Chapter 8
The Dry Grasslands in Slovakia: History, Classification and Management

Daniela Dúbravková and Mária Hajnalová

Abstract Dry steppe-like grasslands are of the most endangered habitats in Slovakia since the natural distribution of suitable sites supporting this vegetation is limited. These sites are refuges for many rare thermophilous species of plants and invertebrates, and significantly contribute to the biodiversity of the European landscapes. The land use of dry grasslands in Slovakia experienced some dramatic changes in the last decades. The most crucial factor negatively influencing the biodiversity of grassland habitats is cessation of traditional extensive management activities, abandonment, afforestation, ploughing and building that resulted in area reduction, fragmentation, and degradation of dry grasslands. We summarise the actual results of rather intense dry grassland research in eastern Central Europe from the perspectives of (I) their establishment history, (II) variability and classification, and (III) conservation and management. Summarizing the actual archaeological and palynological knowledge we polemicize about the potential existence of original dry grassland sites in the contact zone of the Western Carpathians and the Pannonian Basin where the steppe-like vegetation occurred continually since the Holocene. An overview of phytosociological and habitat classification of the steppe-like grasslands according to results of the newest surveys and expert perspectives is given including a call for need of revision of the classification of some European natural habitat types of community interest but with an unclear delimitation. Practical management recommendations, based on the ecological requirements of dry grassland habitats, are discussed.

D. Dúbravková (✉)
Institute of Botany, Slovak Academy of Sciences, Bratislava, Slovakia

Homeland Museum in Považská Bystrica, Považská Bystrica, Slovakia
e-mail: daniela.dubravkova@savba.sk

M. Hajnalová
Department of Archaeology, Faculty of Arts, Constantine the Philosopher University, Nitra, Slovakia
e-mail: mhajnalova@ukf.sk

M.J.A. Werger and M.A. van Staalduinen (eds.), *Eurasian Steppes. Ecological Problems and Livelihoods in a Changing World*, Plant and Vegetation 6,
DOI 10.1007/978-94-007-3886-7_8, © Springer Science+Business Media B.V. 2012

Abbreviations

AT Austria
CZ the Czech Republic

8.1 Introduction

Slovakia is located in the eastern part of Central Europe. It includes the biogeographical regions of the Western Carpathian Mountains and the adjacent northern part of the Pannonian (= Carpathian) Basin. There, the dry grasslands occur in the colline belt of the peri-Carpathian mountains (e.g. Považský Inovec Mts, Tríbeč Mts, Krupinská planina Mts, Slovenský kras Mts) and the lowland landscapes of the Pannonia (Fig. 8.1). The dry grassland vegetation in Slovakia is mostly restricted to smaller extra-zonal stands, although in some attributes of structure and species composition it is similar to the zonal forest-steppe (lesosteppe) in central Eurasia. Central European dry grasslands are western outposts of the vast steppes of Russia and the Ukraine (Walter 1974; Bohn and Neuhäusl 2000–2003). The forest-steppe zone enters Central Europe along the Danube River (Horvat et al. 1974; Illyés and Bölöni 2007). The precise location of the zonal forest-steppes in Central Europe differs in various sources although the main area is considered to be located in the Great Hungarian Plain (Bohn and Neuhäusl 2000–2003; Illyés and Bölöni 2007) (Fig. 8.2).

8.2 History of Dry Grassland Sites

In Central Europe, dry grasslands have existed since the Pleistocene. They occurred in vast areas in lowlands and hilly landscapes with a dry continental climate, harsh winters and short summers (Frenzel et al. 1992; Chytrý et al. 2007; Kuneš et al. 2008). In the full and late glacial the mountain areas of the Carpathians were covered by taiga and hemiboreal forest while towards to the west and southwest the forests tended to be increasingly open or patchy gradually passing into the generally treeless tundra and steppe landscapes (Kuneš et al. 2008). The occurrence of thermophilous species was conditioned by repeated series of their retreat and expansion due to the climatic oscillations in the Quaternary ice ages and interglacial stages (Hewitt 1999). In the interglacials the distribution areas of plant and animal species expanded back to their previous ranges from the cold-stage refugia located in southern Europe (Iberian, Apennine and Balkan peninsulas), Caucasus and Caspian Sea area through various migratory routes (Willis and Whittaker 2000; Ložek 2009). However, many topographically sheltered refugia with favourable microclimates were located also in the present temperate zones (Hewitt 2000). The recent occurrence of thermophilous species of continental, Pontic-Pannonian and sub-Mediterranean distribution in the Pannonian Basin is explained by the survival of some species with wide ecological

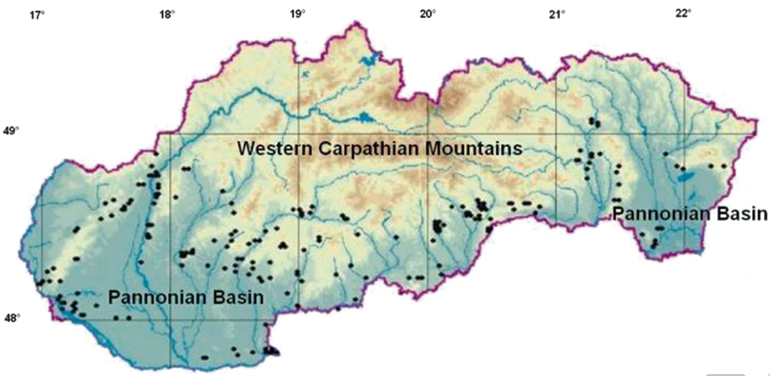

Fig. 8.1 Location of the dry grassland sites in Slovakia. They occur on warm slopes in the colline belt of the peri-Carpathian mountain ranges and in lowland areas of the Pannonian Basin

Fig. 8.2 The distribution of the forest-steppe and steppe zones in Eurasia. The detail shows the approximate location of the forest-steppe zone in the Pannonian Basin (Source: http://wwf.org/, modified by D. Dúbravková)

amplitudes in micro-refugia located directly in this area, while some other species re-colonised Pannonia before and during the early Holocene along the lower Danube (Magyari et al. 2010). Since there are only a limited number of pollen analyses in the Eurasian steppe zone and also only few fossil and phylogeographic studies available it is difficult to appraise the distribution of rare and endemic thermophilous species in the Pannonian Basin and other areas (Hewitt 2004).

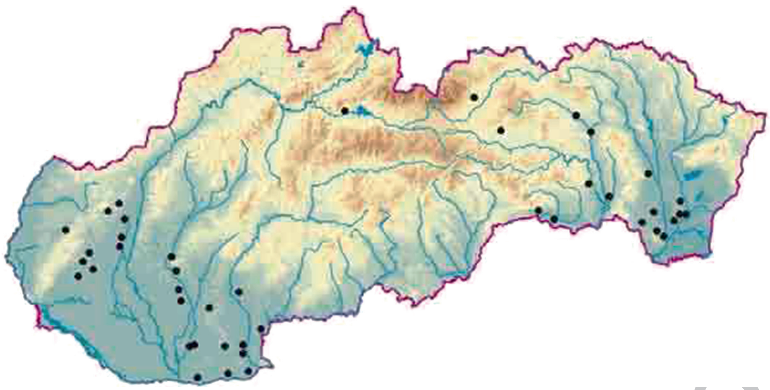

Fig. 8.3 Distribution of Neolithic and Aeneolitic archaeobotanical sites in Slovakia (Hajnalová 2007)

With climate amelioration and forest expansion in the Holocene dry grasslands became fragmented and restricted to the driest landscapes (south facing slopes, dry plateaus) while the forest occupied areas with a humid and cold mesoclimate such as north-facing slopes and valleys (Ložek 1971; Chytrý et al. 2007). In Central Europe the dry grasslands may have existed even before man settled down, although these might not necessarily have been identical with the recent communities (Poschlod and Wallis De Vries 2002). Their spatial extent, however, might have been influenced by human activities (Pott 1996; Bieniek and Pokorný 2005). Humans lived in the lowland and hilly landscapes of the Pannonian Basin since the Palaeolithic (about 2 million years BC). As the climate turned warmer their numbers gradually increased. Agricultural activities in this area started about 7000–6000 BC. The colline areas in Slovakia, particularly the south-western and south-eastern margins of the Western Carpathians that are in direct contact with the Pannonian Basin, were colonised by groups of early farmers in the early Neolithic (5500 BC). They entered current Slovakia from the south along the Danube and the Tisza Rivers and their tributaries (Hajnalová 2007). In these two main corridors, via which farming spread to new areas, archaeobotanical sites contain the oldest macro-remains of cultivated plants excavated in Slovakia (Fig. 8.3). Farming in the montane basins of the Central Western Carpathians appeared later.

Present hypotheses on the character of the vegetation in Central Europe at the time of arrival of the Neolithic farmers differ considerably. Some authors assume that the landscape was covered by deep mixed deciduous forests (Küster 1995) while others claim that Europe's original vegetation were not the closed forests, but rather a more open, park-like landscape of sparse deciduous forests with forest pastures and small grassland stands maintained by the grazing of large primeval herbivores (Vera 2000; Sádlo et al. 2005). As there are very few reliable palynological data from the territory of Slovakia, the following text is based on literature from the adjacent regions and archaeological interpretations on site density. 'The deep forests theory' induces that forest clearing by the slash-and-burn management started near human settlements in the loess areas of the Pannonian Basin about 6000 BC and in the northern areas of the Carpathians some 1,000–2,000 years later. Regarding the sparse population density at those times, the forest clearings might not have left any considerable marks in the landscape and the process of forest re-colonisation in the cleared stands might have been rather quick (Krippel 1986). It is assumed that this is the reason why pollen spectra and archaeological findings dating from those times do not correlate (Dresslerová and Pokorný 2004). Deforestation started to be of a considerable intensity only in the early and full Bronze Age (about 1000 BC) due to the spread of mining and processing of metal, improving the farming techniques and allowing population increase (Lang et al. 2000–2003; Illyés and Bölöni 2007). Large-scale forest clearing as a consequence of the expansion of farming (cultivating, pasturing and hay making) even in the less fertile areas continued with some intermissions until the Modern Time. In the montane areas, e.g. in the Považský Inovec Mts, forests were decimated during the Turkish wars in the seventeenth century. People made charcoal and created pastures for their herds, and flocks sheltered in the mountains (Kňazovický 1962). In Central Europe the area covered by forests was the smallest at about 1700 (Sádlo et al. 2005).

'The open woodland with treeless formations theory' (Vera 2000) assumed that at the time of the arrival of the Neolithic farmers the landscape was covered by open forest with steppe-like enclaves (Sádlo et al. 2005). Much has since been written against, as well as in support of Vera's theory, and several specialists now agree that it can be relevant, although probably not everywhere and not in the exact way as it was presented (Szabó 2009). The theory is also supported by a substantial archaeobotanical analysis (Bogaard 2004) which has presented new facts on the establishment of Neolithic farming in the loess areas of Central Europe. The Neolithic farmers most probably situated their fields at the treeless stands naturally occurring in the landscape. Analyses have dismissed the theory of cyclic slash-and-burn cultivation and, instead, demonstrated the intensive cultivation of permanent plots (Bogaard 2004). Diverse archaeological studies from Slovakia, the Czech Republic and Poland (Hajnalová 1989; Opravil 1999; Bieniek 2002; Bieniek and Pokorný 2005) document archaeobotanical findings of macro-remains of seeds and awns of feather grass (*Stipa pennata* s.l.) in thick layers dated as Neolithic. This potentially edible plant typical for steppe vegetation most probably played a role in the economy of the Neolithic settlers as a material for insulation or for making mattresses. Local gathering, rather than distant transport, best explains the presence in considerable quantities of this xerothermic grass in the remains of Neolithic settlements (Bieniek 2002). The natural occurrence of small steppe stands with xerothermic grassland vegetation in the landscape of Central Europe of those times has now repeatedly been proved by pollen analyses (Nalepka et al. 1998; Bieniek and Pokorný 2005). Some authors suppose that due to its utility value feather grass might have been transported and planted in new areas outside its original range (Behre 1988; Bakels 1992), but considering the ecological requirements of the species, and the difficulties to get it established, this theory is most probably improper. Summing up, it is likely that steppe-like sites with feather grass naturally

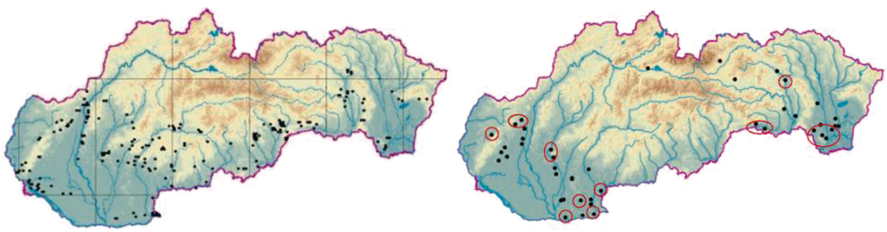

Fig. 8.4 Comparison of the recent distribution of dry grassland sites (*left*) and the Neolithic archaeobotanical excavation sites in Slovakia (*right*). The *red marks* show the co-occurrence of archaeological and dry grassland sites

occurred in south-western Slovakia at the times of establishment of farming in this area (about 5000–3000 BC).

The subsequent climate changes since the Bronze Age (since about 2500 BC) induced in most areas of Europe spontaneous afforestation. However, during this period humans maintained the treeless stands in the landscape of Central Europe and increased the distribution of dry grasslands by forest clearing and extensive livestock grazing (Bieniek and Pokorný 2005). The anthropogenic influences changed the natural boundaries of vegetation belts, induced secondary migrations of some species, and thus caused the creation of the secondary plant communities replacing the original (natural) vegetation. Xerophilous grassland communities developed gradually at sites where *Quercus, Quercus-Carpinus* and eventually *Fagus* forests have been cleared on slopes of warm expositions at low altitudes and on former fields. Xerophytes and steppe species entered these sites from patches of natural steppes located nearby and as seeds transported in the fur of grazing animals.

The problem of a primary or a secondary origin of recent dry grassland sites in the contact zone of the Western Carpathians and the Pannonian Basin is difficult to solve without local palynological studies. The origin of dry grasslands in the more oceanic areas of Western Europe is different. There the first farming communities appeared later (at about 4000 BC) and established themselves in a different climatic zone and another natural vegetation type than the humans dwelling in the Carpatho-Pannonian region. Based on pollen studies and archaeology, it seems that deforestation and maintenance of the treeless sites in Western Europe is a result of the activities of the Neolithic farmers (Pott 1996). Their activities caused the establishment of steppe-like vegetation outside its zonal ranges and isolated glacial steppe refugia (Behre 2000). Thus the dry grassland sites in Western Europe are considered to be of secondary origin. As we showed earlier, this is not valid for the Carpatho-Pannonian region. A very characteristic feature of eastern Central Europe is the co-occurrence of recent dry grassland sites and the areas inhabited and cultivated by humans since the prehistory (Ložek 1999; Bieniek and Pokorný 2005) (Fig. 8.4). We may interpret this fact in two ways: (I) the Neolithic settlements were established in areas of natural distribution of historical (and also recent) steppe-like vegetation, or (II) the dry grasslands subsequently developed at the sites of former

Neolithic settlements and farmland. Whatever the case, it is a fact that recent species-rich dry grasslands occur near archaeological sites that document the agricultural activities of Neolithic farmers (e.g. the hilly landscapes on the south-western edges of the Western Carpathians: Dolní Věstonice-Děvín – CZ, Lančár-Chríb, Nitra, Levice, Kamenín, Bíňa, Čenkov, Štúrovo, and on the north-eastern edge of the Pannonian Basin: Zádiel-Včeláre, Košice; Fig. 8.4), in the Bronze and Iron Ages as well as in the Great Moravian era since about the ninth century (e.g. Ducové, Dražovce, Lupka, Zobor, Bíňa), on the medieval castle hills (e.g. Čachtice, Devín, Turňa nad Bodvou, Krásna Hôrka, Sirotčí hrádek – CZ, Dívčí hrady – CZ, Falkenstein – AT) and at religious sites (e.g. a belfry hill Lančárska zvonica, calvaries in Nitra and Beckov). The dry grassland vegetation at those sites has repeatedly been studied (Maglocký 1979; Vozárová 1986; Unar 2004; David 2009; Dúbravková et al. 2010a). Those prehistoric settlements were set up at naturally sheltered sites with a favourable meso-climate and fertile soil, located mainly on loess terraces and slopes along the river valleys, e.g. along the Morava, Dudváh, Hron, Žitava and Nitra Rivers (Ložek 1999; Bogaard 2004; Hajnalová 2007). Due to the long-term agricultural utilization of the land (fields, pastures, and meadows), soil erosion and occasional fires prevented later establishment of forest at these sites. The hypothesis on the existence of original dry grassland sites, where steppe-like vegetation occurred continuously since the Holocene in the landscape of the Carpatho-Pannonian region, is supported by some palynological studies, analyses of fossil mollusc communities, plant macro-remains as well as by isolated relict occurrences of taxa typical for continental steppes, such as *Helictotrichon desertorum* subsp. *basalticum* (Podpěra 1904; Chytrý et al. 2007).

8.3 Variability and Classification of Dry Grasslands in Slovakia

8.3.1 Phytosociological Classification

In the phytosociological classification system the Central European dry grasslands belong to the class *Festuco-Brometea* Br.-Bl. et Tüxen ex Soó 1947 which includes dry and semi-dry grasslands and Euro-Siberian zonal steppes and forest-steppes (Mucina 1997). The class comprises several orders. The order *Festucetalia valesiacae* Br.-Bl. et R. Tx. ex Br.-Bl. 1949 includes the dry grasslands and steppes on deep to relatively shallow soils dominated by narrow-leaved tussock-forming grasses mostly fescues and feather grasses (e.g. *Festuca pseudodalmatica, F. rupicola, F. valesiaca, Stipa capillata, S. joannis, S. pulcherrima, S. tirsa*, etc.). The species composition is specific due to the occurrence of rare species of continental (e.g. *Astragalus austriacus, A. danicus, A. exscapus, Carex supina, Crambe tataria, Festuca valesiaca, Chamaecytisus ratisbonensis, Iris pumila, Oxytropis pilosa, Potentilla arenaria, Stipa capillata, S. dasyphylla, S. tirsa*), sub-Mediterranean

Photo 8.1 Dry grassland of the *Festuco valesiacae-Stipetum capillatae* Sillinger 1930 association in the Malé Karpaty Mts, Devínska Kobyla Nature Reserve. In the background there is the paleontological sandstone site Sandberg, a Tertiary seabed. The stand is dominated by *Stipa capillata, Festuca valesiaca* and *Koeleria macrantha*. The species in flower are *Jurinea mollis, Lotus borbasii, Dorycnium pentaphyllum* and *Dianthus pontederae* (Photo by D. Dúbravková, May 15, 2006)

(e.g. *Cleistogenes serotina, Fumana procumbens, Chrysopogon gryllus, Melica transsilvanica, Stipa eriocaulis*), and Pontic-Pannonian distribution (e.g. *Cruciata pedemontana, Gypsophila paniculata, Inula ensifolia, Linum hirsutum, Ranunculus illyricus, Tithymalus glareosus*). Based first of all on different geological substrates, and with some corresponding differences in floristic composition, the Slovak dry grasslands of the order *Festucetalia valesiacae* are divided into two alliances. The alliance *Festucion valesiacae* Klika 1931 includes narrow-leaved continental steppe-like communities on alkaline to neutral soils developed over loess, fluvial sediments, carbonate and volcanic rocks (Michálková 2007a; Dúbravková et al. 2010b) (Photo 8.1). The alliance *Koelerio-Phleion phleoidis* Korneck 1974 is restricted to the acidic soils poor in minerals, such as granite, gneiss and quartzite (Photo 8.2). The vegetation includes some acidophilous species (e.g. *Acetosella*

Photo 8.2 A fragment of acidophilous dry grassland in a horse pasture on quartzite (Biele Karpaty Mts, Skalický vrch). The dominant grasses are *Agrostis capillaris, Anthoxanthum odoratum* and *Festuca rupicola; Steris viscaria* is in flower (Photo by J. Košťál, May 13, 2009)

vulgaris, Agrostis vinealis, Armeria vulgaris, Jasione montana) although the overall species composition is similar to the alliance *Festucion valesiacae*. This vegetation occurs in Slovakia only at a few localities, since the distribution of suitable sites is limited (Michálková 2007b).

Besides the closed to semi-closed steppe-like dry grasslands there occur open Pannonian, rocky, dry grasslands on calcareous substrates with *Carex humilis* and *Festuca pallens* (*Bromo pannonici-Festucion pallentis* Zólyomi 1966) and dealpine *Sesleria albicans*-dominated grasslands (*Diantho lumnitherii-Seslerion* (Soó 1971) Chytrý et Mucina in Mucina et al. 1993) in Slovakia (Janišová and Dúbravková 2010) as well as the sub-xerophilous vegetation of the alliances *Cirsio-Brachypodion pinnati* Hadač et Klika ex Klika 1951 and *Bromion erecti* Koch 1926 (Škodová 2007a, b). These, however, are not a topic of the current paper.

8.3.2 Classification at the Habitat Level

The dry grassland communities of the alliance *Festucion valesiacae* present in Slovakia could be classified within three different natural habitat types: 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates, 6240* Sub-Pannonic steppic grasslands, and 6250* Pannonic loess steppic grasslands

(Stanová and Valachovič 2002; European Commission 2007). The contents of these habitat types overlap a great deal, and this makes the classification extremely complicated. Due to the absence of internationally standardized information, the European Community has accepted these vague units as Natural Habitat Types of Community Interest according to Annex I of the Habitats Directive (92/43/EEC), although such types have unclear delimitations and are not supported by data (Dúbravková et al. 2010b). They were designated using an inappropriate combination of two criteria: (I) occurrence of phytogeographically important (sub-)continental and Pannonian species, and (II) type of geological substrate. Applying the results of recent international comparative studies of grassland habitat diversity (Botta-Dukát et al. 2005; Illyés et al. 2007; Dúbravková et al. 2010b) might help to re-evaluate the delimitation of habitat types and establish better criteria for international habitat classification and subsequent effective monitoring of endangered habitats.

One of the most important environmental factors affecting the variability of (sub-) xerophilous vegetation of the class *Festuco-Brometea* is soil moisture (Chytrý et al. 2007). For this reason we suggest to classify the biotope types according to this criterion into the following two proposed categories. The first unit would include more xerophilous vegetation dominated by narrow-leaved grasses (xerophilous *Festuca* and *Stipa* species). It could be called 'narrow-leaved dry grasslands' and include both the recent 6240* and 6250* habitats. Such a unit would comprise the alliance *Festucion valesiacae* (dry grasslands on loess, calcareous and volcanic substrata) as well as the *Koelerio-Phleion phleoidis* (dry grasslands on acidic substrata) and it might be subsequently divided into a few sub-units according to the type of substrate. On the other hand, the 'broad-leaved semi-dry grasslands' would represent the more humid habitat type dominated by *Bromus erectus* and *Brachypodium pinnatum*. From the phytosociological point of view it would include vegetation of the alliances *Bromion erecti* and *Cirsio-Brachypodion pinnati*. In the current habitat classification it partly represents the 6210 habitat. A similar habitat classification is used in practise in the habitat classification scheme of the Czech Republic (Chytrý 2001). It has repeatedly been pointed out that the Slovak habitat classification published by Stanová and Valachovič (2002) needs revision (Michálková et al. 2006; Dúbravková and Janák 2011).

8.4 Conservation and Management of Dry Grasslands in Slovakia

8.4.1 Socio-economic Perspectives on Land-Use Change

The peculiar species-rich composition of the Central European dry grasslands is a result of long-term agricultural activities. The xerophilous grasslands were used for ages as low-productivity pastures which could be occasionally moved in more humid years (Poschlod and Wallis De Vries 2002). The sites in Slovakia are often located at difficult terrain situations, mostly on steep and rocky slopes, and thus were usually used for grazing of smaller animals such as sheep and goats. However, destitute farmers used to graze there all their livestock, including a few cows, horses, sheep, and goats (Barańska et al. 2010). The dry grasslands were managed in a traditional way until about the end of the 1960s (Buček et al. 2006). The main reason for cessation of the low-intensity grazing practice was the intensification of agricultural production during the period of communism in former Czechoslovakia (1948–1989). Private land was collectivised, the majority of former farmers started to work in industry, the number of livestock kept privately in the countryside decreased rapidly, and thus the area that was grazed decreased. The state farming companies tended to enormously intensify the production, and accordingly the animals of low profitability (sheep and goats) were replaced by a higher number of cows. The dry grasslands could not compete in fodder productivity with the less dry grasslands and meadows, and therefore some substitute 'progressive' utilisation of the dry habitats was applied. Many steppe-like grassland sites were thus destroyed by afforestation (Zlinská 2000), ploughing (Deván et al. 2006), and mining, or they were abandoned which led to degradation of their extraordinary species composition. Similar unsuitable and even detrimental management was applied in other post-communistic countries (Meshinev et al. 2005; Buček et al. 2006; Illyés and Bölöni 2007; Molnár et al. 2008; Ruprecht et al. 2009; Barańska et al. 2010) and in the Western Europe as well (Wallis De Vries et al. 2002).

Although the variability of steppe-like grasslands in Slovakia is considerable, their actual status as regards land use and conservation is not optimistic. The majority of the dry grasslands maintained until today are located in nature protection areas, such as national parks and reserves, and also there the traditional low-intensity grazing was ceased a long time ago and the sites became abandoned. Other dry grasslands occur near villages on fragments of formerly communal pastures which used to be grazed at low intensity, even during the communist days, by a few animals privately kept in the countryside (Buček et al. 2006). After 1989 the land was returned to the private owners. But the modern land holders have only limited experience and few facilities for an active management of the sites, and thus many dry grasslands remain abandoned. Farming seems not to be profitable in modern society, and even though agro-environmental payments are provided, very few dry grassland sites have been managed in an effective and habitat-friendly way. Extensive sheep and goat grazing, which is the most suitable management practice for preserving the biodiversity of the steppe-like habitats, is done only at a few sites located in areas of nature conservation (Rajcová 2010).

We also mention the negative impact of the past activities of the official State Conservation Agency. Due to lack of knowledge on the ecology of grasslands and the linkage between species richness and management, since the 1960s conservationists avoided any disturbance activities, including grazing and mowing, in the grasslands located in nature conservation sites (Buček et al. 2006; Mládek et al. 2006; Barańska et al. 2010). This was detrimental for dry grasslands in the protected areas, and what is more, it raised mistrust by locals towards the conservationists when they recently encouraged them to graze and mow the stands, where such activities were prohibited in the past (Šuvada pers. comm.). Present-day nature conservation strategy emphasizes using the same management methods as were applied traditionally by our farming ancestors. The problem is, however, that only a few people remember in detail the past routines performed regularly at particular sites. This knowledge on e.g. the right timing of pasturing, ways of open-air sheep penning, flock and shepherd migration, as well as rotational pasturing, is gradually disappearing as elder persons pass away. But this precious information results from age-old human experience and should be protected as a part of the cultural heritage of Slovakia.

8.4.2 Environmental Perspectives on Abandonment

The majority of xerophilous plant species naturally occurring in the dry grassland habitats are week competitors that can only establish and persist in nutrient-poor stands with a low intensity of competition (Bylebyl 2007). Such grasslands are either naturally open (such as rocky dry grasslands of the *Bromo pannonici-Festucion pallentis*) or managed (grasslands of the *Festucion valesiacae* and *Koelerio-Phleion phleoidis*). Management is therefore crucial for maintenance of the species composition of xerothermophilous steppe-like grasslands (Virágh and Bartha 1996; Enyedi et al. 2008). Cessation of the traditional management (sheep and goat grazing) as a result of a low economical profitability and changes in lifestyle cause rather quick successional changes in these valuable habitats. If not managed, litter accumulates and changes the micro-climatic conditions at the sites. This results in an unfavourable alteration of the temperature and humidity at soil surface as well as shading and the formation of a mechanical barrier preventing germination and establishment. Therefore, species with short life cycles (annuals, biennials) first disappear from the abandoned stands (Černý et al. 2010). But the germination of the perennials, e.g. *Eryngium campestre*, is also negatively affected by shading and strong competition (Bylebyl 2007).

During the first years of abandonment, the sites pass a 'ruderal successional stage' with a higher abundance of species such as *Echium vulgare, Anthemis tinctoria, Bromus sterilis*, etc. (Bylebyl 2007). This stage is usually followed by a 'grass stage' with an increased dominance of sub-xerophilous (e.g. *Brachypodium pinnatum, Bromus erectus*) and mesophilous grasses (e.g. *Arrhenatherum elatius, Avenula pubescens*). Due to the accumulated litter more water is retained and, by its decomposition, higher amounts of nutrients (P, N) cycle in the ecosystem. Nitrogen, originating from the industry and traffic, also is augmented (by about 5 g/m^2/year) through aerial deposition (Willems et al. 1993; Bobbink et al. 1998; Wallis De Vries et al. 2002) and is a serious problem in today's nature conservation. An increase in nutrients, particularly of phosphorus, leads to the decline of oligotrophic species and of species richness (Willems et al. 1993; Chytrý et al. 2009). Since the nutrients persist in the soil for a long time, the vegetation changes induced may remain constant for decades. Abandoned stands with nutrient additions are often invaded by expansive (*Calamagrostis epigejos*) and alien species (e.g. *Ambrosia artemisifolia, Eleagnus angustifolia, Lycium barbarum, Robinia pseudoacacia, Stenactis annua*) (Domán et al. 1997; Buček et al. 2006; David and Záchenská 2010). In the advanced stage of succession polycorm-forming shrubs (e.g. *Crataegus* spp., *Prunus spinosa, Rubus* spp.) and other woody species (e.g.. *Cerasus fruticosa, C. mahaleb, Spiraea media, Quercus* spp., *Fagus sylvatica, Pinus sylvestris*) intrude the sites and develop layers of high cover. Such spontaneously overgrown sites rapidly decrease in species richness.

8.4.3 Management Recommendations

To maintain the species-rich dry grasslands it is necessary to suppress the uncontrolled spread of shrubs and trees at the abandoned sites by manual or mechanical clearing. This is an important precondition for maintaining the light-demanding xerophilous species (Bylebyl 2007). Absence of the woody species, however, does not guarantee the sustainability of dry grasslands. Another important step toward long-term persistence of rare steppe species is regular biomass removal (by grazing, eventually mowing and occasionally a fire) and topsoil disturbance (by grazing, trampling). The disturbance provides creation of gaps with bare soil within the dense grass and litter sod and this allows the seeds to germinate. Germination of small-sized seeds is more disturbance-dependent than that of larger seeds (Burke [AU1] and Grime 1996; Kupferschmid et al. 2000). While practising any management action it is important not to perform it simultaneously in the entire area of the site. A section of the site (each time a different one) should remain untouched so that the variability in vegetation structure is maintained. Variability of habitats and presence of different successional stages in the landscape supports the diversity of invertebrates (Wallis De Vries et al. 2002; Cremene et al. 2005) and the occurrence of rare and endangered plant species (Enyedi et al. 2008; Ruprecht et al. 2009).

The most convenient management of dry grasslands is grazing by sheep and goats in low intensity (Photo 8.3). These light-weight animals are suitable for grazing sites at slopes with a shallow soil (Háková et al. 2004). The proper mix of animals is three sheep to one goat. A sheep is a selectively grazing animal which grazes the stand to a short height (about 3 cm), and thus the biomass removal is sufficient. Goats, however, graze the stand to a taller-height, preferring grasses in flower, bark and leaves of woody species and thus reduce the height of shrubs (Mládek et al. 2006). In low-productivity stands the native breeds of grazing animals are the most suitable ones because they are best adapted to the nutrient-poor fodder, the climate and the terrain situation (Calaciura and Spinelli 2008). The animals prefer spring pasture when the fodder is fresh. At the end of April, when the grazing usually starts, the stand should not be too wet and muddy and the height of the grass must reach at least 5 cm. Strong trampling in spring causes damage to the vegetation sod. Therefore ‘one-shot walk-through grazing’ is positive for the vegetation but permanent grazing could harm some species. Later in the season (in July, August) the grass turns dry and less tasty. The grazing becomes more selective and many

Photo 8.3 Extensive grazing management of steppe-like grasslands with *Festuca valesiaca* in the Hainburger Berge Mts in NE Austria (Hundsheimer Berg Nature Reserve). The pasture was divided into a few sections by solar-powered electric wire fences and the flock rotated through the sections according to the stage of grass growth (Photo by K. Hegedüšová, June 27, 2007)

ungrazed patches are created. However, grazing later in the season does not endanger the sensitive species and the majority of plants may produce ripe seeds that can be transported in the animal fur to other sites.

Spontaneous seed dispersal rarely exceeds a distance of 25 m in dry grasslands. For effective site regeneration and maintenance of the biodiversity seed transport from the species-rich sites located nearby might be necessary (Stampfli and Zeiter 1999; Barbaro et al. 2001). This can best be achieved through herding sheep, as seeds show a high attach potential to sheep fur (Bylebyl 2007), and rotating pasturing with flocks grazing a stand for 3–4 weeks (Poschlod et al. 1998; Calaciura and Spinelli 2008; Háková et al. 2004; Barańska et al. 2010a). The recommended animal density is 5 animals per hectare (Barańska et al. 2010). Annual grazing is preferred, but stands in good condition could be grazed once in several years (Buček et al. 2006).

Other types of management action such as mowing, mulching and burning may also be applied, although only under specific circumstances and regulations. Mowing showed to be an effective way to eliminate expansive grasses e.g. *Brachypodium pinnatum, Bromus erectus* and *Calamagrostis epigeios* (Willems et al. 1993; Klimeš et al. 2008; Házi et al. 2010). It has to be done twice a year and preferably late in the growing season (August, September).

Where there are few farming animals available, mulching recently became a popular and relatively cheap management action. But mulching does not cause seed transport and does not remove biomass; it disrupts the solid litter layer and even long-term mulching does not cause a negative change in species composition (Kahmen et al. 2002).

Burning is another cheep management action, but it is not recommended because, if applied regularly, the species composition shifts to a variant that very much resembles the herbaceous layer of a fallow (Kahmen et al. 2002). If applied, the stands must be burnt in a mosaic pattern and only once in 15–20 years (Háková et al. 2004). While a combination of grazing and infrequent burning increases the species richness of dry habitats, burning without grazing leads to a loss of species (Noy-Meir 1995).

An effective method of restoring degraded dry grasslands and former fields is the import of fresh hay from species-rich sites. Compared to seed sowing, a thin layer of hay serves not only as a source of seeds but also creates proper conditions for germination and establishment (Kiehl and Pfadenhauer 2007; Házi et al. 2010).

To further the proper management of dry grasslands in Slovakia, we prepared guidelines (a management model) for land owners, farmers and the State's nature conservancy which are collectively responsible for management of the steppe-like sites (Dúbravková and Janák 2011). The models and the level of their implementation will also be used to design the rules concerning agro-environmental payments. This may positively motivate land holders and set a high standard for habitat-friendly management activities. The management models for all types of grassland habitats in Slovakia are published at www.daphne.sk/mm/manazmentove-modely.

Acknowledgements This study was supported by the grant 'Management models for grassland habitats' (SK0115) supported through the EEA Financial Mechanism, the Norwegian Financial Mechanism and the state budget of the Slovak Republic and grant VEGA 2/0181/09 financed by the Science Grant Agency of the Ministry of Education of the Slovak Republic and Slovak Academy of Sciences.

References

Bakels CC (1992) Fruits and seeds from the Linearbandkeramik settlement at Meindling, Germany, with special reference to *Papaver somniferum*. Anal Praehist Leid 25:55–68

Barańska K, Chmielewski P, Cwener A, Pluciński P (2010) Conservation and restoration of xerothermic grasslands in Poland – theory and practice. Wydawnictwo Klubu Przyrodników, Świebodzin, 52 pp

Barbaro L, Dutoit T, Cozic P (2001) A six-year experimental restoration of biodiversity by shrub-clearing and grazing in calcareous grasslands of the French Prealps. Biodivers Conserv 10:119–135

Behre K-E (1988) The role of man in European vegetation history. In: Huntley B, Webb T (eds) Vegetation history. Handbook of vegetation science. Kluwer Academic Publications, Dordrecht, pp 633–672

Behre K-E (2000) Der Mensch öffnet die Wälder – zur Entstehung der Heiden und anderer Öffenlandschaften. Rundgespräche der Komission für Ökologie 18:103–116

Bieniek A (2002) Archaeobotanical analysis of some early Neolithic settlements in the Kujawy region, central Poland, with potential plant gathering activities emphasised. Veg Hist Archaeobot 11:33–40

Bieniek A, Pokorný P (2005) A new find of macrofossils of feather grass (*Stipa*) in an Early Bronze Age storage pit at Vliněves, Czech Republic: local implications and possible interpretation in a Central European context. Veg Hist Archaeobot 14:295–302

Bobbink R, Hornung M, Roelofs JG (1998) The effect of air-borne nitrogen pollutant on species diversity in natural and semi-natural European vegetation. J Ecol 86:717–738

Bogaard A (2004) Neolithic farming in central Europe. An archaeobotanical study of crop husbandry practices. Routledge, London/New York, 209 pp

Bohn U, Neuhäusl R (eds) (2000–2003) Karte der natürlichen Vegetation Europas. Bundesamt für Naturschutz, Bonn

Botta-Dukát Z, Chytrý M, Hájková P, Havlová M (2005) Vegetation of lowland wet meadows along a climatic continentality gradient in Central Europe. Preslia 77:89–111

Buček A, Lacina J, Laštůvka Z (2006) Panonské stepní trávníky na Moravě. Veronica – časopis pro ochranu přírody a krajiny 20/17:1–58

Burke MJW, Grime JP (1996) An experimental study of plant community invasibility. Ecology 77:776–790

Bylebyl K (2007) Central European dry grasslands: processes of their development and possibilities for their maintenance. Diss Bot 406:1–142

Calaciura B, Spinelli O (2008) Management of Natura 2000 habitats. 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites). In: European Commission (ed) Technical report 2008 12/24, pp 1–38

Černý T, Petřík P, Boublík K (2010) How did changes in landscape management influence dry grassland composition after the Velvet Revolution? In: Janišová M, Budzáková M, Petrášová M (eds) Seventh European dry grassland meeting. Succession, management and restoration of dry grasslands. Abstracts & excursion guides, 27–31 May 2010, Smolenice, Slovakia, p 17

Chytrý M (2001) Suché trávníky. In: Chytrý M, Kučera T, Kočí M (eds) Katalog biotopů České republiky. Agentura ochrany přírody a krajiny, CR, Praha, pp 129–140

Chytrý M, Hoffmann A, Novák J (2007) Suché trávníky (*Festuco-Brometea*). In: Chytrý M (ed) Vegetace České republiky. 1. Travinná a keříčková vegetace Academia, Praha, pp 371–497

Chytrý M, Hejcman M, Hennekens SM, Schellberg J (2009) Changes in vegetation types and Ellenberg indicator values after 65 years of fertilizer application in the Rengen Grassland Experiment, Germany. Appl Veg Sci 12:167–176

Cremene C, Groza G, Rakosy L, Schileyko AA, Baur A, Erhardt A, Baur B (2005) Alterations of steppe-like grasslands in Eastern Europe: a threat to regional biodiversity hotspots. Conserv Biol 19:1606–1618

David S (2009) Stepní flóra a vegetace zemních valů hradiska v obci Bíňa (okr. Nové Zámky). Bull Slov Bot Spoločn 31:77–85

David S, Záchenská M (2010) Species richness and threatened vascular plant species of the sub-pannonic steppic grasslands in the southern part of Krupinská planina Mts. In: Janišová M, Budzáková M, Petrášová M (eds) Seventh European dry grassland meeting. Succession, management and restoration of dry grasslands. Abstracts & excursion guides, 27–31 May 2010, Smolenice, Slovakia, p 19

Deván P, Devánová K, Mereďa P, Smatanová J, Rajcová K (2006) Charakteristika flóry záujmového územia floristického kurzu v Pruskom. Bull Slov Bot Spoločn 28(suppl 1):13–21

Domán E, Kalivoda B, Kapocsi J (1997) Management of loess grasslands in the Körös-Maros region. In: Tóth E, Horváth R (eds) Proceedings of the "Research, conservation, management" conference. Aggtelek, 1–5 May 1996. Aggtelek National Park Directorate, Aggtelek, pp 199–204

Dresslerová D, Pokorný P (2004) Vývoj osídlení a struktury pravěké krajiny na středním Labi. Pokus o přímé srovnání archelogické a pyloanalytické evidence. Archeologické rozhledy 56:739–762

Dúbravková D, Janák M (2011) Manažmentový model pre xerotermné travinno-bylinné spoločenstvá. MSc, DAPHNE – Inštitút aplikovanej ekológie a Botanický ústav SAV, Bratislava, p 36. URL: http://www.daphne.sk/sites/daphne.sk/files/uploads/MM03_xerotermy.pdf

Dúbravková D, Hegedüšová K, Janišová M, Škodová I (2010a) New vegetation data of dry grasslands in the Western Carpathians and northern Pannonian Basin. Tuexenia 30:357–374

Dúbravková D, Chytrý M, Willner W, Illyés E, Janišová M, Kállayné Szerényi J (2010b) Dry grasslands in the Western Carpathians and the northern Pannonian Basin: a numerical classification. Preslia 82:165–221

Enyedi ZM, Ruprecht E, Deák M (2008) Long-term effects of the abandonment of grazing on steppe-like grasslands. Appl Veg Sci 11:55–62

European Commission (2007) Interpretation manual of European Union habitats. EUR 27:1–142

Frenzel B, Pécsi M, Velichko AA (1992) Atlas of paleoclimates and paleoenvironments of the Northern Hemisphere. Geographical Institute, Gustav Fischer Verlag, Budapest/Stuttgart

Hajnalová E (1989) Katalóg zvyškov semien a plodov v archeologických nálezoch na Slovensku. In: Hajnalová E (ed) Súčasné poznatky z archeobotaniky na Slovensku. Acta Interdisciplinaria Archaelogica, Nitra, pp 3–192

Hajnalová M (2007) Early farming in Slovakia: an archaeobotanical perspective. In: Colledge S, Conolly J (eds) The origins and spread of domestic plants in southwest Asia and Europe. Institute of Archaeology/Left Coast Press, Walnut Creek, pp 295–312

Háková A, Klaudisová A, Sádlo J (eds) (2004) Zásady péče o nelesní biotopy v rámci soustavy Natura 2000. PLANETA XII, Ministerstvo životního prostředí, Praha, 157 pp

Házi J, Bártha S, Szentes S, Penksza K (2010) Seminatural dry grassland management by mowing of *Calamagrostis epigeios* (L.) Roth in Hungary. In: Janišová M, Budzáková M, Petrášová M (eds) Seventh European dry grassland meeting. Succession, management and restoration of dry grasslands. Abstracts & excursion guides, 27–31 May 2010, Smolenice, Slovakia, p 31

Hewitt GM (1999) Postglacial recolonization of European Biota. Biol J Linn Soc 68:87–112

Hewitt GM (2000) The genetic legacy of the quaternary ice ages. Nature 405:907–913

Hewitt GM (2004) Genetic consequences of climatic oscillations in the Quaternary. Philos Trans R Soc Lond B 359:183–195

Horvat I, Glavač V, Ellenberg H (1974) Vegetation Südosteuropas. Gustav Fischer Verlag, Jena

Illyés E, Bölöni J (eds) (2007) Lejtősztyepek, löszgyepek és erdőssztyeprétek Magyarországon. MTA ÖBKI, Budapest, 236 pp

Illyés E, Chytrý M, Botta-Dukát Z, Jandt U, Škodová I, Janišová M, Willner W, Hájek O (2007) Semi-dry grasslands along a climatic gradient across Central Europe: vegetation classification with validation. J Veg Sci 18:835–846

Janišová M, Dúbravková D (2010) Formalized classification of rocky Pannonian grasslands and dealpine Sesleria-dominated grasslands in Slovakia using a hierarchical expert system. Phytocoenologia 40:267–291

Kahmen S, Poschold P, Schreiber K-F (2002) Conservation management of calcareous grasslands. Changes in plant species composition and response of functional traits during 25 years. Biol Conserv 104:319–328

Kiehl K, Pfadenhauer J (2007) Establishment and persistence of target species in newly created calcareous grasslands on former arable fields. Plant Ecol 189:31–48

Klimeš L, Hájek M, Hájková P, Rozbrojová Z (2008) Vliv kosení na flóru a vegetaci. In: Jongepierová I (ed) Louky Bílých Karpat. ZO ČSOP Bílé Karpaty, Veselí nad Moravou, pp 325–345

Kňazovický J (1962) História dolného Považia. Správa VÚLH. VÚLH, Zvolen

Krippel E (1986) Postglaciálny vývoj vegetácie Slovenska. Veda, Bratislava, 307 pp

Kuneš P, Pelánková B, Chytrý M, Jankovská V, Pokorný P, Petr L (2008) Interpretation of the last-glacial vegetation of eastern-central Europe using modern analogues from southern Siberia. J Biogeogr 35:2223–2236

Küster H (1995) Geschichte der Landschaft in Mitteleuropa. Verlag C. H. Beck, München, 424 pp

Lang G, Rybníček K, Rybníčková E (2000–2003) Spätglaziale und holozäne Vegetationsgeschichte Europas. In: Bohn U, Neuhäusl R (eds) Karte der natürlichen Vegetation Europas. Bundesamt für Naturschutz, Bonn, pp 87–104

Ložek V (1971) K otázce stepí ve střední Evropě. Zprávy Československ Bot Společn 6:226–232

Ložek V (1999) Ochranářské otázky ve světle vývoje přírody. 8. Zemědělská kolonizace a její dopad. Ochr Přír 54/8:227–233

Ložek V (2009) Refugia, migrace a brány I. Ohlédnutí za starými problémy. Živa 4:146–149

Maglocký Š (1979) Xerotermná vegetácia v Považskom Inovci. Biol Pr SAV 25(3):1–129

Magyari EK, Chapman JC, Passmore DG, Allen JRM, Huntley JP, Huntley B (2010) Holocene persistence of wooded steppe in the Great Hungarian Plain. J Biogeogr 37:915–935

Meshinev T, Apostolova I, Georgiev V, Dimitrov V, Petrova A, Veen P (2005) Grasslands of Bulgaria. Final report on the National Grasslands Inventory Project (PINMATRA/2001/020). Dragon Publishers, Sofia, 104 pp

Michálková D (2007a) *Festucion valesiacae* Klika 1931. In: Janišová M (ed) Travinnobylinná vegetácia Slovenska – elektronický expertný systém na identifikáciu syntaxónov. Botanický ústav SAV, Bratislava, pp 33–49

Michálková D (2007b) *Koelerio-Phleion phleoidis* Korneck 1974. In: Janišová M (ed) Travinnobylinná vegetácia Slovenska – elektronický expertný systém na identifikáciu syntaxónov. Botanický ústav SAV, Bratislava, pp 86–89

Michálková D, Škodová I, Mertanová S (2006) Príspevok k fytocenológii xerotermných rastlinných spoločenstiev v Považskom Inovci. In: Rajcová K (ed) Zborník výsledkov inventarizačného výskumu územia európskeho významu Tematínske vrchy. KOZA a Pre Prírodu, Trenčín, pp 35–44

Mládek J, Pavlů V, Hejcman M, Gaisler J (eds) (2006) Pastva jako prosředek údržby trvalých travních porostů v chráněných územích. VÚRV, Praha, 104 pp

Molnár Z, Bölöni J, Horváth F (2008) Threatening factors encountered: actual endangerment of the Hungarian (semi-)natural habitats. Acta Bot Hung Suppl 50:195–210

Mucina L (1997) Conspectus of classes of European vegetation. Folia Geobot Phytotax 32:117–172

Nalepka D, Wasilykowa K, Tomczyńska Z, Bieniek A (1998) Szata roślinna Pojezierza Kujawskiego i uzitkowanie roślin w okresie osadnictwa kultury lendzielskiej: wstępne doniesienie. Prace Mater Muz Archeol Etnogr w Łodzi Ser Archeol 39:139–174

Noy-Meir I (1995) Interactive effects of fire and grazing on structure and diversity of Mediterranean grasslands. J Veg Sci 6:701–710

Opravil E (1999) Archeologické nálezy kavylu na Moravě. Pravěk 9:153–157

Podpěra J (1904) O vlivu periody glaciální na vývoj květeny zemí českých. Věst Kl Přír Prostějov 6(1903):127–141

Poschlod P, Kiefer S, Tränkle U, Fischer S, Bonn S (1998) Plant species richness in calcareous grasslands as affected by dispersibility in space and time. Appl Veg Sci 1:75–91

Poschlod P, Wallis De Vries MF (2002) The historical and socioeconomic perspective of calcareous grasslands – lessons from the distant and recent past. Biol Conserv 104:361–376

Pott R (1996) Die Entwicklungsgeschichte und Verbreitung xerothermer Vegetationseinheiten in Mitteleuropa unter dem Einflußdes Menschen. Tuexenia 16:337–369

Rajcová K (2010) Starostlivosť o prírodnú rezerváciu Beckovské Skalice. In: Májsky J, Rajcová K (eds) Beskovské Skalice. Zborník inventarizačných výskumov prírodnej rezervávie Beckovské Skalice. Pre Prírodu, Trenčín, pp 62–65

Ruprecht E, Szabó A, Enyedi ZM, Dengler J (2009) Steppe-like grasslands in Transylvania (Romania): characterisation and influence of management on species diversity and composition. Tuexenia 29:353–368

Sádlo J, Pokorný P, Hájek P, Dreslerová D, Cílek V (2005) Krajina a revoluce. Významné přelomy ve vývoji kulturní krajiny českých zemí. Malá Skála, Praha, 248 pp

Škodová I (2007a) *Bromion erecti* Koch 1926. In: Janišová M (ed) Travinnobylinná vegetácia Slovenska – elektronický expertný systém na identifikáciu syntaxónov. Botanický ústav SAV, Bratislava, pp 71–78

Škodová I (2007b) *Cirsio-Brachypodion pinnati* Hadač et Klika ex Klika 1951. In: Janišová M (ed) Travinnobylinná vegetácia Slovenska – elektronický expertný systém na identifikáciu syntaxónov. Botanický ústav SAV, Bratislava, pp 78–86

Stampfli A, Zeiter M (1999) Plant species decline due to abandonment of meadows cannot easily be reversed by mowing. A case study from the southern Alps. J Veg Sci 10:151–164

Stanová V, Valachovič M (eds) (2002) Katalóg biotopov Slovenska. DAPHNE – Inštitút aplikovanej ekológie, Bratislava, 225 pp

Szabó P (2009) Open woodland in Europe in the Mesolithic and in the Middle Ages: can there be a connection? Forest Ecol Manag 257:2327–2330

Unar J (2004) Xerotermní vegetace Pavlovských vrchů. Sborn Přír Klubu Uh Hradiště Suppl 11:1–140

Vera FWM (2000) Grazing ecology and forest history. CABI Publishing, Wallingford, 506 pp

Virágh K, Bartha S (1996) The effect of current dynamical state of a loess steppe community on its responses to disturbances. Tiscia 30:3–13

Vozárová M (1986) Xerotermné travinno-bylinné spoločenstvá Zoborskej skupiny Tríbeča. Zborn Slov Nár Múz 32:3–31

Wallis De Vries MF, Poschlod P, Willems JH (2002) Challenges for the conservation of calcareous grasslands in northwestern Europe: integrating the requirements of flora and fauna. Biol Conserv 104:265–273

Walter H (1974) Die Vegetation Osteuropas, Nord- und Zentralasiens. Gustav Fischer Verlag, Stuttgart

Willems JH, Peet RK, Bik L (1993) Changes in chalk-grassland structure and species richness resulting from selective nutrient addition. J Veg Sci 4:203–212

Willis KJ, Whittaker RJ (2000) The refugial debate. Science 287:1406–1407

Zlinská J (2000) Vegetácia Holubyho lesostepi pri Vinosadoch v Malých Karpatoch. Acta Environ Univ Comen 10:139–152