subsection 3.3. Relationships between the first three DCA axes on the one hand, and floristic and environmental parameters on the other were analysed with Pearson correlations in SPSS 14 (SPSS Inc., Chicago, USA).

We tested for floristic and environmental differences among the nine associations with one-way ANOVAs carried out in SPSS 14. We tested whether the prerequisites of the ANOVA models (normal distribution, equal variance) were sufficiently met by visually inspecting the distribution of the residuals (QUINN & KEOUGH 2002). When the ANOVA detected a significant pattern, we used Tukey’s HSD *post hoc* test at  $\alpha = 0.05$  to determine homogenous groups of syntaxa.

Finally, we used the nested-plot data for a coarse analysis of species-area relationships (SARs). We did this with the power-law function applied with linear regression to log<sub>10</sub>-transformed area and richness data as proposed as one possible standard procedure by DENGLER (2009a). For the regression we used averaged values of the pair of richness values available from the two opposite corners of each “biodiversity plot” for all grain sizes below 100 m<sup>2</sup> as recommended by DENGLER (2008) and DENGLER & BOCH (2008).

## 4. Vegetation

### 4.1. Proposed syntaxonomic scheme

Here, we give a brief overview of the phytosociological classification that we adopt in this paper (for arguments, see Subsections 4.2–4.4). Synonyms and a nomenclatural revision (including typifications) are provided in Appendix 1. The communities dominated by *Sesleria heuflerana* on rocks (1.1.1a) and by *Stipa tirsia* (3.1.4a) might warrant the status of separate associations. However, as we had only one relevé each, we retained them in the next most similar community for the statistical analyses. We elucidate the possibility of splitting these associations off in the syntaxonomic discussion.

Class: *Festuco-Brometea* Br.-Bl. & Tx. ex Klika & Hadač 1944

Order 1: *Stipo pulcherrimae-Festucetalia pallentis* Pop 1968

Alliance 1.1: *Seslerion rigidae* Zólyomi 1939

Association 1.1.1: *Avenastretum decori* Zólyomi 1939

Association 1.1.1a: *Seslerietum heufleranae* Soó 1927

Association 1.1.2: *Carici humilis-Leontodontetum asperi* Zólyomi 1939

Order 2: *Festucetalia valesiaca* Soó 1947

Alliance 2.1: *Stipion lessingiana* Soó 1947

Association 2.1.1: *Artemisietum pontico-sericeae* Soó 1947

Association 2.1.2: *Stipetum lessingiana* Soó 1947

Association 2.1.3: *Stipetum pulcherrimae* Soó 1942 [central association]

Order 3: *Brachypodietalia pinnati* Korneck 1974

Alliance 3.1: *Cirsio-Brachypodion pinnati* Hadač & Klika in Klika & Hadač 1944

Association 3.1.1: *Orchido militaris-Seslerietum heufleranae* Schneider ex Dengler et al. 2012

Association 3.1.2: *Festuco sulcatae-Brachypodietum pinnati* Soó 1927

Association 3.1.3: *Agrostio-Danthonietum alpinae* Soó 1947

Association 3.1.4: *Cirsium furiens-Brachypodium pinnatum* community [central association]

Association 3.1.4a: *Stipetum tirsae* Meusel 1938

## 4.2. Phytosociological classification derived from the numerical analyses

Initial TWINSPAN resulted in floristically very well defined vegetation units, both at the three-cluster level and at the nine-cluster level. Therefore, only two relevés were reassigned between the three main clusters and further 13 between the association-level clusters according to the crispness maximisation procedure described in Subsection 3.3. These changes compared to the original TWINSPAN classification are highlighted in Table 3 in the Supplement. On the three-cluster level, Clusters 1 and 2 are floristically more similar to each other than to Cluster 3, which is reflected by the cluster tree (not shown) and the 10 joint diagnostic species of these grasslands against Cluster 3 (see Table 3).

In the ordination (Fig. 3), the separation of the vegetation units after the manual re-arrangement described above, was clear both for the higher level (interpreted as orders) and for the lower level (interpreted as associations). The three orders were already completely separated on the plane of the first two axes, with the opposition of orders 1 and 2 against order 3 occurring on the first DCA axis. Also the two associations of the first order were well separated on this plane, whereas those of the second order showed some and that of the third order nearly complete overlap here. However, on the plane of first vs. third axis, the associations of orders 2 and 3 were reasonably well separated with only little overlap (Fig. 3). Among the associations, floristic variation was highest in 2.3 and 3.4 and lowest in 2.2 and 3.2 (Fig. 3).

## 4.3. Identity and placement of the alliances

The units at the three-cluster level correspond to ecologically and physiognomically distinct entities: 1 = rocky dry grasslands; 2 = xeric grasslands on deep soils; 3 = mesoxeric grasslands on deep soils. They could readily be identified with the orders *Stipo pulcherrimae-Festucetalia pallentis* (1), *Festucetalia valesiaca* (2), and *Brachypodietalia pinnati* = *Brometalia erecti* nom. amb. propos. (3) as delimited in some major recent syntaxonomic overviews (e.g. MUCINA & KOLBEK 1993, BORHIDI 2003, DENGLER 2004, SANDA et al. 2008). We agree that the placement of the *Festuco-Brometea* communities of Central Europe s.l. into these three orders plus the *Artemisio albae-Brometalia erecti* Ubaldi ex Dengler & Mucina 2009 (see MUCINA et al. 2009), which replaces the two xeric orders in the western parts, reflects floristic and ecological relationships much better than the widespread, “classical” separation into only two orders, the western *Brometalia erecti* and the eastern *Festucetalia valesiaca*, each containing meso-xeric, xeric, and rock-inhabiting alliances (e.g. BRAUN-BLANQUET & TÜXEN 1943, ROYER 1991, POTT 1995, THEURILLAT et al. 1995).

Regarding the rocky dry grasslands in our study, there is considerable disagreement in the literature about their appropriate syntaxonomic placement. Originally, ZOLYOMI (1939) had placed his *Seslerion rigidae* in the order *Seslerietalia coeruleae* Br.-Bl. in Br.-Bl. & Jenny 1926, belonging to the alpine class *Elyno-Seslerietea* Br.-Bl. 1948. By contrast, SOÓ (1947) subordinated this alliance to the *Festuco-Brometea*. Moreover, various authors considered some of the rock-inhabiting, calciphilous dry grasslands of Transylvania, particularly the *Seslerietum heufleriana*, as belonging to the alliance *Seslerio-Festucion pallentis* Klika 1931

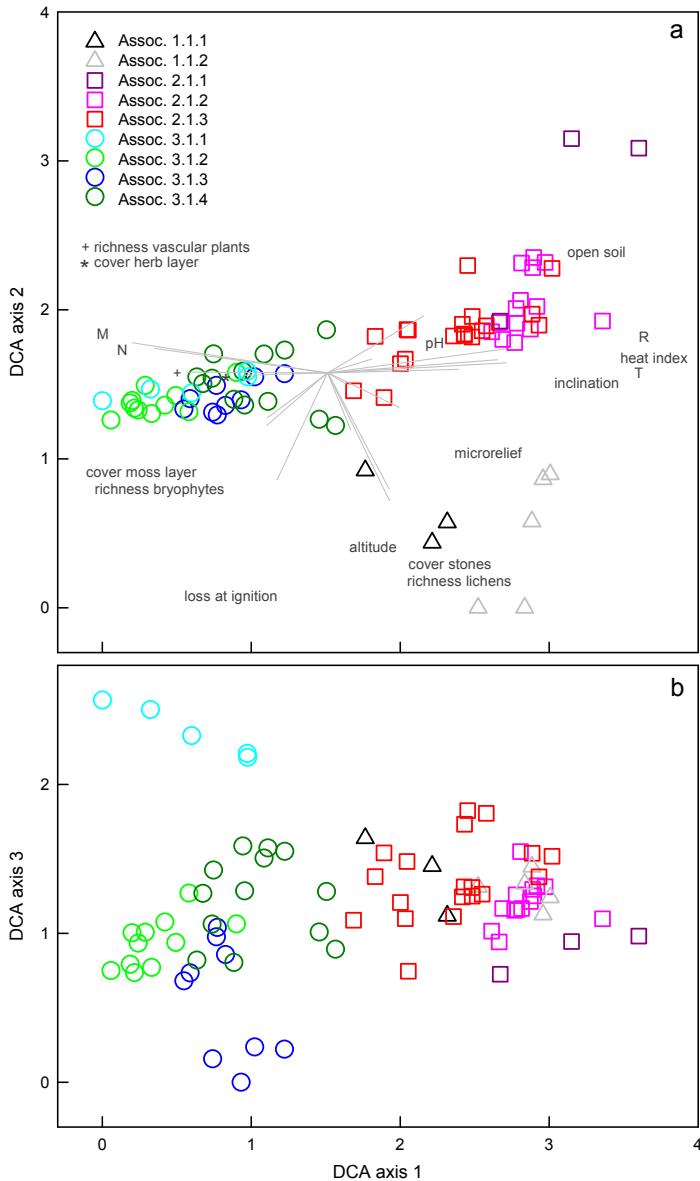


Fig. 3: DCA Ordination diagrams of the 82 10-m<sup>2</sup> vegetation plots. The planes of (a) 1st vs. 2nd axis and (b) of 1st vs. 3rd axis are depicted. The plots are coded according to the accepted classification in orders/alliances and associations (triangles: *Stipo pulcherrimae-Festucetalia pallentis/Seslerion rigidae*; squares: *Festucetalia valesiaca/Stipion lessingiana*; circles: *Brachypodietalia pinnati/Cirsio-Brachypodion pinnati*). Rare species were down-weighted. Eigenvalues: 1st axis: 0.51; 2nd axis: 0.23; 3rd axis: 0.19. Ellenberg indicator values for M = moisture, N = nutrients, R = soil reaction, T = temperature.

Abb. 3: DCA-Ordinationsdiagramme der 82 10 m<sup>2</sup>-Aufnahmeflächen. Die Ebenen (a) 1. vs. 2. Achse und (b) 1. vs. 3. Achse sind dargestellt. Die Aufnahmeflächen sind den Ergebnissen der Klassifikation entsprechend nach Ordnungen/Verbände (Dreiecke: *Stipo pulcherrimae-Festucetalia pallentis/Seslerion rigidae*; Quadrate: *Festucetalia valesiaca/Stipion lessingiana*; Kreise: *Brachypodietalia pinnati/Cirsio-Brachypodion pinnati*) und Assoziationen (s. Text) dargestellt. Seltene Arten wurden herabgewichtet. Eigenwerte: 1. Achse: 0,51; 2. Achse: 0,23; 3. Achse: 0,19. Ellenberg-Zeigerwerte für M = Feuchte, N = Nährstoffe, R = Bodenreaktion, T = Temperatur.

(correct name: *Diantho lummitzeri-Seslerion* (Soó 1971) Chytrý & Mucina in Mucina & Kolbek 1993) within the *Festuco-Brometea* (ZÓLYOMI 1939, POP 1968, 1991, SANDA et al. 2008). According to both the original description by ZÓLYOMI (1939) and our own data, the relevant communities are floristically very similar, occur at submontane to montane, but not alpine altitudes and show a prevalence of thermophilous *Festuco-Brometea* species over dealpine elements. Therefore, we consider it presently as the best solution to place all the Transylvanian (and probably some further eastern Carpathian) rocky dry grassland over limestone at lower altitudes as a single alliance *Seslerion rigidae* within the *Stipo pulcherrimae-Festucetalia pallentis* (*Festuco-Brometea*). This alliance is a geographic vicariant to the *Diantho lummitzeri-Seslerion* found mainly in the western Carpathians and the Alps (see MUCINA & KOLBEK 1993, CHYTRÝ et al. 2007).

For the (xeric) *Festucetalia valesiacae* communities of Transylvania, SOÓ (1947) had proposed the new alliance *Stipion lessingiana*. This alliance is now widely accepted in the Romanian literature (e.g. SCHNEIDER-BINDER 1975, 1977, OROIAN et al. 2007, SANDA et al. 2008), but the floristic and geographic delimitation against the *Festucion sulcatae* Soó 1930 nom. amb. propos. (= *Festucion valesiacae* Klika 1931), which by all these authors is also given for Transylvania, remained rather vague. In supra-national overviews, the *Stipion lessingiana* was partly included in the *Festucion valesiacae* (ROYER 1991), partly considered as distinct alliance (RODWELL et al. 2002). Our data clearly support the second view since our stands, in addition to widespread diagnostic species of the class and the order *Festucetalia valesiacae*, are characterised by the consistent occurrence of a group of mostly Pontic species or Transylvanian (sub-) endemics that are absent or very rare in *Festucetalia valesiacae* communities further west (i.e. Hungary, Slovakia, Czech Republic, Austria, Germany; compare CHYTRÝ 2007, DÚBRAVKOVÁ et al. 2010), namely *Stipa lessingiana*, *Salvia nutans*, *Centaurea trinervia*, *Cephalaria uralensis*, *Nepeta ucranica*, *Carduus candicans*, and *Plantago argentea*. Unlike the more recent Romanian overviews (SCHNEIDER-BINDER 1975, 1977, OROIAN et al. 2007, SANDA et al. 2008), we, however, consider the *Stipion lessingiana* as the only alliance of the order being present in the study area. The overall distribution of the *Stipion lessingiana* is not well known. According to the synoptic table and distribution maps of SCHNEIDER-BINDER (1977), the alliance is also found in the eastern Romanian regions of Dobrogea and Moldova. The occurrence of some diagnostic species suggests that certain stands in Ukraine (ANON. 2010) and even in the southern Urals, Russia (e.g. YAMALOV et al. 2009) might as well be included, but the latter point needs to be addressed with a large-scale classification.

SÓO (1947) placed the meso-xeric dry grasslands of Transylvania partly in the *Festucion sulcatae* Soó 1947, non Soó 1930, which he later equalised with the *Cirsio-Brachypodium pinnati* (SOÓ 1949), and the provisional alliance *Danthonio-Stipion stenophyllae*, which he validated in the second paper. In recent syntaxonomic treatments of Romanian dry grasslands (e.g. OROIAN et al. 2007, SANDA et al. 2008), the *Danthonio-Stipion stenophyllae* is not usually accepted, and its content is now typically placed within an alliance *Danthonio-Brachypodium* Boşcaiu 1972, which sometimes is assigned to the Balkanic order *Brachypodio-Chrysopogonetalia* (Horvatic 1958) Boşcaiu 1972 nom. illeg. OROIAN et al. (2007) accept even a third alliance of meso-xeric grasslands in Transylvania, the *Bromion erecti* “Br.-Bl. 1936” (correct authority would be “W. Koch 1926”). However, neither our relevés nor the literature data support the existence of more than one meso-xeric alliance in Transylvania. We therefore assign all our associations to the *Cirsio-Brachypodium pinnati*, which is the widespread alliance in eastern central Europe. Similar to the situation in the *Festucetalia valesiacae*, the communities of the Transylvanian Plateau show some consistent floristic differences towards the stands further west. As the differentiation in the case of the *Brachypodietaalia pinnati*, however, is less pronounced and mainly based on differential not on character species, according to present knowledge no separate alliance is warranted in this case, but it might be possible to recognise a suballiance (J. Dengler, unpubl. data).

#### 4.4. Description of the associations (Tables 3 and 6, Appendix 1)

##### Association 1.1.1: *Avenastretum decori*

**Characterisation:** Very species poor community, which is, however, floristically well characterised by 13 highly diagnostic species, most importantly *Seseli gracile*, *Tortella tortuosa*, and *Helictotrichon decorum*. *Sesleria heuflerana* is a joint diagnostic species with the *Orchido-Seslerietum heufleranae* (Assoc. 3.1.1). The stands are dominated by one or several of the following graminoids: *Sesleria heuflerana*, *Helictotrichon decorum*, and *Carex montana*. *Potentilla cinerea* agg., *Teucrium montanum*, and *Asperula cynanchica* are most frequent in the herb layer, while *Tortella tortuosa* and *Rhytidium rugosum* are the most frequent and dominant mosses.

**Ecology and distribution:** Occurs on steep south-facing slopes with soils rich in humus (16.7% loss at ignition) and skeleton (41% superficial stone cover). The community is restricted to hard bedrock, which is only found at the margins of the Transylvanian Plateau and thus at higher altitudes than the grasslands of the second and third order. Due to the inaccessibility, the sites are not used and at least partly the grasslands should be natural. Our only relevés are from the Turda Gorge (Cheile Turzii).

**Syntaxonomy:** This *Avenastretum decori* had first been mentioned from the Turda Gorge bei DOMIN (1932) as a *nomen nudum*, and later been validly described by ZÓLYOMI (1939) with relevés from the various places in the Carpathian Mts. surrounding the Transylvanian Plateau, including again the Turda Gorge. While ZÓLYOMI (1939) and likewise POP (1968), POP et al. (1988), and SANDA et al. (2008) subordinated the association to the class *Elyno-Seslerietea* Br.-Bl. 1948, we believe that it better should be placed in the *Festuco-Brometea* (for reasons, see Subsection 4.3).

Species-poor rocky dry grasslands dominated by *Sesleria heuflerana* likely warrant the status of a separate association (1.1.1a: *Seslerietum heufleranae*), not to be confused with the species-rich *Sesleria*-dominated semi-dry grasslands, treated here as Assoc. 3.1.1), but as we had only one such relevé (No. 44 = ROR004 in Table 3) we preliminarily included it in the *Avenastretum decori* as the next similar community. Outside Transylvania, the *Seslerietum heufleranae* is also known from Southeastern Slovakia (JANIŠOVÁ 2007: there included in the *Bromo panonici-Festucion pallentis* Zólyomi 1966) and Northern Hungary (ZÓLYOMI 1936).

##### Association 1.1.2: *Carici humilis-Leontodontetum asperi*

**Characterisation:** Moderately species poor community, which with 22 highly diagnostic species is floristically well defined. Most important among them are *Linaria angustissima*, *Sedum hispanicum*, *Genista januensis*, *Carduus candicans*, and *Centaurea atropurpurea*. Dominating grasses are *Stipa pulcherrima*, *Dichanthium ischaemum*, *Festuca* ser. *Valesiaca*, and/or *Carex humilis*, while the particularly well developed moss layer is dominated by *Weissia longifolia*, *Syntrichia ruralis* var. *ruraliformis*, and *Rhytidium rugosum*. The most frequent forbs include *Thymus pannonicus* agg., *Sedum hispanicum*, *Iris pumila*, and *Helianthemum nummularium* subsp. *obscurum*. Among all studied vegetation types, this is the only association with noteworthy lichen richness (mean: 3.0 species on 10 m<sup>2</sup>).

**Ecology and distribution:** Site conditions are similar to the *Avenastretum decori* (Assoc. 1.1.1), but the stone cover is lower (21%) while the humus content reaches the highest values among all studied communities (20.1%). Likewise, we found this association only in the Turda Gorge.

**Syntaxonomy:** A range of other association names has been published for this group of rocky dry grasslands in Transylvania that have been placed in at least four different alliances: *Seslerion rigidae*, *Seslerio-Festucion pallentis* Klika 1931 corr. Zólyomi 1966, *Bromo panonici-Festucion pallentis* Zólyomi 1966, and *Thymo comosi-Festucion sulcatae* Pop 1968 (ZÓLYOMI 1939, 1966, POP 1968, 1991, POP et al. 1988, SANDA et al. 2008). However, it seems that our name is the oldest valid one. To sort out the nomenclature of the other associations will be a demanding task as many names are illegitimate or invalid, while the valid ones are often based only on a synoptic table so thus a sound syntaxonomic solution would first





Fig. 4: Stand of the *Carici humilis-Leontodontetum asperi* (alliance: *Seslerion rigidae*) in the nature reserve “Cheile Turzii” (biodiversity plot RO15) (Photo: J. Dengler, 20 July 2009; JD093032).

Abb. 4: Bestand des *Carici humilis-Leontodontetum asperi* (Verband: *Seslerion rigidae*) im Naturschutzgebiet „Cheile Turzii“ (Biodiversitäts-Plot RO15) (Foto: J. Dengler, 20.07.2009; JD093032).

require defining neotypes. When significantly more high quality data than our few relevés are available in a joint database, probably more than one association could be accepted.

#### Association 2.1.1: *Artemisietum pontico-sericeae*

**Characterisation:** Extremely species poor community, which, despite its low diversity, is moderately well characterised by five highly diagnostic species, with *Brassica elongata*, *Cephalaria uralensis*, and *Ephedra distachya* being the most important. The most frequent other herbs are *Teucrium montanum*, *Artemisia campestris*, and *Elymus hispidus*. The cover of the herb layer is on average only 28% and thus the lowest of all studied communities, while both moss layer and litter are virtually absent.

**Ecology and distribution:** Occurs on extremely steep (average: 47°), instable, southerly exposed slopes, as they are typically occur on slumping hills. We found the community only in Suatu and in Dealul viilor.

**Syntaxonomy:** This association has already been mentioned in the protologue of the alliance *Stipion lessingiana* as one of five associations included (SÓO 1947), but strangely it is no longer listed in SANDA et al. (2008). While the association name is not particularly meaningful, our unit exactly corresponds to the description of SÓO (1947), and the floristic composition clearly support the status of an association of its own and its placement in the *Stipion lessingiana*.

#### Association 2.1.2: *Stipetum lessingiana*

**Characterisation:** Moderately species poor community, which is moderately well defined by seven highly diagnostic species: *Stipa lessingiana*, *Plantago argentea*, *Carduus hamulosus*, *Prunus tenella*, *Tragopogon dubius*, *Centaurea trinervia*, and *Nepeta ucranica*. The herb layer is typically dominated by more than one graminoid, the most covering and frequent are (in this sequence): *Stipa pulcherrima*, *Carex humilis*, *Dichanthium ischaemum*, *Stipa lessingiana*, *Elymus hispidus*, and *Stipa capillata*. Typically only one or two moss species with very low cover occur.



Fig. 5: Stand of the *Stipetum lessingianae* (alliance: *Stipion lessingianae*) in Ploscoș (biodiversity plot RO06) (Photo: J. Dengler, 16 July 2009, JD092680).

Abb. 5: Bestand des *Stipetum lessingianae* (Verband: *Stipion lessingianae*) in Ploscoș (Biodiversitäts-Plot RO06) (Foto: J. Dengler, 16.07.2009, JD092680).

**Ecology and distribution:** Occurs on steep, south facing slopes. Soils are base-rich (pH: 7.90), but poorest in humus among all studied communities (5.8% loss at ignition). Nearly all stands belong to extensive pastures and the majority is still grazed, mostly by cattle. According to our observations and to the map of SCHNEIDER-BINDER (1977), the community is relatively widespread in the county of Cluj, and is also found in the eastern Romanian regions of Moldova and Dobrogea, albeit in slightly different composition.

**Syntaxonomy:** This community was one of five associations included in the protologue of the *Stipion lessingianae* and according to ICPN must be considered its lectotype (see Appendix 1). Note, however, that our delimitation focusses on the whole species composition, while SÓO (1947) and even more so later treatments distinguished many different *Stipion lessingianae* associations in Transylvania (partly placed in the *Festucion valesiacae* Klika 1931 = *Festucion sulcatae* Sóo 1929 nom. amb. propos.) based on the dominating graminoid species (e.g. POP et al. 1988, OROIAN et al. 2007, SANDA et al. 2008). In our delimitation, the stands of this association while indeed nearly always containing the eponymous *Stipa* species, are more often dominated by other graminoids (see above).

#### Association 2.1.3: *Stipetum pulcherrimae*

**Characterisation:** Very species poor community, which with only seven diagnostic (most importantly: *Astragalus austriacus*, *Linum tenuifolium*, and *Allium paniculatum* subsp. *fuscum*) and no highly diagnostic species, is considered as the negatively characterised central association of the *Stipion lessingianae*. The most frequent and dominant species are (in this sequence): *Carex humilis*, *Stipa pulcherrima*, *Teucrium chamaedrrys*, *Inula ensifolia*, *Dichanthium ischaemum*, *Festuca* ser. *Valesiacae*, *Elymus hispidus*, and *Stipa capillata*.

**Ecology and distribution:** Site conditions are similar to the *Stipetum lessingianae* (Assoc. 2.1.2), only the soils are slightly more humus-rich (8.4% loss at ignition). Likewise, most stands are low-intensity pastures, used partly by sheep and partly by cattle. In the Transylvanian Plateau, this association is more widespread than the *Stipetum lessingianae*, with occurrences not only in the county of Cluj, but also in the counties of Brașov, Mureș, Sălaj,

and Sibiu. According to SCHNEIDER-BINDER (1977), it is additionally found in the eastern Romanian region of Moldova.

**Syntaxonomy:** Like the two preceding associations also the *Stipetum pulcherrimae* was already included in the protologue of the *Stipion lessingianae* (SÓO 1947). This fact makes it very clear that this association does not mean any *Stipa pulcherrima*-dominated stands anywhere, but first of all only those within the range of the alliance (see the distinction between occurrences of the eponymous species and of the association in the map of SCHNEIDER-BINDER 1977). To our understanding, not even within Transylvania all stands dominated by *Stipa pulcherrima* belong to this association, but *S. pulcherrima* often also dominates the *Carici humilis-Leontodontetum asperi* (Assoc. 1.1.2) and the *Stipetum lessingianae* (Assoc. 2.1.2). In fact, *S. pulcherrima* is for sure not an association character species, but only a joint diagnostic species of the two xeric *Festuco-Brometea* orders (Table 3). On the other hand, *Stipa pulcherrima* is not dominating in or even absent from a significant number of relevés placed by us in this association.

#### Association 3.1.1: *Orchido militaris-Seslerietum heufleranae*

**Characterisation:** Very species rich community, which at the same time is floristically very well defined with 20 highly diagnostic species. The most important diagnostic herbs are *Peucedanum oreoselinum*, *Lembotropis nigricans*, *Campanula rapunculoides*, *Astrantia major*, *Laserpitium latifolium*, and – shared with the *Avenastretum decori* (Assoc. 1.1.1) – *Sesleria heuflerana*, while *Weissia brachycarpa* and *Fissidens taxifolius* have the highest diagnostic value among the cryptogams. While *Sesleria heuflerana* normally has the highest cover value, typical subdominant graminoids are *Brachypodium pinnatum*, *Carex michelii*, *Festuca* ser. *Valesiaca*, and *Briza media*. While the cover of the herb layer with a mean of only 55% is unusually low for a *Cirsio-Brachypodium pinnati* community, the moss layer is particularly well developed with an average cover of 24% and a mean richness of 6.8 on 10 m<sup>2</sup>. Among all studied communities, this association has the highest litter coverage (57%).

**Ecology and distribution:** This community occurs on steep (mean inclination: 32°) north-, east- or west-facing slopes, typically of slumping hills. Among all studied communities, the soils are the most alkaline (mean pH: 8.00) and contain a moderate amount of humus (9.7%). We recorded the community only around Saschiz (county of Mureş), but the distribution map of *Sesleria heuflerana* by SCHNEIDER (1994) suggests that the community occurs also sporadically in other places on deep soils throughout the Transylvanian Plateau (but note that the stands on rocky substrata found on the margins of the Plateau towards the Carpathians belong to Assoc. 1.1.1a).

**Syntaxonomy:** Already SÓO (1947) recognised two completely different *Sesleria heuflerana* communities: he placed the *Seslerietum heufleranae biharicum* of rocky sites (our Assoc. 1.1.1a) in the *Seslerion rigidae* and the *Seslerietum heufleranae praerossicum* in the *Festucetum sulcatae* SÓO 1947, an alliance which he later equated with the *Cirsio-Brachypodium pinnati* (SÓO 1949). A similar idea was elaborated in more detail by SCHNEIDER (1994), who distinguished two meso-xeric *Sesleria heuflerana* associations placed in *Cirsio-Brachypodium pinnati* and two more xeric ones without definitive assignment to an alliance. Strangely, the mesoxeric *Sesleria heuflerana* stands are completely ignored in the most recent syntaxonomic overview of Romania, despite this book otherwise accepts huge numbers of associations. As our numerical classification fully supported the idea of two very different *Sesleria heuflerana*-dominated community types in Transylvania, while the association names of SÓO (1947) were illegitimate and those of SCHNEIDER (1994) invalid, we validate here one of SCHNEIDER's two association names for the meso-xeric type (see Appendix 1).

#### Association 3.1.2: *Festuco sulcatae-Brachypodietum pinnati*

**Characterisation:** Extremely species rich community, which, with an average of 82.6 species on 10 m<sup>2</sup>, hosts more than 15 more species than the second richest dry grassland community of the region. With 49 diagnostic species, including 22 highly diagnostic species,





Fig. 6: Stand of the *Festuco sulcatae-Brachypodietum pinnati* (alliance: *Cirsio-Brachypodion pinnati*) in the nature reserve “La Craiu” near Cluj-Napoca (biodiversity plot RO02). Some of the world records of small-scale vascular plant species richness originate from this particular grassland (see Table 8) (Photo: J. Dengler, 14 July 2009, JD092517).

Abb. 6: Bestand des *Festuco sulcatae-Brachypodietum pinnati* (Verband: *Cirsio-Brachypodion pinnati*) im Naturschutzgebiet “La Craiu” nahe Cluj-Napoca (Biodiversitäts-Plot RO02). Einige der Weltrekorde des Gefäßpflanzenartenreichtums für kleine Korngrößen stammen aus diesem Grasland (siehe Tab. 8) (Foto: J. Dengler, 14.07.2009, JD092517).

this is at the same time the most well-characterised dry grassland community in the regional context. *Campanula glomerata*, *Avenula pubescens*, *Vicia tenuifolia*, and *Centaurea triumfetti* have the highest diagnostic value. The herb layer is the densest of all studied communities (average cover: 92%), with *Brachypodium pinnatum*, *Festuca* ser. *Valesiaca* (mostly *F. rupicola*), *Plantago media*, *Elymus hispidus*, *Vicia tenuifolia*, and *Centaurea scabiosa* agg. typically reaching the highest cover values, but hardly more than 20% per species. By contrast, the moss layer is only moderately developed and relatively species poor, with *Homalothecium lutescens* being the most frequent and most covering species.

**Ecology and distribution:** This community mostly grows on planes and slightly northwards or eastwards inclined slopes (mean heat index:  $-0.13$ ). Soils are relatively rich in humus (13.6%), but contain least carbonate among the studied communities with a mean pH of “only” 7.00. Nearly all stands of the association are still used as hay fields (82%) or had been used as such until recently. We found the association only in three nature reserves in the counties of Cluj and Mureş (Fănaşele Clujului – Copârşai, La Craiu, Paeonia – Rezervaţia de bujori Zau de Câmpie).

**Syntaxonomy:** As to our knowledge, this is the oldest applicable name for the extremely species rich, typically mown, semi-dry basiphilous grasslands in the surroundings of Cluj-Napoca. Strangely, this association is not included in the extensive list of Romanian syntaxa by SANDA et al. (2008), not even as a synonym. The association has some similarities to the *Brachypodium pinnati-Molinietum arundinaceae* Klika 1939 known mainly from the White Carpathians in Czechia and Slovakia (CHYTRÝ et al. 2007, JANIŠOVÁ 2007), including the extreme species richness (KLIMEŠ et al. 2001). Also the *Polygalo majoris-Brachypodietum pinnati* Wagner 1941 shows similarities in species composition and structure (CHYTRÝ et al. 2007, JANIŠOVÁ 2007). However, our stands contain quite some typical species not present in the other two associations (e.g. *Centaurea triumfetti*, *Clematis integrifolia*, *C. recta*, *Echium*

*russicum*, *Linum nervosum*, *Paeonia tenuifolia*, *Veratrum nigrum*) so that it would be premature to propose any fusion.

### Association 3.1.3: *Agrostio-Danthonietum alpinae*

**Characterisation:** Very species rich community, which is well circumscribed by 27 diagnostic species, including 13 highly diagnostic species, with *Cichorium intybus*, *Prunella laciniata*, *Cirsium vulgare*, *Trifolium pratense*, *T. repens*, and *Lolium perenne* being the most important ones. Among the diagnostic species only few (e.g. *Prunella laciniata*, *Linum austriacum*, *Potentilla heptaphylla*) are typical *Festuco-Brometea* taxa, while many others are typical for mesophilous pastures (*Molinio-Arrhenatheretea* Tx. 1937: *Cynosurion cristati* Tx. 1947 nom. cons. propos.) or are spiny or poisonous pasture weeds (*Cirsium vulgare*, *Carduus acanthoides*, *Eryngium campestre*, *Adonis vernalis*). *Salvia austriaca* is a joint diagnostic species with the *Stipetum lessingiana* (Assoc. 2.1.2). The herb layer is usually dominated by *Festuca* ser. *Valesiaca*, followed by *Thymus pannonicus* agg., *Lotus corniculatus*, *Fragaria viridis*, and *Plantago media*. The moss layer is relatively well developed (23%) and moderately species rich (4.1 species on 10 m<sup>2</sup>), with *Abietinella abietina* and *Homalothecium lutescens* being the main species.

**Ecology and distribution:** The sites inhabited by this community are slightly inclined in various directions and mostly grazed (55%), more rarely mown (45%). Soils have an intermediate humus content (11.0%) and a relatively low pH (7.11). Our records are from various locations in the county of Cluj, but the association is likely occurring also in other places in Transylvania.

**Syntaxonomy:** As to our knowledge, *Agrostio-Danthonietum alpinae* is the oldest valid name available for the grazed Transylvanian *Cirsio-Brachypodium pinnati* communities with some transition character towards the *Cynosurion cristati*. While it is likely that similar stands also occur outside Transylvania (the diagnostic species are mostly widespread), there is no easy match with associations described elsewhere. The *Scabioso ochroleucae-Brachypodium pinnati* Klika 1933 has some similarities, but seemingly does not show as much the character of a pasture as our stands (compare descriptions in CHYTRÝ et al. 2007, JANIŠOVÁ 2007). Another association with considerable floristic similarities is the *Anthoxantho odorati-Agrostietum tenuis* Sillinger 1933, which by HÁJKOVÁ et al. (2007) is placed in the *Cynosurion cristati* Tx. 1947 and by JANIŠOVÁ (2007) in the *Arrhenatherion elatioris* Luquet 1926. Our data match the lists of diagnostic and constant species in HÁJKOVÁ et al. (2007) rather well, except that the Czech stands lack several continental *Festuco-Brometea* species that are frequent in the Transylvanian stands (*Adonis vernalis*, *Carex michelii*, *Danthonia alpina*, *Eryngium campestre*, *Festuca* ser. *Valesiaca*, *Filipendula vulgaris*).

### Association 3.1.4: *Cirsium furiens-Brachypodium pinnatum*-[*Cirsio-Brachypodium pinnati*] community

**Characterisation:** Moderately species poor community, which is the mainly negatively characterised central association within the Transylvanian *Cirsio-Brachypodium pinnati* communities. There is no highly diagnostic species, and only five infrequent diagnostic species, namely *Cirsium furiens*, *Agrimonia eupatoria*, the shrub *Prunus spinosa*, and the two mosses *Thuidium assimile* and *Campyliadelphus chrysophyllus*. The herb layer is dominated by *Brachypodium pinnatum* and/or *Festuca* ser. *Valesiaca*, while the most covering forbs are *Fragaria viridis*, *Dorycnium pentaphyllum* subsp. *herbaceum*, and *Salvia verticillata*. The cover values of moss layer and litter are above average.

**Ecology and distribution:** Site conditions are similar to the *Agrostio-Danthonietum alpinae* (Assoc. 3.1.3), only the soil reaction is more alkaline on average (pH 7.64). While the majority of sites is still extensively grazed (54%), a significant part (38%) has been abandoned for several years. We recorded the association in the counties of Braşov, Cluj, and Sibiu, but it is probably widespread throughout the Transylvanian Plateau.



**Syntaxonomy:** To determine whether among the many association names of semi-dry basiphilous grasslands described from Transylvania one is applicable for this central association is a tricky task that best should be done based on a numerical classification of a much more comprehensive set of relevés from the region, including all the relevant type relevés. The same applies for a possible matching with associations described elsewhere, *Scabioso ochroleuca-Brachypodietum pinnati* Klika 1933 probably being the closest match (see descriptions in CHYTRÝ et al. 2007, JANIŠOVÁ 2007). For the time being, we prefer to list this association under the given informal name.

Since MEUSEL's (1938) description of a *Stipetum stenophyllae* many researchers have proposed one or even several specific associations for dry grasslands dominated by *Stipa tirsae* (= *S. stenophylla*) (e.g. GHIȘA 1941, SÓO 1947, SCHUBERT et al. 2001, BORHIDI 2003, CHYTRÝ et al. 2007, SANDA et al. 2008, YAMALOV et al. 2009, DÚBRAVKOVÁ et al. 2010). We have one such relevé (No. 54 = ROR014), which by our numerical classification was placed within Association 3.1.4, while otherwise *Stipa tirsae* is more frequent (albeit with much less cover) in the *Festuco sulcatae-Brachypodietum pinnati* (Assoc. 3.1.2). It is beyond the scope of the present article to elucidate the justification of a special *Stipa tirsae*-dominated association. However, if a large-scale numerical analysis should support this concept, it is clear that this association is a meso-xeric community (as already stated in the protologue by MEUSEL 1938) and thus belongs to the alliance *Cirsio-Brachypodion pinnati* (e.g. SCHUBERT et al. 2001), and not to the xeric *Festucion valesiacae* Klika 1931 as recently proposed by CHYTRÝ et al. (2007) and DÚBRAVKOVÁ et al. (2010) despite also in their relevés *Cirsio-Brachypodion pinnati* species prevail over *Festucion valesiacae* species. Moreover, at least within the range of the *Cirsio-Brachypodion pinnati*, i.e. west of the former Sovietunion, a character species-based approach would allow for not more than one such association, and the correct name for this would be *Stipetum stenophyllae* Meusel 1940.

## 5. Ecology and biodiversity

### 5.1. Vegetation-environment relationships

Among the studied vegetation plots, 50% were used as pasture (i.e. were grazed by cattle or sheep), 17% were used as hay field (i.e. were regularly mown), while 33% were not used at all (i.e. either were abandoned or were natural grasslands). The humus content in the soils varied widely (mean: 10.6%; range: 1.1–30.1%). Soils were generally base rich with a mean pH (H<sub>2</sub>O) of 7.61 (range: 6.05–8.41) and a mean pH(CaCl<sub>2</sub>) of 7.12 (range: 5.19–7.81). Accordingly, most soils contained carbonate, frequently even more than 10%, only 23% of the samples were carbonate free. In most soils, the fractions of silt and clay clearly prevailed, with the German texture classes (for definitions, see AD-HOC-AG BODEN 2005) Tu3 (26%), Ut4 (25%), and Ut3 (18%) being the most frequent ones.

The first DCA axis was strongly positively correlated with heat index (also indicated by the indicator value for temperature) and inclination of the slope, and negatively with EIVs for moisture and for nutrients and with vegetation cover (Fig. 3). This supports the assumption that water supply is the main cause of floristic dissimilarity of the grasslands, resulting in a separation between closed stands of mostly flat and more mesic sites, which may be extremely species rich, and open stands at the steeper and dryer sites containing fewer species (Table 4). Moreover, the pH value of the soil and the indicator value for soil reaction increased slightly with the first axis, indicating that floristic variation is also affected by soil characteristics. A decreasing cover of herb layer and increasing cover of moss layer along the first axis separated the more open stands of the *Stipo pulcherrimae-Festucetalia pallentis* and *Festucetalia valesiacae* from the denser *Brachypodietalia pinnati*.

The second axis was most strongly negatively correlated with loss at ignition, proportion of stony ground, richness of bryophytes and lichens as well as altitude, indicating a gradient from open grasslands with many cryptogam species at rocky (partly eroded) sites with less humus to dense grasslands with fewer cryptogam species on consolidated substrates containing more humus. The third axis showed little correlation with environmental or vegetation variables.

Table 4: Correlation of the DCA axes with environmental and vegetation parameters. EIV = Ellenberg indicator value. Pearson correlation coefficients ( $r$ ) are shown; signs indicate the direction of correlation. Significant correlations ( $\alpha = 0.05$ ) are indicated in bold. Note, that significance levels of EIV correlations should not be taken at face value because due to the non-independence of the variables, the actual error probabilities are normally higher than those calculated with Pearson correlations.

Tab. 4: Zusammenhänge zwischen den Achsen der DCA und Umweltvariablen. Es sind die Pearson-Korrelationskoeffizienten ( $r$ ) dargestellt; das Vorzeichen gibt die Richtung des Zusammenhangs an. Signifikante Zusammenhänge ( $\alpha = 0,05$ ) sind fett dargestellt. Man beachte, dass die Signifikanzwerte der Pearson-Korrelationen mit den Zeigerwerten nicht überbewertet werden sollten, da die Variablen voneinander abhängig sind und Pearson-Korrelationen daher die tatsächlichen Typ-I-Fehlerraten unterschätzen.

	DCA axis 1		DCA axis 2		DCA axis 3		<i>n</i>
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	
Altitude	0.13	0.237	<b>-0.41</b>	< 0.001	<b>0.37</b>	0.001	82
Inclination	<b>0.70</b>	< 0.001	<b>0.32</b>	0.004	<b>0.29</b>	0.008	82
Heat index	<b>0.85</b>	< 0.001	<b>0.40</b>	< 0.001	-0.07	0.560	82
Microrelief	<b>0.36</b>	0.001	-0.04	0.720	0.06	0.596	82
Loss at ignition of the soil	<b>-0.28</b>	0.013	<b>-0.62</b>	< 0.001	-0.01	0.905	80
pH (H <sub>2</sub> O) of the soil	<b>0.46</b>	< 0.001	<b>0.36</b>	0.001	<b>0.40</b>	< 0.001	80
EIV for temperature (T)	<b>0.90</b>	< 0.001	<b>0.41</b>	< 0.001	0.03	0.815	82
EIV for moisture (M)	<b>-0.89</b>	< 0.001	-0.13	0.231	0.01	0.934	82
EIV for soil reaction (R)	<b>0.87</b>	< 0.001	<b>0.46</b>	< 0.001	0.09	0.443	82
EIV for nutrients (N)	<b>-0.82</b>	< 0.001	-0.15	0.177	-0.19	0.079	82
Cover of herb layer	<b>-0.48</b>	< 0.001	-0.20	0.074	<b>-0.26</b>	0.019	82
Cover of moss layer	<b>-0.36</b>	0.001	<b>-0.41</b>	< 0.001	0.07	0.556	82
Cover of litter	-0.13	0.244	-0.07	0.540	<b>0.45</b>	< 0.001	82
Cover of stones	0.20	0.070	<b>-0.57</b>	< 0.001	0.07	0.540	82
Cover of open soil	<b>0.52</b>	< 0.001	<b>0.59</b>	< 0.001	-0.02	0.855	82
Maximum vegetation height	<b>-0.26</b>	0.021	0.09	0.447	0.01	0.943	76
Species richness all taxa (10 m <sup>2</sup> )	<b>-0.73</b>	< 0.001	<b>-0.39</b>	< 0.001	-0.09	0.422	82
Species richness vascular plants (10 m <sup>2</sup> )	<b>-0.73</b>	< 0.001	<b>-0.31</b>	0.004	-0.12	0.273	82
Species richness bryophytes (10 m <sup>2</sup> )	<b>-0.38</b>	0.001	<b>-0.50</b>	< 0.001	0.21	0.061	82
Species richness lichens (10 m <sup>2</sup> )	0.19	0.080	<b>-0.62</b>	< 0.001	0.03	0.769	82

Strong ecological variation and also variation in vegetation became evident when comparing higher syntaxa (Table 5), but partly even among associations within the same order (Table 6). *Brachypodietalia pinnati* communities occurred on the gentlest slopes (17% inclination) with lowest radiation (heat index of -0.03) and lowest microrelief of the soil. Ellenberg indicator values indicate that habitats here were the coolest and the moistest and exhibited the highest nutrient supply. Moderate growing conditions in these stands resulted in a dense herb layer (83%) and high species richness of vascular plants (62 species on 10 m<sup>2</sup>). In contrast, the *Stipo pulcherrimae-Festucetalia pallentis* communities occurred on steeper slopes (heat index of 0.47) with higher radiation at higher altitudes within the study area (617 m a.s.l. vs. about 470 m a.s.l. in the two other orders). Ellenberg indicator values here indicated that habitats were warmer, drier, and less nutrient rich. The stands were more open (54% cover of herb layer) and occurred on rocky substrate indicated by 28% cover of stones. The stands contained more lichen species (2.3 vs. about 0.1), but overall species richness was much lower than in the *Brachypodietalia pinnati*. However, it was comparable to the *Festucetalia valesiacae*. These typical steppe-like grasslands also occurred on steep slopes with high radiation but on less stony soils. The sites of the *Festucetalia valesiacae* were characterised by the largest amount of bare soil (24%), related to the drought indicated by Ellenberg indicator values for moisture. Moreover, these typical steppe-like grasslands were species-rich in vascular plants but poor in bryophytes and lichens probably due to light competition by the relatively high and moderately dense herb layer in combination with drought.

Table 5: Characteristics of the three dry-grassland orders in Transylvania. Means and standard deviations are given. Different letters indicate significant differences between communities at  $\alpha = 0.05$  from Tukey's HSD test. EIV = Ellenberg indicator value.  $p$  values derived from ANOVA. A small fraction of parameters was not available for all plots, see Table 4. Note, that the presented significance levels of EIV comparisons between communities should not be taken at face value because Type I error rates are inflated due to the non-independence of the values.

Tab. 5: Eigenschaften der drei Trockenrasenordnungen in Siebenbürgen. Mittelwerte mit Standardabweichung sind dargestellt. Werte mit unterschiedlichen Buchstaben unterscheiden sich signifikant bei  $\alpha = 0,05$  nach Tukeys HSD-Test. EIV =Ellenberg-Zeigerwert. Die  $p$ -Werte stammen aus Varianzanalysen. Einige wenige Parameter standen nicht für alle Aufnahmen zur Verfügung, siehe Tabelle 4. Man beachte, dass die Signifikanzwerte der EIV-Vergleiche nicht überbewertet werden dürfen, da die Variablen voneinander abhängig und die Typ-I-Fehlerraten daher in einer einfachen Varianzanalyse unterschätzt werden.

	<i>Stipo pulcherrimae-Festucetalia pallentis</i>	<i>Festucetalia valesiacae</i>	<i>Brachypodietalia pinnati</i>	$p$
No. of relevés ( $n$ )	8	36	38	
Altitude (m a.s.l.)	617 ± 59 <sup>a</sup>	472 ± 64 <sup>b</sup>	474 ± 70 <sup>b</sup>	< 0.001
Inclination (°)	31 ± 4 <sup>a</sup>	33 ± 8 <sup>a</sup>	17 ± 11 <sup>b</sup>	< 0.001
Heat index	0.47 ± 0.21 <sup>a</sup>	0.58 ± 0.23 <sup>a</sup>	-0.03 ± 0.25 <sup>b</sup>	< 0.001
Microrelief (cm)	15.8 ± 14.1 <sup>a</sup>	8.9 ± 9.0 <sup>ab</sup>	4.8 ± 6.3 <sup>b</sup>	0.003
Loss at ignition of the soil	18.8 ± 8.4 <sup>a</sup>	7.3 ± 3.8 <sup>c</sup>	11.8 ± 3.2 <sup>b</sup>	< 0.001
pH (H <sub>2</sub> O) of the soil	7.5 ± 0.3 <sup>ab</sup>	7.9 ± 0.3 <sup>a</sup>	7.4 ± 0.7 <sup>b</sup>	0.001
EIV for temperature (T)	6.5 ± 0.2 <sup>a</sup>	6.6 ± 0.3 <sup>a</sup>	5.8 ± 0.2 <sup>a</sup>	< 0.001
EIV for moisture (M)	2.6 ± 0.3 <sup>c</sup>	2.9 ± 0.2 <sup>b</sup>	3.6 ± 0.3 <sup>a</sup>	< 0.001
EIV for soil reaction (R)	7.6 ± 0.2 <sup>b</sup>	7.8 ± 0.2 <sup>a</sup>	7.2 ± 0.2 <sup>c</sup>	< 0.001
EIV for nutrients (N)	2.3 ± 0.1 <sup>b</sup>	2.5 ± 0.3 <sup>b</sup>	3.1 ± 0.2 <sup>a</sup>	< 0.001
Cover of herb layer (%)	54 ± 14 <sup>b</sup>	66 ± 21 <sup>ab</sup>	83 ± 25 <sup>a</sup>	< 0.001
Cover of moss layer (%)	21 ± 17 <sup>a</sup>	1 ± 2 <sup>b</sup>	18 ± 20 <sup>a</sup>	< 0.001
Cover of litter (%)	32 ± 34	19 ± 19	27 ± 24	0.165
Cover of stones (%)	28 ± 25 <sup>a</sup>	0 ± 1 <sup>b</sup>	0 ± 0 <sup>b</sup>	< 0.001
Cover of open soil (%)	6 ± 4 <sup>b</sup>	24 ± 20 <sup>a</sup>	6 ± 7 <sup>b</sup>	< 0.001
Maximum vegetation height (cm)	64 ± 17 <sup>b</sup>	79 ± 18 <sup>ab</sup>	83 ± 28 <sup>a</sup>	0.101
Species richness all taxa (10 m <sup>2</sup> )	46.4 ± 12.9 <sup>b</sup>	40.2 ± 11.2 <sup>b</sup>	66.0 ± 16.3 <sup>a</sup>	< 0.001
Species richness vascular plants (10 m <sup>2</sup> )	39.5 ± 11.5 <sup>b</sup>	38.9 ± 10.6 <sup>b</sup>	62.2 ± 16.1 <sup>a</sup>	< 0.001
Species richness bryophytes (10 m <sup>2</sup> )	4.6 ± 2.8 <sup>a</sup>	1.3 ± 1.4 <sup>b</sup>	3.6 ± 2.1 <sup>a</sup>	< 0.001
Species richness lichens (10 m <sup>2</sup> )	2.3 ± 2.0 <sup>a</sup>	0.0 ± 0.2 <sup>b</sup>	0.1 ± 0.3 <sup>b</sup>	< 0.001

In our study, vegetation composition and thus community differentiation was mainly affected by water availability of the soil. This finding was expected, and has been shown in several other studies combining dry and semi-dry grasslands throughout the range of the *Festuco-Brometea* (e.g. in the central German arid region; BECKER et al. 2007, 2011). This fact shows that dry grasslands in Eastern Europe are driven by the same ecological factors as those in central Europe. Presumably, east European dry-grasslands are also affected (and threatened) in a very similar manner e.g. by changes in landuse (for example through moister conditions due to abandonment) or by climate change as the central European stands. We also expect that tree growth is possible at most of the sites with the exception of those of the *Stipetum lessingiana* which naturally seems to be far-reaching treeless as a result of extreme summer drought. The low influence of the soil pH – which is known as a strong ecological factor in many nutrient-poor grasslands (e.g. CHYTRÝ et al. 2003, BECKER et al. 2007, 2012) – on the vegetation composition of our stands confirms our expectations because of less carbonate leaching due to lower precipitation and high evapotranspiration in summer.

Table 6: Characteristics of the seven analysed dry grassland associations in Transylvania. Means and standard deviations are given. Different letters indicate significant differences between communities at  $\alpha = 0.05$  according to Tukey's HSD test. EIV = Ellenberg indicator value,  $p$  values derived from ANOVA. Note that a small fraction of parameters was not available for all plots, see Table 4. Note, that the presented significance levels of EIV comparisons between communities should not be taken at face value because Type I error rates are inflated due to the non-independence of the values.

Tabelle 6: Eigenschaften der sieben untersuchten Trockenrasenassoziationen in Siebenbürgen. Es sind Mittelwerte mit Standardabweichungen angegeben. Werte mit unterschiedlichen Buchstaben unterscheiden sich signifikant bei  $\alpha = 0,05$  nach dem Tukeys HSD-Test. EIV = Ellenberg-Zeigerwert. Die  $p$ -Werte stammen aus Varianzanalysen. Einige wenige Parameter standen nicht für alle Aufnahmen zur Verfügung, siehe Tab. 4. Man beachte, dass die Signifikanzwerte der EIV-Vergleiche nicht überbewertet werden dürfen, da die Variablen voneinander abhängig sind und die Typ-I-Fehlerrate daher in einer einfachen Varianzanalyse unterschätzt wird.

	Assoc. 1.1.1	Assoc. 1.1.2	Assoc. 2.1.1	Assoc. 2.1.2	Assoc. 2.1.3	Assoc. 3.1.1	Assoc. 3.1.2	Assoc. 3.1.3	Assoc. 3.1.4	$p$
No. of relevés ( $n$ )	3	5	3	14	19	5	11	9	13	
Altitude (m a.s.l.)	603 ± 91 <sup>ab</sup>	624 ± 42 <sup>a</sup>	404 ± 14 <sup>c</sup>	492 ± 32 <sup>bc</sup>	463 ± 79 <sup>c</sup>	498 ± 22 <sup>bc</sup>	489 ± 60 <sup>bc</sup>	423 ± 74 <sup>c</sup>	480 ± 78 <sup>c</sup>	< 0.001
Inclination (°)	28 ± 6 <sup>bc</sup>	33 ± 1 <sup>b</sup>	47 ± 5 <sup>a</sup>	34 ± 7 <sup>ab</sup>	29 ± 7 <sup>bc</sup>	32 ± 9 <sup>b</sup>	12 ± 6 <sup>d</sup>	17 ± 10 <sup>cd</sup>	16 ± 10 <sup>cd</sup>	< 0.001
Heat index	0.51 ± 0.10 <sup>b</sup>	0.45 ± 0.26 <sup>bc</sup>	1.06 ± 0.15 <sup>a</sup>	0.60 ± 0.15 <sup>b</sup>	0.49 ± 0.18 <sup>b</sup>	-0.32 ± 0.23 <sup>e</sup>	-0.13 ± 0.13 <sup>de</sup>	0.04 ± 0.16 <sup>d</sup>	0.12 ± 0.25 <sup>cd</sup>	< 0.001
Microrelief (cm)	10.7 ± 5.1 <sup>bc</sup>	18.8 ± 17.5 <sup>ab</sup>	25.0 ± 22.9 <sup>a</sup>	7.1 ± 3.8 <sup>bc</sup>	7.7 ± 6.5 <sup>bc</sup>	11.4 ± 6.1 <sup>abc</sup>	1.8 ± 2.4 <sup>c</sup>	8.6 ± 9.6 <sup>bc</sup>	2.2 ± 1.0 <sup>c</sup>	< 0.001
Loss at ignition of the soil	16.7 ± 3.8 <sup>ab</sup>	20.1 ± 10.6 <sup>a</sup>	8.3 ± 11.5 <sup>cd</sup>	5.8 ± 1.7 <sup>d</sup>	8.4 ± 3.0 <sup>cd</sup>	9.7 ± 3.5 <sup>bcd</sup>	13.6 ± 1.6 <sup>abc</sup>	11.0 ± 3.3 <sup>bcd</sup>	11.8 ± 3.8 <sup>bcd</sup>	< 0.001
pH (H <sub>2</sub> O) of the soil	7.7 ± 0.2 <sup>ab</sup>	7.4 ± 0.4 <sup>ab</sup>	7.9 ± 0.1 <sup>ab</sup>	7.9 ± 0.4 <sup>ab</sup>	7.9 ± 0.3 <sup>ab</sup>	8.0 ± 0.2 <sup>a</sup>	7.0 ± 0.7 <sup>b</sup>	7.1 ± 0.9 <sup>ab</sup>	7.6 ± 0.6 <sup>ab</sup>	< 0.001
EIV for temperature (T)	6.2 ± 0.1 <sup>cd</sup>	6.6 ± 0.1 <sup>bc</sup>	7.0 ± 0.5 <sup>a</sup>	6.6 ± 0.1 <sup>ab</sup>	6.5 ± 0.3 <sup>bc</sup>	5.6 ± 0.2 <sup>e</sup>	5.9 ± 0.1 <sup>de</sup>	5.8 ± 0.2 <sup>e</sup>	5.9 ± 0.2 <sup>de</sup>	< 0.001
EIV for moisture (M)	2.8 ± 0.2 <sup>bcd</sup>	2.5 ± 0.2 <sup>d</sup>	2.5 ± 0.2 <sup>cd</sup>	2.9 ± 0.2 <sup>bc</sup>	3.0 ± 0.2 <sup>b</sup>	3.9 ± 0.3 <sup>a</sup>	3.7 ± 0.1 <sup>a</sup>	3.6 ± 0.2 <sup>a</sup>	3.5 ± 0.3 <sup>a</sup>	< 0.001
EIV for soil reaction (R)	7.6 ± 0.3 <sup>ab</sup>	7.6 ± 0.1 <sup>ab</sup>	7.9 ± 0.4 <sup>a</sup>	7.8 ± 0.1 <sup>a</sup>	7.8 ± 0.2 <sup>a</sup>	7.0 ± 0.2 <sup>d</sup>	7.2 ± 0.1 <sup>cd</sup>	7.2 ± 0.2 <sup>cd</sup>	7.3 ± 0.2 <sup>bc</sup>	< 0.001
EIV for nutrients (N)	2.4 ± 0.1 <sup>bc</sup>	2.3 ± 0.2 <sup>bc</sup>	2.1 ± 0.1 <sup>c</sup>	2.5 ± 0.2 <sup>b</sup>	2.5 ± 0.3 <sup>bc</sup>	3.0 ± 0.2 <sup>a</sup>	3.1 ± 0.2 <sup>a</sup>	3.1 ± 0.3 <sup>a</sup>	3.0 ± 0.2 <sup>a</sup>	< 0.001
Cover of herb layer (%)	52 ± 25 <sup>cd</sup>	55 ± 4 <sup>bcd</sup>	28 ± 19 <sup>d</sup>	69 ± 8 <sup>abc</sup>	69 ± 22 <sup>abc</sup>	55 ± 51 <sup>bcd</sup>	92 ± 4 <sup>a</sup>	89 ± 8 <sup>ab</sup>	81 ± 25 <sup>abc</sup>	< 0.001
Cover of moss layer (%)	8 ± 10 <sup>ab</sup>	28 ± 16 <sup>a</sup>	0 ± 0 <sup>b</sup>	1 ± 1 <sup>b</sup>	1 ± 2 <sup>b</sup>	24 ± 28 <sup>ab</sup>	9 ± 3 <sup>ab</sup>	23 ± 25 <sup>ab</sup>	18 ± 20 <sup>ab</sup>	< 0.001
Cover of litter (%)	37 ± 47 <sup>ab</sup>	30 ± 30 <sup>ab</sup>	2 ± 2 <sup>b</sup>	19 ± 15 <sup>b</sup>	21 ± 21 <sup>ab</sup>	57 ± 15 <sup>a</sup>	15 ± 17 <sup>b</sup>	12 ± 12 <sup>b</sup>	36 ± 24 <sup>ab</sup>	0.001
Cover of stones (%)	41 ± 35 <sup>a</sup>	21 ± 17 <sup>b</sup>	0 ± 0 <sup>c</sup>	1 ± 2 <sup>c</sup>	0 ± 0 <sup>c</sup>	0 ± 0 <sup>c</sup>	0 ± 0 <sup>c</sup>	0 ± 0 <sup>c</sup>	0 ± 1 <sup>c</sup>	< 0.001
Cover of open soil (%)	2 ± 1 <sup>b</sup>	7 ± 5 <sup>b</sup>	70 ± 22 <sup>a</sup>	20 ± 12 <sup>b</sup>	20 ± 16 <sup>b</sup>	13 ± 11 <sup>b</sup>	4 ± 3 <sup>b</sup>	7 ± 10 <sup>b</sup>	4 ± 5 <sup>b</sup>	< 0.001
Maximum vegetation height (cm)	68 ± 20 <sup>b</sup>	61 ± 16 <sup>b</sup>	87 ± 21 <sup>ab</sup>	84 ± 12 <sup>ab</sup>	73 ± 20 <sup>b</sup>	77 ± 22 <sup>b</sup>	113 ± 22 <sup>a</sup>	65 ± 16 <sup>b</sup>	72 ± 22 <sup>b</sup>	< 0.001
Species richness all taxa (10 m <sup>2</sup> )	39.3 ± 9.1 <sup>c</sup>	50.8 ± 13.5 <sup>bc</sup>	15.0 ± 10.4 <sup>d</sup>	46.6 ± 7.7 <sup>c</sup>	39.9 ± 7.5 <sup>c</sup>	67.4 ± 6.2 <sup>ab</sup>	82.6 ± 10.8 <sup>a</sup>	66.0 ± 10.2 <sup>ab</sup>	51.3 ± 12.2 <sup>bc</sup>	< 0.001
Species richness vascular plants (10 m <sup>2</sup> )	33.3 ± 9.5 <sup>d</sup>	43.2 ± 11.9 <sup>d</sup>	15.0 ± 10.4 <sup>e</sup>	44.5 ± 6.9 <sup>cd</sup>	38.5 ± 7.3 <sup>d</sup>	60.6 ± 5.3 <sup>bc</sup>	80.2 ± 10.5 <sup>a</sup>	61.9 ± 9.0 <sup>b</sup>	47.9 ± 11.2 <sup>bd</sup>	< 0.001
Species richness bryophytes (10 m <sup>2</sup> )	5.0 ± 4.4 <sup>ab</sup>	4.4 ± 2.1 <sup>abc</sup>	0.0 ± 0.0 <sup>d</sup>	1.6 ± 1.2 <sup>cd</sup>	1.3 ± 1.6 <sup>cd</sup>	6.8 ± 1.9 <sup>a</sup>	2.5 ± 0.9 <sup>bcd</sup>	3.9 ± 1.6 <sup>abc</sup>	3.2 ± 2.1 <sup>bc</sup>	< 0.001
Species richness lichens (10 m <sup>2</sup> )	1.0 ± 1.7 <sup>b</sup>	3.0 ± 1.9 <sup>a</sup>	0.0 ± 0.0 <sup>b</sup>	0.1 ± 0.3 <sup>b</sup>	0.0 ± 0.0 <sup>b</sup>	0.0 ± 0.0 <sup>b</sup>	0.0 ± 0.0 <sup>b</sup>	0.2 ± 0.4 <sup>b</sup>	0.2 ± 0.4 <sup>b</sup>	< 0.001

## 5.2. Biodiversity patterns

The *Brachypodietalia pinnati* were by far the most species rich order at all analysed spatial scales from 1 cm<sup>2</sup> to 100 m<sup>2</sup>, both for all taxa and vascular plants (Tables 5 and 7). However the differences decreased slightly from smaller to larger grain sizes, with the *Brachypodietalia pinnati* being twice as rich as the two xeric orders at small scales, but only 50% richer at the 100-m<sup>2</sup> scale (mean total phytodiversity 106.2 vs. 70.1 species). The differences between the two other orders were not significant because of the low number of replicates, but for the 10-m<sup>2</sup> scale Table 5 indicates a tendency of the *Stipo pulcherrimae-Festucetalia pallentis* to be approx. 15% richer than the *Festucetalia valesiaca* when all taxonomic groups are combined. While the number of vascular plants was practically the same, the *Stipo pulcherrimae-Festucetalia pallentis* contained more lichens than either of the two orders and together with the *Brachypodietalia pinnati* more bryophytes than the *Festucetalia valesiaca*. However, these differences for cryptogam richness were only significant for the plot sizes from 1 m<sup>2</sup> upwards. Among the associations at the 10-m<sup>2</sup> level, the *Festuco sulcatae-Brachypodietum pinnati* was richest in all taxa (mean: 82.6 species), followed with clear separation by *Orchido militaris-Seslerietum heufleranae* (67.4) and *Agrostio-Danthonietum alpinae* (66.0) (Table 6). The bulk of associations from all three orders contained between 39–52 species at 10 m<sup>2</sup> (values that would be considered extremely species rich in most other parts of Europe), while the pioneer-like vegetation of the *Artemisietum pontico-sericeae* contained the fewest species (15.0) (Table 6).

The most species rich stands both for all taxa and for vascular plants alone at all spatial scales from 1 cm<sup>2</sup> to 100 m<sup>2</sup> belonged to meso-xeric alliance *Cirsio-Brachypodion pinnati*. While for grain sizes below 0.1 m<sup>2</sup> some extreme values also occurred in grazed stands of the *Agrostio-Danthonietum alpinae* (Assoc. 3.1.3), from 0.1 m<sup>2</sup> upwards the typically mown stands of the *Festuco sulcatae-Brachypodietum pinnati* (Assoc. 3.1.2) surpassed all other Transylvanian dry grassland types. Most extreme were the stands in one particular site close to Cluj-Napoca (nature reserve Fânațele Clujului; long known in the botanical literature, see e.g. PRODAN 1931, GHIȘA 1946). According to WILSON et al. (in press), our nested plot series RO01 and RO02 (documented in Table 8) contained the highest ever recorded vascular plant species richness at two spatial scales (0.1 m<sup>2</sup> and 10 m<sup>2</sup>) in any vegetation type worldwide, and was equal to the world records for 1 cm<sup>2</sup> (5 species found in two of our Transylvanian series). For the other spatial scales, the maxima in the *Festuco sulcatae-Brachypodietum pinnati* are only slightly below the vascular plant richness records (WILSON et al. in press): 8 vs. 12 species (67%) found in 0.001 m<sup>2</sup> of a Swedish limestone grassland (VAN DER MAAREL & SYKES 1993, corrected in WILSON et al. in press); 18 vs. 25 species (72%) found in 0.01 m<sup>2</sup> of wooded meadow in Estonia (KULL & ZOBEL 1991) and 79 vs. 89 species (89%) found in 1 m<sup>2</sup> of mountain grassland in Argentina (CANTERO et al. 1999). At some intermediate scales, mown semi-dry basiphilous grasslands (*Brachypodio pinnati-Molinietum arundinaceae* Klika 1939) in the White Carpathians (Czechia), which are floristically and ecologically similar to those in Transylvania, hold the world records (KLIMEŠ et al. 2001, WILSON et al. in press). It is interesting and challenging to ecological theories to realise that at scales below 100 m<sup>2</sup> maxima of vascular plant species richness are exclusively found in semi-natural (i.e. grazed or mown at low intensity) grasslands of the temperate zone (WILSON et al. in press). The sites are typically oligo-mesotrophic, base-rich, cover relatively small areas, but seem to have continuously been in use as grasslands for centuries or even millennia. Only from 100 m<sup>2</sup> upwards do tropical rainforests “outcompete” the temperate grasslands in plant diversity (Tables 7 and 8).

While semi-dry basiphilous grasslands (*Brachypodietalia pinnati*) are also typically the most species rich vascular plant communities (at small scale) in other regions of temperate Europe (HOBBOHM 1998, DENGLER 2005, BOCH & DENGLER 2006, LÖBEL & DENGLER 2008), the values encountered here are much higher than elsewhere. In Northeast Germany (DENGLER 2005: Fig. 1), Estonia (BOCH & DENGLER 2006) and South Sweden (LÖBEL & DENGLER 2008) the association-level means are only around 30 vascular plant taxa on 10 m<sup>2</sup>



Table 7: Scale-dependent species richness parameters (means  $\pm$  standard deviations) of the three phytosociological orders derived from 20 nested-plot series. Differences in mean values among orders have been tested with ANOVAs; the respective  $p$ -values are given in the last column and homogeneous groups according to Tukey's HSD test at  $\alpha = 0.05$  are indicated with identical superscript letters. Note that in some cases the overall pattern was significant, while there was no significant pairwise difference. The columns Min and Max denote the minimum and maximum values encountered in the dataset.

Tab. 7: Skalenabhängige Diversitätsparameter (Mittelwerte  $\pm$  Standardabweichungen) für die drei pflanzensoziologischen Ordnungen, basierend auf 20 *nested plot*-Serien. Mögliche Unterschiede in den Mittelwerten zwischen den Ordnungen wurden mittels Varianzanalyse getestet; die zugehörigen  $p$ -Werte sind in der letzten Spalte angegeben, während hochgestellte Kleinbuchstaben homogene Gruppen gemäß Tukeys HSD-Test auf einem Signifikanzniveau von  $\alpha = 0.05$  bezeichnen. Man beachte, dass das Gesamtmuster in einigen Fällen signifikant war, ohne dass es eine signifikante Paardifferenz gab. Die Spalten Min und Max bezeichnen die insgesamt aufgetretenen Extremwerte.

Plot size	Min	Max	<i>Stipo pulcherrimae-Festucetalia pallentis</i>	<i>Festucetalia valesiaca</i>	<i>Brachypodietalia pinnati</i>	$p$
$n$	40*	40*	2	8	10	
<b>Species richness all taxa</b>						
0.0001 m <sup>2</sup>	0	5	1.8 $\pm$ 1.1 <sup>b</sup>	1.7 $\pm$ 1.0 <sup>b</sup>	3.4 $\pm$ 0.8 <sup>a</sup>	0.002
0.001 m <sup>2</sup>	0	9	3.0 $\pm$ 0.0 <sup>b</sup>	2.9 $\pm$ 1.4 <sup>b</sup>	6.2 $\pm$ 1.3 <sup>a</sup>	< 0.001
0.01 m <sup>2</sup>	3	20	5.5 $\pm$ 1.4 <sup>b</sup>	7.2 $\pm$ 2.2 <sup>b</sup>	13.5 $\pm$ 4.3 <sup>a</sup>	0.002
0.1 m <sup>2</sup>	7	45	13.0 $\pm$ 2.8 <sup>b</sup>	15.7 $\pm$ 4.8 <sup>b</sup>	30.4 $\pm$ 7.6 <sup>a</sup>	< 0.001
1 m <sup>2</sup>	18	82	27.0 $\pm$ 7.8 <sup>b</sup>	29.6 $\pm$ 6.2 <sup>b</sup>	51.0 $\pm$ 12.3 <sup>a</sup>	0.001
10 m <sup>2</sup>	37	101	45.8 $\pm$ 11.0 <sup>b</sup>	47.7 $\pm$ 5.1 <sup>b</sup>	73.7 $\pm$ 13.8 <sup>a</sup>	< 0.001
100 m <sup>2</sup>	58	134	68.5 $\pm$ 12.0 <sup>b</sup>	70.5 $\pm$ 7.6 <sup>b</sup>	106.2 $\pm$ 20.8 <sup>a</sup>	< 0.001
<b>Species richness vascular plants</b>						
0.0001 m <sup>2</sup>	0	5	1.3 $\pm$ 1.1 <sup>b</sup>	1.6 $\pm$ 1.0 <sup>ab</sup>	3.1 $\pm$ 0.7 <sup>a</sup>	0.003
0.001 m <sup>2</sup>	0	8	2.5 $\pm$ 0.0 <sup>b</sup>	2.9 $\pm$ 1.3 <sup>b</sup>	5.6 $\pm$ 0.9 <sup>a</sup>	< 0.001
0.01 m <sup>2</sup>	3	18	4.8 $\pm$ 1.1 <sup>b</sup>	6.9 $\pm$ 2.0 <sup>b</sup>	12.6 $\pm$ 3.9 <sup>a</sup>	0.002
0.1 m <sup>2</sup>	7	43	10.5 $\pm$ 0.7 <sup>b</sup>	14.8 $\pm$ 4.5 <sup>b</sup>	28.3 $\pm$ 7.7 <sup>a</sup>	< 0.001
1 m <sup>2</sup>	16	79	22.5 $\pm$ 4.9 <sup>b</sup>	27.8 $\pm$ 5.7 <sup>b</sup>	48.2 $\pm$ 12.5 <sup>a</sup>	0.001
10 m <sup>2</sup>	33	98	38.5 $\pm$ 7.1 <sup>b</sup>	45.6 $\pm$ 4.6 <sup>b</sup>	70.2 $\pm$ 14.5 <sup>a</sup>	< 0.001
100 m <sup>2</sup>	52	127	55.5 $\pm$ 4.9 <sup>b</sup>	67.5 $\pm$ 7.4 <sup>b</sup>	101.5 $\pm$ 20.7 <sup>a</sup>	< 0.001
<b>Species richness bryophytes</b>						
0.0001 m <sup>2</sup>	0	1	0.5 $\pm$ 0.0	0.1 $\pm$ 0.2	0.3 $\pm$ 0.3	0.096
0.001 m <sup>2</sup>	0	2	0.5 $\pm$ 0.0	0.1 $\pm$ 0.2	0.6 $\pm$ 0.5	0.031
0.01 m <sup>2</sup>	0	2	0.8 $\pm$ 0.4	0.3 $\pm$ 0.4	0.9 $\pm$ 0.5	0.025
0.1 m <sup>2</sup>	0	5	1.8 $\pm$ 1.1	0.9 $\pm$ 0.6	1.9 $\pm$ 0.9	0.052
1 m <sup>2</sup>	0	6	3.0 $\pm$ 1.4 <sup>a</sup>	1.4 $\pm$ 0.7 <sup>b</sup>	2.6 $\pm$ 0.9 <sup>ab</sup>	0.016
10 m <sup>2</sup>	0	7	4.3 $\pm$ 2.5	1.8 $\pm$ 0.8	3.3 $\pm$ 1.6	0.044
100 m <sup>2</sup>	1	8	6.0 $\pm$ 2.8	2.4 $\pm$ 1.1	4.3 $\pm$ 2.4	0.052
<b>Species richness lichens</b>						
0.0001 m <sup>2</sup>	0	0	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	–
0.001 m <sup>2</sup>	0	0	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	–
0.01 m <sup>2</sup>	0	0	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	–
0.1 m <sup>2</sup>	0	3	0.8 $\pm$ 1.1	0.0 $\pm$ 0.0	0.2 $\pm$ 0.3	0.054
1 m <sup>2</sup>	0	3	1.5 $\pm$ 1.4 <sup>a</sup>	0.4 $\pm$ 0.4 <sup>b</sup>	0.2 $\pm$ 0.3 <sup>b</sup>	0.016
10 m <sup>2</sup>	0	5	3.0 $\pm$ 1.4 <sup>a</sup>	0.4 $\pm$ 0.4 <sup>b</sup>	0.2 $\pm$ 0.3 <sup>b</sup>	< 0.001
100 m <sup>2</sup>	0	10	7.0 $\pm$ 4.2 <sup>a</sup>	0.6 $\pm$ 0.7 <sup>b</sup>	0.4 $\pm$ 0.5 <sup>b</sup>	< 0.001
<b>Species-area relationship all taxa</b>						
$z$	0.204	0.404	0.258 $\pm$ 0.027	0.284 $\pm$ 0.014	0.294 $\pm$ 0.053	0.183

\* = only 20 for 100 m<sup>2</sup>

compared to 51–83 for the four Transylvanian associations (Table 6). Similarly, at least two of the *Festucetalia valesiaca* associations in Transylvania with mean vascular richness of 39–45 species on 10 m<sup>2</sup> surpass those in Northeast Germany (approx. 25 species; see DENGELER 2005: Fig. 1) by approximately the same factor.

By contrast, non-vascular plants in Transylvanian *Festuco-Brometea* communities play a smaller role in terms of diversity and cover, when compared to syntaxonically similar stands in most other parts of Europe. In the *Brachypodietalia pinnati* communities, on average only 3.6 bryophyte and 0.1 lichen species are found at 10 m<sup>2</sup> in Transylvania, while val-

ues of 4–5 are typical for Northeast German (DENGLER 2005: Fig. 1) and 5–15 for hemiboreal associations of this order (BOCH & DENGLER 2006, LÖBEL & DENGLER 2008), in the latter case including also a significant amount of lichens. In combination with the higher vascular plant richness, the contribution of non-vascular plants to overall phytodiversity is untypically low in Transylvanian dry grasslands compared to other regions in Europe.

The *z*-values, i.e. the slope of the power-law SAR in log-log representation, ranged from 0.204–0.404, with an overall mean of 0.275 and no significant differences between the three orders (Table 7). These values are unusually high, at least for shoot presence (any-part) sampling. Typical values of various types of dry grasslands across Europe range from 0.193 to 0.249 with an average of approx. 0.21 (DENGLER 2005). Our values are also clearly above average compared to the *z*-values given for a wide range of different vegetation types by HOBÖHM (1998) and DOLNIK (2003). As the *z*-values are a measure of spatial turnover in species composition, we can conclude that the Transylvanian dry grasslands are not only extraordinary in terms of  $\beta$ -diversity but also in terms of  $\alpha$ -diversity. This is furthermore despite the fact we had carefully selected visually homogenous areas of 100 m<sup>2</sup> for our nested-plot analyses.

Table 9: Distribution of red-listed vascular plant taxa in nine dry grassland associations in Transylvania. Status of red-listed species: v = vulnerable, r = rare, e = endemic. Percentage constancies for all relevés (= Total) and per association are given. For association codes, see Subsection 4.1.

Tab. 9: Verbreitung von Gefäßpflanzenarten der Roten Liste in neun Trockenrasen-Assoziationen Siebenbürgens. Rote-Liste-Kategorien: v = gefährdet, r = selten, e = endemisch. Dargestellt sind prozentuale Stetigkeiten für jede Assoziation und für alle Aufnahmen zusammen („Total“). Die Bedeutung der Assoziationskürzel kann der syntaxonomischen Übersicht in Abschnitt 4.1 entnommen werden.

Red-listed vascular plants	Status	Total	1.1.1	1.1.2	2.1.1	2.1.2	2.1.3	3.1.1	3.1.2	3.1.3	3.1.4
<i>Adonis vernalis</i>	v	32	33	–	–	36	26	20	45	67	23
<i>Allium albidum</i> subsp. <i>albidum</i>	r	13	33	60	–	36	5	20	–	–	–
<i>Astragalus peterfii</i>	e/r	1	–	–	–	–	5	–	–	–	–
<i>Centaurea atropurpurea</i> subsp. <i>atropurpurea</i>	r	4	–	60	–	–	–	–	–	–	–
<i>Centaurea trinervia</i>	r	5	–	–	–	29	–	–	–	–	–
<i>Cephalaria radiata</i>	r	5	–	–	–	–	11	20	–	–	8
<i>Crambe tataria</i>	v/r	6	–	–	–	7	16	–	–	11	–
<i>Dictamnus albus</i>	v/r	21	33	100	–	29	21	–	27	–	–
<i>Ephedra distachya</i> subsp. <i>distachya</i>	r	1	–	–	33	–	–	–	–	–	–
<i>Genista januensis</i>	r	7	33	100	–	–	–	–	–	–	–
<i>Iris aphylla</i>	r	13	–	–	–	7	5	–	73	11	–
<i>Iris pontica</i>	v/r	2	–	–	–	–	–	–	18	–	–
<i>Jurinea mollis</i> subsp. <i>transylvanica</i>	r	24	–	60	33	36	32	–	18	11	15
<i>Nepeta ucranica</i>	v/r	5	–	–	–	29	–	–	–	–	–
<i>Paeonia tenuifolia</i>	v/r	5	–	–	–	–	–	–	36	–	–
<i>Paronychia cephalotes</i>	r	1	–	20	–	–	–	–	–	–	–
<i>Peucedanum tauricum</i>	r	17	–	80	–	36	16	–	–	–	15
<i>Poa badensis</i>	r	5	33	60	–	–	–	–	–	–	–
<i>Prunus tenella</i>	v	28	33	60	33	100	21	–	–	–	–
<i>Rosa micrantha</i>	r	1*	–	–	–	–	–	–	–	–	8*
<i>Salvia nutans</i>	v	18	–	–	–	36	32	–	9	11	15
<i>Scorzonera purpurea</i> subsp. <i>rosea</i>	r	1	–	–	–	–	–	–	9	–	–
<i>Sempervivum marmoreum</i>	r	4	33	40	–	–	–	–	–	–	–
<i>Serratula lycopifolia</i>	v/r	2*	–	–	–	–	–	–	18*	–	–
<i>Serratula radiata</i> subsp. <i>radiata</i>	r	22	33	20	–	64	21	–	18	11	–
<i>Seseli gracile</i>	r	4	100	–	–	–	–	–	–	–	–
<i>Stipa pennata</i> subsp. <i>ericaulis</i>	r	4	33	–	–	7	–	–	–	–	8
<i>Stipa pulcherrima</i>	r	39	–	100	67	93	53	–	9	–	8
Mean number of red-listed plants on 10 m <sup>2</sup>		2.9	4.0	7.6	1.7	5.4	2.6	0.6	2.8	1.2	1.0

\* These determinations were not sure (“cf.”)

### 5.3. Conservation values

Beyond counting richness, Table 9 shows the distribution of vascular plant species of special conservation concern (i.e. threatened, rare, and endemic taxa) among the associations. The associations with the highest number of red-listed species are *Carici humilis-Leontodontetum asperi* (1.1.2) and *Stipetum lessingianae* (2.1.2), with a mean of 7.6 and 5.4 species per relevé, respectively. These associations of stony or dry habitats contained considerably more red-listed species than the semi-dry grasslands. The most frequent red-listed species were *Stipa pulcherrima* (39% frequency over all relevés), *Serratula radiata* subsp. *radiata* (22%), *Dictamnus albus* (21%), *Salvia nutans* (18%), and *Peucedanum tauricum* (17%). Most rare red-listed species (1% frequency each) were *Astragalus peterfii* (a rare endemic restricted to the Transylvanian Plateau), *Ephedra distachya* subsp. *distachya*, *Paronychia cephalotes*, *Rosa micrantha*, and *Scorzonera purpurea* subsp. *rosea*.

## 6. Conclusions and outlook

While the dataset analysed by us was limited in the number of relevés and therefore the results are to be considered preliminary, this study nevertheless make a significant contribution to the understanding of Transylvanian dry grasslands both in the regional and in the European context. Unlike most of the numerous previous works on Transylvanian (or more generally Romanian) grasslands, we used a highly standardised sampling protocol, thorough recording not only of vascular plants but also bryophytes and lichens, and modern statistical approaches to address syntaxonomic classification, vegetation-environment relationships, and biodiversity patterns.

### 6.1. Syntaxonomy

In the realm of syntaxonomy, we confirmed three orders with one alliance each, with together nine (eleven) associations for the Transylvanian Plateau. At the alliance and order level, this is much less than recent syntaxonomic overviews of Romania (e.g. SANDA et al. 2008) suggest, which claim the co-existence of various higher rank units with different chorological centres. To our knowledge, the claim of different alliances from the three major groups being present in Transylvania was neither supported with numerical analyses that could show such higher-rank divisions among the Transylvanian relevés nor by a comparison with relevés from the known core distribution areas of the respective alliances. According to present knowledge, therefore the occurrence of *Diantho lumnitzeri-Seslerion* (Soó 1971) Chytrý & Mucina in Mucina & Kolbek 1993 (= *Seslerio-Festucion pallentis* Klika 1931), *Festucion valesiaca* Klika 1931 (= *Festucion sulcatae* Soó 1930 nom. amb. propos.), and *Bromion erecti* W. Koch 1926 cannot be confirmed for Transylvania and is also not expected for chorological reasons, while *Danthonio-Stipion stenophyllae* Soó 1949 and *Danthonio-Brachypodion* Boşcaiu 1972 are considered as part of the *Cirsio-Brachypodion pinnati*. While it was beyond the scope of the present paper to analyse relevés of Transylvania jointly with those of other Romanian regions and other countries, the overall floristic composition of the three *Festucetalia valesiaca* associations support the view that they belong to another alliance than the *Festucion valesiaca*. This support of the *Stipion lessingianae* as a Transylvanian-Pontic vicariant of the *Festucion valesiaca* s.str. with Pannonian distribution and some outliers in Bohemia, Poland and subcontinental areas of Germany, can be seen as a step towards a chorologically more meaningful subdivision of this order compared to concepts that reported the same alliance “*Festucion valesiaca*” from western Germany (e.g. POTT 1995) to southern Urals (YAMALOV et al. 2009).

While at the association level due to our limited sampling, we probably have not covered the full variety of extant communities, the number of floristically well-defined and ecologically meaningful communities is probably closer to our number (eleven) than to the far higher number given, for example, by SANDA et al. (2008). Deviating from practically all available Romanian treatments, we delimited associations (and higher syntaxa) based on the

full species composition and overall floristic similarity, not only on the basis of one or few dominant species. This leads to floristically well-defined and ecologically meaningful associations, which however might occur with different dominating species. For example, the *Carici humilis-Leontodontetum asperi* (Assoc. 1.1.2), the *Stipetum lessingianae* (Assoc. 2.1.2), and the *Stipetum pulcherrimae* (Assoc. 2.1.3) can be dominated by *Carex humilis*, *Stipa pulcherrima* or some other xerophilous grasses, but nevertheless are floristically and ecologically much different units. For all associations distinguished, we used names described from Transylvania. For the *Seslerion rigidae* and *Stipion lessingianae* as specific Transylvanian alliances, this is probably correct. In the case of the *Cirsio-Brachypodion pinnati*, however, which has a much larger range from Germany and Austria in the west to Romania (and possibly even Ukraine) in the east, our associations 3.1.2–4 with some probability will turn out to be the same as associations that have been described elsewhere; some indications in this direction are given in Subsection 4.4. Giving a correct answer to the question whether and which of the many associations described within the *Cirsio-Brachypodion pinnati* should be joined, will only be possible with a consistent supra-national vegetation classification based on a comprehensive vegetation-plot database; therefore, we prefer to stick to the Transylvanian association names for the time being.

Unlike most Romanian phytosociological studies of recent decades we also included bryophytes and lichens in our sampling. It turned out that cryptogams are generally less frequent in Transylvanian compared to other dry grasslands, which could give some of the species diagnostic value for the non-Transylvanian syntaxa, even at higher syntaxonomic level. Additionally, the most frequent bryophytes were clearly different to those prevailing in dry grasslands in other parts of Central or Northern Europe. For example, *Hypnum cupressiforme* var. *lacunosum*, perhaps the most frequent dry grassland moss in many parts of Europe, was infrequent in Transylvania (only in 7% of the plots), while *Weissia longifolia* was unusually common (34%) and *Plagiomnium rostratum* more or less replaced *P. affine*, which is frequent in semi-dry grasslands in other regions.

## 6.2. Biodiversity

While the other European grassland regions that host world records in vascular plant species richness (WILSON et al. in press), Öland, Estonia, and White Carpathians, had been highlighted in various publications, the fact that Transylvania also belongs to those exceptional places had previously gone unrecognised. Given the high species richness of Transylvanian grasslands, it now remains to explore the likely reasons. Unfortunately we are not in the position to answer this question here, but merely can highlight this unexpected pattern in order to encourage further studies on that subject. Possible explanations include (a) reduced competition due to low nutrient supply and regular biomass extraction through mowing, (b) favourable, intermediate environmental conditions that allow species from dry grassland, meadows, fens, forest-edges, and forests to survive, and (c) accumulation of a large species pool due to long continuous history as a grassland (see Subsection 2.3 and compare a similar situation in the White Carpathians: HÁJKOVÁ et al. 2011) and generally richer flora on base-rich soils (e.g. EWALD 2003).

## 6.3. Conservation

The finding that Transylvanian dry grasslands are with a few exceptions generally very species rich and some managed semi-dry grasslands of the regions contain even global maxima of plant diversity at certain spatial scales emphasises the conservation value of these community types. The particularly species rich stands have a long history of low-intensity landuse, mostly through mowing. This underlines the high importance of traditional cultural landscapes in Europe for biodiversity conservation and calls for a diversification of conservation attention from solely concentrating on “untouched” wilderness areas mainly in the tropics to include also the biodiversity human-influenced landscapes in Europe that resulted from traditional landuse practices over millennia. While formerly species-rich semi-natural

grasslands (High Nature Value grasslands) were widespread in many parts of Europe, they became more and more restricted to marginal areas of low economic power (VEEN et al. 2009). As shown in this contribution, the dry grasslands of Transylvania are nowadays an exceptional and still well preserved example.

The analysis of red-listed species in Subsection 5.3 demonstrates a common problem with the use of conservation instruments in assessing threat levels. Whilst an appraisal based on number and abundance of listed species points to the *Brachypodietalia pinnati* as being of least concern, these are in fact currently the most threatened stands due to their strong reliance on extensive agricultural management, which under present-day framework is no longer economic. The associations with the highest occurrence of Red List species, on the other hand, are largely natural communities and thus relatively stable and unthreatened. By contrast, the associations that hold the world record for plant species richness at several spatial scales are ranked only third. This mismatch between a conservation assessment focused on rarity and a knowledge-based assessment of real conservation importance demonstrates the need to use Red Lists with caution. Species that are locally common such as *Stipa pulcherrima*, the most frequent Red List species in our relevés and a widespread competitor that even spreads after abandonment (see RUPRECHT et al. 2009), do not point to particular valuable dry grassland stands in the regional context. On the other hand, the Habitats Directive Annex II species *Echium russicum* and the non-competitive *Scorzonera purpurea* (which is very sensitive to abandonment) are not included in the national Red Lists (DIHORU & DIHORU 1994, OLTEAN & NEGREAN 1994).

An appropriate and effective tool for identifying conservation needs is, however, clearly necessary. As outlined in this paper, the level of threat Transylvanian dry grasslands are facing in general is critical and has been highlighted before. However, a more differentiated picture for individual community types, was not available. Clearly defined syntaxa, as we have provided in this study, will help to assign knowledge on conservation value, threats and possible solutions more specifically to individual vegetation types.

#### 6.4. Outlook

We believe that our study is a small, but important step towards a more sound and consistent classification of grasslands in Romania and their appropriate placement in a supra-national or even continent-wide syntaxonomic scheme (for a precursor, see RODWELL et al. 2002). The high plant diversity found in general and the exceptionally high values found in a certain association (*Festuco sulcatae-Brachypodietum pinnati*, order *Brachypodietalia pinnati*) call both for extensive scientific research to address this riddle how such an unexpected “species packing” could emerge and for conservation to maintain this natural heritage of global importance. The EDGG Research Expeditions will continue to collect in international teams similar standardised high-quality datasets from (dry) grasslands in other undersampled regions of the Palearctic realm and make them available in a public database (see DENGLER et al. in press) in order to enhance our knowledge. Likewise, EDGG is one of the main initiators of emerging supra-national to continental classifications of European grasslands, to be published in a *Virtual Special Feature of Applied Vegetation Science*, for which also the data from this study will be used.

#### Author contribution statement and acknowledgements

The study was planned by J.D., while the field work was mainly conducted by E.R., A.S., J.D. and E.U., with smaller contributions by M.B., P.D.T., T.B., and U.B. Critical vascular plants were revised by E.R. and A.S., critical bryophytes and lichens were determined by C.D. and I.G., and soil analyses were done by J.P. and L.M.E.S. The statistical analyses were led by J.D. (classification) and T.B. (vegetation-environment relationships). The phytosociological nomenclature was sorted out by J.D. with the help of C.B.-N., while the map was prepared by A.S. J.D. led the writing up of the paper, with T.B. and P.D.T. contributing significant parts, all authors critically revising the whole text, and L.M.E.S. checking it linguistically.



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## Appendix 1: Overview and revision of the syntaxa included

### Anhang 1: Übersicht und Revision der nachgewiesenen Syntaxa

An asterisk (\*) after the year of an author citation indicates that the protologue (original description) has been checked by us, and the source is included in the reference list. No attempt has been made to resolve misapplied association names that originate from regions far away (Germany, Austria, Switzerland) but are frequently used in Romanian syntaxonomic overviews.

#### Class: *Festuco-Brometea* Br.-Bl. & Tx. ex Klika & Hadač 1944

Protologue: „*Festuco-Brometea* Br.-Bl. u. Tx. 1943“ (KLIKA & HADAČ 1944b: p. 288)

Typus: *Brometalia erecti* W. Koch 1926\* (= *Brachypodietalia pinnati* Korneck 1974\*) [Holotypus]

Syn.: *Festuco-Brometea* Br.-Bl. & Tx. 1943\* nom. inval. [Art. 8]

*Festuco-Brometea* Br.-Bl. & Tx. ex Soó 1947\* nom. illeg. [Art. 31]

Notes: While MUCINA (1997) and CHYTRÝ et al. (2007) consider the name published by KLIKA & HADAČ (1944b) as a *nomen nudum*, we consider it as the first validation of the name proposed by BRAUN-BLANQUET & TÜXEN (1943) and thus the correct name of the class. KLIKA & HADAČ (1944b: p. 288) subordinated to the new class only the order “*Brometalia* (Koch 1926 n.n.) Br.-Bl. 1936”. While in the reference list of KLIKA & HADAČ (1944b) “Koch 1926” and “Br.-Bl. 1936” were not included, with “Praktikum” they refer to the textbook of KLIKA & NOVÁK (1941), to which they give a unanimous bibliographic reference in the first paper of the publication series (KLIKA & HADAČ 1944a: p. 249). In the named textbook, “Koch 1926” is included in the reference list, while again “Br.-Bl. 1936” is missing. The latter fact, however, is nomenclaturally irrelevant as, contrary to the assumption of KLIKA & NOVÁK (1941) and KLIKA & HADAČ (1944b), already KOCH (1926) had published the order *Brometalia erecti* validly.

#### Order 1: *Stipo pulcherrimae-Festucetalia pallentis* Pop 1968

Protologue: POP (1968: p. 272)

Typus: *Seslerio-Festucion pallentis* [“Klika 1931”] Pop 1968\* nom. illeg. [Art. 31; lectotypus hoc loco: *Melico flavescens-Saturejetum kitaibelii* Zólyomi 1939\*] [lectotypus hoc loc]

Syn.: *Stipo eriocaulis-Festucetalia pallentis* (Pop 1968\*) Pop 1991\* nom. illeg. [Art. 29a]

Notes: In the protologue of the order, POP (1968) included two alliances, *Seslerio-Festucion pallentis* Klika 1931\* and *Thymo comosi-Festucion sulcatae* Pop 1968\*. As he, however, did not provide a reference to “Klika 1931” he unintentionally described a new alliance *Seslerio-Festucion pallentis* Pop 1968, which is chosen here as nomenclatural type.

#### Alliance 1.1: *Seslerion rigidae* Zólyomi 1939

Protologue: ZÓLYOMI (1939: pp. 66–67)

Typus: *Seslerietum rigidae praebiharicum* Zólyomi 1939\* nom. illeg. [lectotypus hoc loco]

Syn.: *Seslerio-Festucion pallentis* Klika 1931\* corr. Zólyomi 1966\* sensu auct. p.p. [typus excl.]

*Thymo comosi-Festucion sulcatae* Pop 1968\* [Syntax. syn.]

#### Association 1.1.1: *Avenastretum decori* Zólyomi 1939

Protologue: ZÓLYOMI (1939: pp. 75–76, 120–123)

Typus: ZÓLYOMI (1939: pp. 120–123, table III, rel. 4) [lectotypus hoc loco]

Syn.: *Avenastretum decori* Domin 1932\* nom. inval. [Art. 7]

Incl.: *Festuca saxatilis* Konsoz. of the *Seslerietum rigidae praebiharicum* Zólyomi 1939\* nom. illeg. [Art. 34a]

#### Association 1.1.1a: *Seslerietum heufleranae* Soó 1927

Protologue: “*Seslerietum heuflerianae*” SOÓ (1927: 81)

Typus: This paper (table 3, rel. 44 = ROR004) [neotypus hoc loco]

Syn.: *Seslerietum heuflerianum biharicum* Soó (1927\*) 1947\* nom. illeg. [Art. 29a, 34a]

*Genisto spatulatae-Seslerietum heufleranae* nom. inval. Schneider 1994\* [Art. 5, 8]

*Stipo pulcherrimae-Seslerietum heufleranae* nom. inval. Schneider 1994\* [Art. 5, 8]

Notes: In the original description, the association name as well as the name of the eponymous taxon were erroneously spelled with “j”. We correct this typographic error here to the spelling accepted in TUTIN et al. (1980). As the original description contained only a synoptic table, we select a neotype here.

**Association 1.1.2: *Carici humilis-Leontodontetum asperi* Zólyomi 1939**

Protologue: “*Carex humilis-Leontodon asper* Ass.” (ZÓLYOMI 1939: pp. 77–80, 124–129)

Typus: ZÓLYOMI (1939: pp. 124–129, table IV, rel. 5) [lectotypus hoc loco]

Syn.: *Caricetum humilis transilvanicum* Zólyomi 1939\* nom. illeg. [Art. 34a]

Notes: ZÓLYOMI (1939: p. 77) has published this name as a legitimate alternative to the illegitimate name *Caricetum humilis transilvanicum*.

**Order 2: *Festucetalia valesiaca* Soó 1947**

Protologue: “*Festucetalia (valesiaca)* Soó 1940 (N. A.)” (Soó 1947: pp. 22–34)

Typus: *Stipion lessingiana* Soó 1947\* [lectotypus hoc loco]

Syn.: *Festucetalia valesiaca* Br.-Bl. & Tx. 1943\* nom. inval. [Art. 8]

*Festucetalia valesiaca* Br.-Bl. & Tx. ex Br.-Bl. 1950\* nom. illeg. [Art. 31]

Notes: It is unclear to which paper Soó (1947: p. 22) refers with “Soó 1940”; there is no such publication in his reference list.

**Alliance 2.1: *Stipion lessingiana* Soó 1947**

Protologue: Soó (1947: pp. 29–34)

Typus: *Stipetum lessingiana* Soó 1947\* [lectotypus (Art. 20 ICPN)]

Incl.: *Calamagrostis epigejos-Koeleria gracilis-Melica ciliata*-Ass. Soó 1927\* nom. illeg. [Art. 34c]

*Stipetum pennata* Soó 1927\* nom. inval. [Art. 3f]

Notes: The *Stipetum pennata* described by Soó (1927: pp. 98–99) is invalid as the author refers with his name evidently to *Stipa pennata* agg., while in his synoptic table only four different microspecies are listed (*S. longifolia*, *S. joannis*, *S. pulcherrima*, *S. lessingiana*).

**Association 2.1.1: *Artemisietum pontico-sericeae* Soó 1947**

Protologue: “*Artemisietum ponticae-(campestris) sericeae* Soó 1942 (AGH)” (Soó 1947: p. 33)

Typus: Soó (1949: p. 96–97, table 29, rel. 7) [neotypus hoc loco]

Syn.: *Artemisio pontico-sericeae* Soó 1942\* nom. inval. [Art. 7]

Notes: In 1942, Soó mentioned the *Artemisio pontico-sericeae* for the first time. Even though he presented a vegetation table with individual relevés (pp. 147–149), this publication is considered invalid because this table contains several associations and the author does not specify which column should be which unit. Following Recommendation 21A ICPN, we chose the neotype from the relevés underlying the synoptic table in the protologue, which have been published by the author two years later (Soó 1949).

**Association 2.1.2: *Stipetum lessingiana* Soó 1947**

Protologue: “*Stipetum Lessingiana* Soó (G. M. sol. nom.) emend. (Meusel, Prodan)” (Soó 1947: p. 32)

Typus: Soó (1949: p. 94–95, table 28, rel. 2) [neotypus hoc loco]

Syn.: *Stipetum lessingiana* Soó 1927\* nom. inval. [Art. 7]

*Caricetum humilis* Soó 1942\* p.p. [typus excl.; see association 2.1.3]

*Festuco sulcatae-Caricetum humilis praerossicum* Soó 1947\* nom. illeg. [Art. 34a]

Notes: Following Recommendation 21A ICPN, we chose the neotype from the relevés underlying the synoptic table in the protologue, which have been published by the author two years later (Soó 1949).

**Association 2.1.3: *Stipetum pulcherrimae* Soó 1942**

Protologue: Soó (1942: pp. 147 + 149)

Typus: Soó (1949: table 29, rel. 8) [neotypus hoc loco]

Syn.: *Caricetum humilis* Soó 1942\* p.p. [Syntax. syn.; typus: Soó (1942: pp. 146–147, rel. 4) lectotypus hoc loco]

*Salvio nutantis-Stipetum pulcherrimae* (Soó 1942) Boşcaiu et al. 1984\* nom. illeg. [Art. 29a]

Notes: Soó (1942: p. 149) presented a vegetation table with three individual relevés, however, the companion species occurring in only one of these relevés were only listed and not assigned to any of these relevés. Therefore, we consider this table only as an equivalent to a synoptic table, and accordingly the designation of a neotype according to Art. 21 ICPN became necessary.

**Order 3: *Brachypodietalia pinnati* Korneck 1974**

Protologue: KORNECK (1974: pp. 123 et seq.)

Typus: *Cirsio-Brachypodium pinnati* Hadač & Klika in Klika & Hadač 1944b\* [Lectotypus designated by DENGLER et al. (2003: p. 608)]

Syn.: *Brometalia erecti* W. Koch 1926\* nom. amb. propos. [Holotypus: *Bromion erecti* W. Koch 1926\*]

Notes: DENGLER et al. (2003: p. 608) explain why *Brometalia erecti* should be rejected as a *nomen ambiguum*. If the Phytosociological Nomenclature Commission follows this proposal, *Brachypodietalia pinnati* would be the next youngest valid and thus the correct name of the order.

**Alliance 3.1: *Cirsio-Brachypodium pinnati* Hadač & Klika in Klika & Hadač 1944**

Protologue: „*Cirsio-Brachypodium pinnati* Hadač-Klika 1944“ (KLIKA & HADAČ 1944b: 289)

Typus: *Seslerio calcariae-Cirsietum pannonici* Klika 1933\* [Lectotypus designated by HADAČ (in TOMAN 1981: p. 569)]

Syn.: *Danthonio-Stipion stenophyllae* Soó 1947\* nom. inval. [Art. 3b]

*Festucion sulcatae* Soó 1947\*, non Soó 1930\* nom. illeg. [Art. 31]

*Danthonio-Stipion stenophyllae* Soó 1949\* [Syntax. syn.; lectotypus hoc loco: *Agrostio-Danthonietum* Soó 1949\* nom. illeg. [Art. 31] (= *Agrostio-Danthonietum alpinae* Soó 1947\*)]

*Cirsio-Brachypodium pinnati* Hadač & Klika ex Klika 1951 nom. illeg. [Art. 31]

Notes: Deviating from CHYTRÝ et al. (2007), we consider the description of the *Cirsio-Brachypodium pinnati* by KLIKA & HADAČ (1944b) as valid. Indeed, the references to the protologues of the three associations subordinated to the alliance are not directly listed in the reference list in KLIKA & HADAČ (1944b). However, with “Praktikum” the authors refer to the textbook of KLIKA & NOVÁK (1941), to which they give a unanimous bibliographic reference in the first paper of the publication series (KLIKA & HADAČ 1944a: p. 249). In this textbook, unambiguous references to the original descriptions of the three associations are included, whereby according Art. 8 ICPN the alliance description is valid. The addition of the species epitheton “*pannonicum*” to the alliance name, as can be found frequently in the literature, is not warranted as the protologue names two *Cirsium* species (Art. 40a and Recommendation 10C ICPN).

Soó (1947: p. 22–29) unintentionally described a new alliance because he did not provide the references cited after the name *Festucion sulcatae* (“Soó 1929 emend Soó 1940”). While in the older and thus valid description (Soó 1930: pp. 28–31), the author described a xerophytic alliance (now mostly termed *Festucion valesiaca* Klika 1931, e.g. CHYTRÝ et al. 2007), all associations included in the protologue of Soó (1947) are meso-xeric and thus correspond to the *Cirsio-Brachypodium pinnati*.

**Association 3.1.1: *Orchido militaris-Seslerietum heufleranae* Schneider ex Dengler et al. ass. nova hoc loco**

Typus: SCHNEIDER (1994: table 1, rel. 9) [holotypus]

Syn.: *Seslerietum heufleriana praerossicum* Soó 1947\* nom. illeg. [Art. 34a]

*Festuco rupicolae-Seslerietum heufleranae* Schneider 1994\* nom. inval. [Art. 3b, 5, 8]

*Orchido militaris-Seslerietum heufleranae* Schneider 1994\* nom. inval. [Art. 3b, 5]

Notes: As SCHNEIDER’s (1994) invalidly described associations *Orchido militaris-Seslerietum heufleranae* and *Festuco rupicolae-Seslerietum heuflerianae* completely match our unit, we valid the first of her names here, for which she provided a table with nine individual relevés.

**Association 3.1.2: *Festuco sulcatae-Brachypodium pinnati* Soó 1927**

Protologue: „*Festuceto (sulcatae)-Brachypodium pinnati*“ (Soó 1927: pp. 85, 87–89)

Typus: This paper (table 3: rel. 1 = RO01NW) [neotypus hoc loco]

Syn.: *Brachypodio pinnati-Caricetum montanae* Soó 1947\* [Syntax. syn.]

*Danthonio-Brachypodium pinnati* Soó 1948\* nom. inval. p.max.p. [Art. 3b]

*Pediculari campestris-Caricetum montanae* Soó 1947\* [Syntax. syn.]

Notes: Note that this association is not identical with the *Festuco rupicolae-Brachypodium pinnati* Mahn 1965\* described from Germany. As *Festuca sulcata* (Hack.) Nyman and *F. rupicola* Heuff. are heterotypic synonyms, both association names are valid, and Art. 32b ICPN does not apply. As Soó (1927) published only a synoptic table, a neotype from the same region is selected here. Note that the microspecies of *Festuca* ser. *Valesiaca* in the type relevé is *F. rupicola* = *F. sulcata*.

**Association 3.1.3: *Agrostio-Danthonietum alpinae* Soó 1947**

Protologue: “*Agrostideto-Danthonietum* Soó 1946” (Soó 1947: p. 26)

Typus: Soó (1949: table 23, rel. 9) [neotypus hoc loco]

Syn.: *Festucetum sulcatae* Soó 1927\* nom. amb. propos. p.p.

*Festuco sulcatae-Danthonietum calycinae* Soó 1942\* nom. dub.

Notes: Soó (1927: 89–92) described the *Festucetum sulcatae* based on a synoptic list, which to our understanding corresponds to several present-day associations. As it is impossible to sort out the correct assignment and also the name “*Festucetum sulcatae*” has been in use in the phytosociological literature with different author citations for many different plant communities, we propose to reject it as a *nomen ambiguum* according to Art. 36 ICPN. The *Festuco sulcatae-Danthonietum calycinae* was validly described by Soó (1942: pp. 143–145), but the single relevé is evidently very incomplete (only 18 species recorded) that an assignment to a present-day association is doubtful and we thus reject the name as a *nomen dubium* according to Art. 37 ICPN.

Following Recommendation 21A ICPN, we chose the neotype from the relevés underlying the synoptic table in the protologue, which have been published by the author two years later (Soó 1949). It is not possible to add an epitheton to “*Agrostio-*” as Soó (1947) explicitly named his association after *Agrostis canina* agg. (likely *A. vinealis*) and *A. alba* agg. (i.e. *A. stolonifera* + *A. gigantea*).

**Association 3.1.4: *Cirsium furiens-Brachypodium pinnatum*-[*Cirsio-Brachypodium pinnati*] community**  
Syn.: *Festucetum sulcatae* Soó 1927\* nom. amb. propos. p.p.

“*Carex humilis* (-*Festuca sulcata*) és *Brachypodium pinnatum* ass. Soó 1942\* nom. illeg. [Art. 34c]

*Carici humilis-Brachypodietum pinnati transilvanicum* Soó 1947\* nom. illeg. [Art. 34a]

*Dantbonio-Brachypodietum pinnati* Soó 1947\* nom. inval. p.p. [Art. 3b]

Notes: For the rejection of the *Festucetum sulcatae* Soó 1927\*, see the Note under association 3.1.3.

**Association 3.1.4a: *Stipetum stenophyllae* Meusel 1938**

Protologue: MEUSEL (1938: pp. 297–308)

Typus: MEUSEL (1938: p. 305: rel. from Harsleber Berge) [lectotypus hoc loco]

Syn.: *Stipetum stenophyllae* Ghişa 1941\*, non Meusel 1938\* nom. illeg. [Art. 31; lectotypus hoc loco: GHIŞA (1942: pp. 60–62, rel. 1)]

*Stipo stenophyllae-Festucetum sulcatae* Soó 1942\* [Syntax. syn.; lectotypus hoc loco: Soó (1942: p. 144–145, rel. c)]

*Stipetum stenophyllae transilvanicum* Soó 1947\* nom. illeg. [Art. 34a]

## Appendix 2: Geographic origin of the relevés

### Anhang 2: Herkunftsnachweis der Aufnahmen

Geographic coordinates are according to WGS-84.

Natura 2000 sites: 1 = ROSCI0035 Cheile Turzii; 2 = ROSCI0040 Coasta Lunii; 3 = ROSCI0078 Fânațele Clujului - Copârșaie; 4 = ROSCI0099 Lacul Țtiucilor - Sic - Puini - Bonțida; 5 = ROSCI0227 Sighișoara - Târnavă Mare; 6 = ROSCI0238 Suatu-Cojocna-Crairât; 7 = ROSCI0295 Dealurile Clujului de Est; 8 = ROSPA0099 Podisul Hartibaciului.

No.	Plot No.	Date	Latitude [° N]	Longitude [° E]	Altitude [m a.s.l.]	County	Municipality	Natura 2000	Nature reserve
1	RO01NW	14.07.2009	46.84008	23.65644	549	Cluj	Cluj-Napoca	7	La Craiu
2	RO01SE	14.07.2009	46.84000	23.65652	549	Cluj	Cluj-Napoca	7	La Craiu
3	RO02NW	14.07.2009	46.83997	23.65360	544	Cluj	Cluj-Napoca	7	La Craiu
4	RO02SE	14.07.2009	46.83990	23.65372	547	Cluj	Cluj-Napoca	7	La Craiu
5	RO03NW	15.07.2009	46.64985	24.09875	407	Mureș	Zau de Câmpie	-	Paeonia - Rezervația de bujori Zau de Câmpie
6	RO03SE	15.07.2009	46.64979	24.09887	402	Mureș	Zau de Câmpie	-	Paeonia - Rezervația de bujori Zau de Câmpie
7	RO04NW	15.07.2009	46.64956	24.09796	440	Mureș	Zau de Câmpie	-	Paeonia - Rezervația de bujori Zau de Câmpie
8	RO04SE	15.07.2009	46.64952	24.09799	419	Mureș	Zau de Câmpie	-	Paeonia - Rezervația de bujori Zau de Câmpie
9	RO05NW	16.07.2009	46.65847	23.83838	499	Cluj	Ploscoș	6	-
10	RO05SE	16.07.2009	46.65835	23.83850	502	Cluj	Ploscoș	6	-
11	RO06NW	16.07.2009	46.65811	23.83844	491	Cluj	Ploscoș	6	-
12	RO06SE	16.07.2009	46.65803	23.83856	495	Cluj	Ploscoș	6	-
13	RO07NW	16.07.2009	46.66006	23.83809	494	Cluj	Ploscoș	6	-
14	RO07SE	16.07.2009	46.65997	23.83826	490	Cluj	Ploscoș	6	-
15	RO08NE	17.07.2009	46.74423	23.91857	470	Cluj	Căianu	6	-
16	RO08SW	17.07.2009	46.74421	23.91838	468	Cluj	Căianu	6	-
17	RO09NW	17.07.2009	46.74422	23.91798	454	Cluj	Căianu	6	-
18	RO09SE	17.07.2009	46.74412	23.91808	452	Cluj	Căianu	6	-
19	RO10NW	17.07.2009	46.77811	23.90251	315	Cluj	Căianu	6	-
20	RO10SE	17.07.2009	46.77801	23.90263	321	Cluj	Căianu	6	-
21	RO11NW	18.07.2009	46.81257	23.62450	531	Cluj	Cluj-Napoca	7	-
22	RO11SE	18.07.2009	46.81248	23.62461	525	Cluj	Cluj-Napoca	7	-
23	RO12NE	18.07.2009	46.81230	23.62544	531	Cluj	Cluj-Napoca	7	-
24	RO12SW	18.07.2009	46.81225	23.62529	525	Cluj	Cluj-Napoca	7	-
25	RO13NW	19.07.2009	46.83553	23.62691	510	Cluj	Cluj-Napoca	3	Fânațele Clujului - Copârșaie
26	RO13SE	19.07.2009	46.83541	23.62706	506	Cluj	Cluj-Napoca	3	Fânațele Clujului - Copârșaie

No.	Plot No.	Date	Latitude [° N]	Longitude [° E]	Altitude [m a.s.l.]	County	Municipality	Natura 2000	Nature reserve
27	RO14NW	20.07.2009	46.56625	23.68930	583	Cluj	Petreștii de Jos și Mihai Viteazu	1	Cheile Turzii
28	RO14SE	20.07.2009	46.56618	23.68943	583	Cluj	Petreștii de Jos și Mihai Viteazu	1	Cheile Turzii
29	RO15NW	20.07.2009	46.56606	23.68521	670	Cluj	Petreștii de Jos și Mihai Viteazu	1	Cheile Turzii
30	RO15SE	20.07.2009	46.56602	23.68523	663	Cluj	Petreștii de Jos și Mihai Viteazu	1	Cheile Turzii
31	RO16NW	21.07.2009	46.79638	23.96104	445	Cluj	Suatu	6	-
32	RO16SE	21.07.2009	46.79631	23.96115	455	Cluj	Suatu	6	-
33	RO17NE	22.07.2009	46.53033	23.93964	434	Cluj	Viișoara	2	-
34	RO17SW	22.07.2009	46.53025	23.93949	438	Cluj	Viișoara	2	-
35	RO18NW	23.07.2009	46.86108	23.90122	475	Cluj	Vișea	4	-
36	RO18SE	23.07.2009	46.86099	23.90138	475	Cluj	Vișea	4	-
37	RO19NW	23.07.2009	46.87010	23.88941	436	Cluj	Vișea	4	-
38	RO19SE	23.07.2009	46.86996	23.88946	427	Cluj	Vișea	4	-
39	RO20NE	23.07.2009	46.83738	23.62271	507	Cluj	Cluj-Napoca	7	Fânațele Clujului - Copârșaic
40	RO20SW	23.07.2009	46.83732	23.62255	510	Cluj	Cluj-Napoca	7	Fânațele Clujului - Copârșaic
41	ROR001	17.07.2009	46.74330	23.91588	414	Cluj	Căianu	7	-
42	ROR002	18.07.2009	46.83444	23.62857	511	Cluj	Cluj-Napoca	7	Fânațele Clujului - Copârșaic
43	ROR003	20.07.2009	46.56640	23.68882	621	Cluj	Petreștii de Jos și Mihai Viteazu	1	Cheile Turzii
44	ROR004	20.07.2009	46.56988	23.67531	692	Cluj	Petreștii de Jos și Mihai Viteazu	1	Cheile Turzii
45	ROR005	20.07.2009	46.56896	23.67045	607	Cluj	Petreștii de Jos și Mihai Viteazu	1	Cheile Turzii
46	ROR006	20.07.2009	46.56922	23.67025	511	Cluj	Petreștii de Jos și Mihai Viteazu	1	Cheile Turzii
47	ROR007	20.07.2009	46.56940	23.67044	525	Cluj	Petreștii de Jos și Mihai Viteazu	1	Cheile Turzii
48	ROR008	21.07.2009	46.77952	23.97497	363	Cluj	Suatu	6	-
49	ROR009	21.07.2009	46.77722	23.97487	393	Cluj	Suatu	6	Nature reserve Suatu II
50	ROR010	21.07.2009	46.77726	23.97492	398	Cluj	Suatu	6	Nature reserve Suatu II
51	ROR011	21.07.2009	46.79153	23.96612	402	Cluj	Suatu	6	Nature reserve Suatu I
52	ROR012	21.07.2009	46.79738	23.95451	351	Cluj	Suatu	6	-
53	ROR013	22.07.2009	46.52550	23.94532	460	Cluj	Viișoara	2	-
54	ROR014	22.07.2009	46.53286	23.93727	439	Cluj	Viișoara	2	-
55	ROR015	22.07.2009	46.54202	23.92716	452	Cluj	Viișoara	2	-
56	ROR016	22.07.2009	46.54462	23.92209	420	Cluj	Viișoara	2	-
57	ROR017	22.07.2009	46.54571	23.92141	417	Cluj	Viișoara	2	-
58	ROR018	23.07.2009	46.86394	23.89588	419	Cluj	Vișea	4	-
59	ROR019	25.07.2009	45.93620	24.94884	513	Brașov	Șoarș	-	-
60	ROR020	25.07.2009	45.93612	24.94898	515	Brașov	Șoarș	-	-
61	ROR021	25.07.2009	46.06325	24.90850	604	Sibiu	Țeline - Brădeni	-	-
62	ROR022	26.07.2009	46.18915	25.07575	487	Mureș	Archita - Vânători	5	-
63	ROR023	26.07.2009	46.20197	25.15229	581	Harghita	Mujna - Dârjju	5	-
64	RORA01	20.08.2009	46.16972	24.95219	530	Mureș	Saschiz	5	-
65	RORA02	26.08.2009	46.16950	24.95253	518	Mureș	Saschiz	5	-
66	RORA03	15.09.2009	46.17211	24.96567	462	Mureș	Saschiz	5	-
67	RORA04	16.09.2009	46.16997	24.96603	510	Mureș	Saschiz	5	-
68	RORA05	16.09.2009	46.17022	24.96683	495	Mureș	Saschiz	5	-
69	RORA06	17.09.2009	46.16687	24.96997	503	Mureș	Saschiz	5e	-
70	RORD01	04.08.2009	46.92353	23.41267	454	Cluj	Topa Mica	-	-
71	RORD02	06.08.2009	47.04729	23.30781	296	Sălaj	Hida	-	-
72	RORD03	11.08.2009	46.60717	24.41350	365	Mureș	Madaras	-	-
73	RORD04	14.08.2009	46.79965	23.26934	482	Cluj	Capusu Mic	-	-



No.	Plot No.	Date	Latitude [° N]	Longitude [° E]	Altitude [m a.s.l.]	County	Municipality	Natura 2000	Nature reserve
74	RORM01	10.08.2009	46.75028	23.86650	378	Cluj	Cojocna	6	-
75	RORM06	06.08.2009	46.76673	23.86144	392	Cluj	Cojocna	6	-
76	RORM07	13.09.2009	46.73345	23.83459	380	Cluj	Cojocna	6	-
77	RORT01	26.07.2011	46.17438	24.95549	518	Mureş	Saschiz	5	-
78	RORT02	27.07.2011	46.07617	24.84121	532	Sibiu	Bradeni	8	-
79	RORT03	27.07.2011	46.07616	24.84123	532	Sibiu	Bradeni	8	-
80	RORT04	27.07.2011	46.07768	24.84121	552	Sibiu	Bradeni	8	-
81	RORT05	28.07.2011	46.07655	25.07336	601	Braşov	Bunesti	5	-
82	RORT06	28.07.2011	46.07700	25.07230	610	Braşov	Bunesti	5	-

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Table 3: Sorted vegetation table of the Festuco-Brometea communities of the Transylvanian Plateau. Species are arranged according to decreasing phi-values in the respective species blocks (only those species that were significant according to Fisher's exact test are included) and according to decreasing overall constancy for the non-diagnostic species. Left of the species name a letter indicates the species group (W = woody plant, i.e. juvenile of tree or shrub; H = herb or dwarf shrub; B = bryophyte; L = lichen; A = "alga"). In the constancy columns in the left part of the table, percentage constancies are given, while the superscript symbols represent the phi values (phi > 0.50; \* 0.25; \*\* 0.00), and means of the header data. In the right part of the table, individual relevés are shown, with percentage cover values. Location and dates of the vegetation plots can be retrieved via the consecutive number or plot number from

Appendix 2. Finally, diagnostic species of associations are highlighted in dark grey and those of higher syntaxia in light grey.

Tab. 3: Sortierte Vegetationstabelle der Festuco-Brometea-Gesellschaften des Siebenbürgischen Beckens. In der linken Spalte sind die Arten nach abnehmendem phi-Wert angeordnet, wobei nur Arten berücksichtigt wurden, die nach Fishers exaktem Test eine signifikante Häufung aufwiesen. Nicht diagnostische Arten sind dagegen nach abnehmender Stetigkeit angeordnet. Die Buchstaben vor den Artnamen zeigen die funktionelle Gruppen an, zu der die Arten gehören (W = Holzpflanze, d. h. Jungwuchs von Bäumen und Sträuchern; H = Krautiger oder Zwergrstücker; B = Moos; L = Flechte; A = "Alge"). In der Stetigkeitsspalte im linken Teil der Tabelle stehen prozentuale Stetigkeiten, wobei hochgestellte Symbole die Treuegrade symbolisieren (phi > 0,50; \* phi > 0,25; \*\* phi > 0,00), sowie die Mittelwerte der Kopfdaten. Im rechten Teil der Tabelle sind die einzelnen Aufnahmen mit Prozentdeckungsgraden dargestellt. Weitere Daten, etwa die Lage einer Aufnahmefläche kann über die laufende Nummer oder die Aufnahmeummer aus Anhang 2 entnommen werden. Die diagnostischen Arten der Assoziationen sind dunkelgrau und die der höheren Syntaxa hellgrau hervorgehoben.

Main data table with columns for Order 1, Order 2 (Festucalia valisilaeae), and Order 3 (Brachypodietalia pinasti). Rows include species names, their functional groups, and their presence/cover in various relevés. The table is organized into sections for different orders and associations, with diagnostic species highlighted in dark grey and higher syntaxia in light grey.



Table 8: Documentation of the scale-dependent species composition (rooted presence = any part) of the "world record" nested-plot series (RO01 and RO02). The stands in the nature reserve "La Craiu" near Cluj-Napoca belong to the *Festuca sulcata-Brachypodium pinnati* and have a long history of being mown. World records of vascular plant species richness according to WILSON et al. (in press) are indicated by dark grey shading, while Transylvanian maxima of total and vascular plant species richness are light grey shaded. Note that for 0.01 m<sup>2</sup> the Transylvanian maxima occurred in another nested-plot series (RO04SE: 20 species in total and 18 vascular plants). Header data for the plots are available in Appendix 2 and in Table 3.

Tab. 8: Dokumentation der skalenabhängigen Artenzusammensetzung der *nested plot*-Aufnahmeserien RO01 und RO02, welche Weltrekorde der Gefäßpflanzenartendiversität halten. Die Bestände im Naturschutzgebiet „La Craiu“ nahe bei Cluj-Napoca gehören zum *Festuca sulcata-Brachypodium pinnati*; sie werden seit Langem gemäht. Globale Maxima des Artenreichtums der Gefäßpflanzen nach WILSON et al. (in press) sind dunkelgrau hervorgehoben, während Maximalwerte für Siebenbürgen beim Gesamt- und Gefäßpflanzenartenreichtum hellgrau dargestellt sind. Man beachte, dass für 0,01 m<sup>2</sup> innerhalb von Siebenbürgen die Maxima des Artenreichtums in einer anderen Aufnahmeserie auftraten (RO04SE: 20 Arten gesamt und 18 Gefäßpflanzenarten). Die Kopfdaten der Aufnahmen sind in Anhang 2 und in Tabelle 3 verfügbar.

Series No.	RO01												RO02																
	NW						SE						x	NW						SE						x			
	0,01	0,03	0,1	0,32	1	3,2	0,01	0,03	0,1	0,32	1	3,2		0,01	0,03	0,1	0,32	1	3,2	0,0001	0,001	0,01	0,1	1	10		0,0001	0,001	0,01
Edge length [m]	0,01	0,03	0,1	0,32	1	3,2	0,01	0,03	0,1	0,32	1	3,2	10	0,01	0,03	0,1	0,32	1	3,2	0,01	0,03	0,1	0,32	1	3,2	10			
Area [m <sup>2</sup> ]	0,0001	0,001	0,01	0,1	1	10	0,0001	0,001	0,01	0,1	1	10	100	0,0001	0,001	0,01	0,1	1	10	0,0001	0,001	0,01	0,1	1	10	100			
<b>Species richness (all taxa)</b>	<b>3</b>	<b>7</b>	<b>18</b>	<b>45</b>	<b>82</b>	<b>101</b>	<b>2</b>	<b>5</b>	<b>18</b>	<b>39</b>	<b>55</b>	<b>86</b>	<b>134</b>	<b>3</b>	<b>4</b>	<b>6</b>	<b>37</b>	<b>55</b>	<b>83</b>	<b>5</b>	<b>9</b>	<b>13</b>	<b>35</b>	<b>79</b>	<b>99</b>	<b>129</b>			
Species richness (vascular plants)	2	6	17	43	79	98	2	5	16	37	51	82	125	3	4	6	35	53	81	5	8	12	34	77	97	127			
Species richness (bryophytes)	1	1	1	2	3	3	0	0	2	2	4	4	8	0	0	0	2	2	2	0	1	1	1	2	2	2			
Species richness (lichens)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
<b>Vascular plants</b>																													
<i>Achillea millefolium</i> agg.						1					x	1	x				x	x	1					x	x	1	x		
<i>Adonis vernalis</i>				x	x	15						1	x						3					x	x	7	x		
<i>Agrimonia eupatoria</i> subsp. <i>eupatoria</i>																			0,3										
<i>Agrostis capillaris</i>						0,3			x	x	x	7	x			x	x	x	15					x	x	3	x		
<i>Ajuga genevensis</i>					x	0,3																		x	x	0,3	x		
<i>Anthericum ramosum</i>				x	x	0,3													0,3							x	0,3		
<i>Anthoxanthum odoratum</i>	x	x	x	x	x	0,3			x	x	x	1	x						3						x	1	x		
<i>Anthyllis vulneraria</i>																										x	0,3		
<i>Arrhenatherum elatius</i>						0,3													0,3						x	0,3	x		
<i>Asperula cynanchica</i>		x	x	x	x	1						1	x					x	3					x	x	1	x		
<i>Asperula tinctoria</i>																			0,3										
<i>Avenula pratensis</i> subsp. <i>pratensis</i>			x	x	x	0,3													0,3										
<i>Avenula pubescens</i>						0,3													0,3	x	x	x	x	x	1	x			
<i>Brachypodium pinnatum</i> subsp. <i>pinnatum</i>			x	x	x	7				x	x	7	x	x	x	x	x	x	7					x	x	7	x		
<i>Briza media</i>					x	1			x	x	x	1	x					x	1						x	3	x		
<i>Bromus arvensis</i>																													
<i>Bupleurum falcatum</i>																									x	0,3	x		
<i>Calamagrostis epigejos</i>						0,3				x	x	x	0,3	x															
<i>Campanula glomerata</i>				x	x	1							0,3	x					x	0,3				x	x	0,3	x		
<i>Campanula patula</i>																													
<i>Campanula persicifolia</i>					x	0,3																							
<i>Campanula rotundifolia</i>																													
<i>Campanula sibirica</i>										x	x	0,3	x				x	x	0,3							x			
<i>Carex cf. flacca</i>																			0,3										
<i>Carex michelli</i>	x	x	x	x	x	15	x	x	x	x	x	15	x				x	x	x						x	1	x		
<i>Carex montana</i>			x	x	x	0,3							x						1			x	x	x	3	x			
<i>Carex tomentosa</i>																							x	x	x	3	x		
<i>Carlina acaulis</i>																			0,3					x	0,3	x			
<i>Carlina vulgaris</i>				x	x	0,3							x																
<i>Caucalis platycarpus</i>			x	x	x	0,3						x	0,3	x															
<i>Centaurea phrygia</i> agg.													0,3	x												0,3			
<i>Centaurea spiculata</i> subsp. <i>spinulosa</i>														x	x	x	x	x	0,3					x	1	x			
<i>Centaurea triumfetti</i>				x	x	0,3							0,3	x										x	0,3	x			
<i>Cerastium fontanum</i> subsp. <i>vulgare</i>																													
<i>Cerintho minor</i>					x	0,3																							
<i>Chamaecytisus albus</i>																													
<i>Cirsium pannonicum</i>					x	0,3							0,3	x												0,3			
<i>Clematis integrifolia</i>													0,3	x										x	0,3	x			
<i>Clematis recta</i>					x	0,3				x	x	x	0,3	x					x	7					x	7	x		
<i>Clinopodium vulgare</i> subsp. <i>vulgare</i>																													
<i>Convolvulus arvensis</i>				x	x	0,3												x	x	1				x	x	1	x		
<i>Coronilla varia</i>				x	x	1					x	x	3	x										x	0,3	x			
<i>Crepis nicaeensis</i>													0,3	x															
<i>Cruciata glabra</i>				x	x	1				x	x	x	1	x				x	x	1					x	1	x		
<i>Dactylis glomerata</i> subsp. <i>glomerata</i>				x	x	1		x	x	x	x	1	x					x	x	3				x	x	7	x		
<i>Daucus carota</i> subsp. <i>carota</i>																			0,3										
<i>Dianthus carthusianorum</i>					x	0,3							0,3	x					x	0,3				x	x	0,3	x		
<i>Dorycnium pentaphyllum</i> subsp. <i>herbaceum</i>					x	0,3								x															
<i>Echium russicum</i>																			0,3					x	x	0,3	x		
<i>Elymus hispidus</i>			x	x	x	15			x	x	x	25	x				x	x	7				x	x	7	x			
<i>Equisetum arvense</i>																		x	0,3						x	1	x		
<i>Erophila verna</i>						0,3							x																
<i>Erysimum odoratum</i>																													
<i>Euphorbia epithymoides</i>					x	0,3					x	x	1	x				x	x	0,3						0,3	x		
<i>Euphorbia esula</i> subsp. <i>tommasiniana</i>						0,3							0,3	x										x	0,3	x			
<i>Euphorbia sp.</i>																			0,3										
<i>Euphorbia sp. (hairy)</i>																									x	0,3	x		
<i>Fallopia convolvulus</i>																													
<i>Festuca pratensis</i>					x	0,3			x	x	x	x	0,3	x															
<i>Festuca ser. Valesiaca</i>				x	x	7				x	x	x	15	x				x	x	7			x	x	x	15	x		
<i>Filipendula vulgaris</i>					x	1			x	x	x	x	3	x					x	7				x	x	3	x		
<i>Galium boreale</i>										x	x	x	1	x												0,3			
<i>Galium glaucum</i>					x	0,3							0,3	x											x	0,3	x		
<i>Galium mollugo</i> agg.						1							1	x												0,3			
<i>Galium verum</i>						0,3					x	15	x						x	1									
<i>Geranium sanguineum</i>					x	1					x	x	0,3	x										x	0,3	x			
<i>Glechoma hirsuta</i>																			0,3							0,3			
<i>Heracleum sphondylium</i>	</																												