Studies on vegetation, land use, and phytodiversity of traditional hay meadows in the Eastern Hills of Cluj Natura 2000 site (Transylvania, Romania)

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Abstract

In the peri-Carpathian region some basiphilous semi-dry grasslands (meadow steppes) feature exceptionally high values of vascular plant species richness, especially when managed as hay meadows. The goal of this thesis was to survey traditional hay meadows in the Hills of Cluj (Transylvania, Romania), which were suspected to contain these very species-rich type of semi-dry grasslands as well. In addition to vegetation and phytodiversity data, the research included aspects of land tenure and land use change. This interdisciplinary approach aimed to show which aspects are important to consider for a successful conservation of Transylvania's cultural landscapes and their biodiversity.

The study was carried out in three traditional hay meadows in the communes Dăbâca and Borșa in the north-western part of the Transylvanian Plateau. In a phytosociological survey with priority on meadow steppes and *Molinia* meadows, Braun-Blanquet-relevés were carried out in the years 2009-2013. The historical land use and tenure from 1880 onwards was determined through cadastral maps. Interviews provided information about the traditional meadow management and land use changes in the post-communist era. In the years 2010-2014 the mown plots were mapped in the field. In the meadow steppes, regularly mown stands were compared with unmown or permanently grazed stands regarding their plant diversity and vegetation, using nested-plot series.

Four of nine identified plant communities belong to semi-dry basiphilous grasslands. This includes the *Polygalo majoris-Brachypodietum pinnati* Wagner 1941 with the highest mean vascular plant species richness (61 species / 10 m^2) and the *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939, which is often associated with the highest values of plant species richness on a small scale. Furthermore, the first description for Romania of the *Molinietum caeruleae* Koch 1926 which explicitly mentions *Molinia arundinacea* is provided.

The meadows have been managed continuously as hay meadows for a minimum of 140 years. Their tenure pattern consists of hundreds of small, narrow plots, which has its origin at least 100 years ago. The meadows were traditionally mown once a year between June to August, were not fertilised and were grazed in spring and autumn. Abandonment of mowing, the advent of year-round sheep grazing, and the resulting scrub encroachment are the most important land use changes in the post-communist era.

One of the worldwide highest values of vascular plant species richness on 0.01 m^2 was found (26 species). Short-term abandonment of mowing in the steppe meadows resulted in a decrease of plant species richness and a shift in species composition within the typical species inventory. Conversion of the meadows to permanent sheep pastures led to a decrease in plant species richness and evenness and a replacement of typical meadow species through species of other communities, including ruderal vegetation.

The thesis provides a holistic view on the traditional hay meadows of the study area and reveals possible factors contributing to the high plant diversity of the meadow steppes. Despite their location in a Natura 2000 site, the existing laws on grassland protection and agri-environment payments seem unable to protect the valuable grasslands in the face of delayed land restitution, illegal sheep grazing and decline of small family farming. Management measures and strategies are proposed which might successfully protect the meadows.

Keywords

Hay meadows, meadow steppes, *Molinia arundinacea, Molinietum caeruleae, Brachypodio pinnati-Molinietum arundinaceae, Polygalo majoris-Brachypodietum pinnati,* land use continuity, mowing, grazing of meadows, small-scale plant species richness, *Phengaris, Maculinea,* tenure structure, agri-environment payments

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1 Introduction

1.1 Hay meadows of outstanding importance

The study area in the communes Borșa and Dăbâca, Transylvania, attracted scientific attention when Prof. Dr. László Rákosy discovered in 2008 that its grasslands harbour five taxa of the butterfly genus *Phengaris* (syn.: *Maculinea*). These taxa all are considered near threatened, vulnerable or endangered on the European level (Van Swaay et al. 2010). At the time when the syntopic occurrence of the *Phengaris* taxa was discovered, something which is probably unique in Europe (Timuş 2014), their habitats had not yet been studied botanically. Thus, the starting point for this thesis was to identify and describe the vegetation types important for the *Phengaris* taxa in a number of sites in Borșa and Dăbâca communes.

The butterflies of the genus *Phengaris* have a complex life-cycle, including specific host plant species for oviposition and for feeding on by the young larvae. The host plants occur either in mesic to wet grasslands, like *Sanguisorba officinalis and Gentiana pneumonanthe*, or in semi-dry and dry grasslands and fringe communities, like *Origanum vulgare* and species of the genus *Thymus* (Rákosy and Vodă 2008).

The first field surveys in 2009 revealed that the *Phengaris* taxa and their host plants were found in three sites which had been managed as hay meadows for a long unbroken period (see Figure 1).

Figure 1: Hay making in one of the hay meadows in which *Phengaris* spp. are present (Dăbâca commune, 02.08.2013)

These meadows were all located on north-facing slopes and were between 42 to 200 hectares in area. They were characterised by a savannah-like appearance and a complex, small-scale relief reflected in a mosaic of different vegetation types, with meadow steppes being the most common grassland type. Meadow steppes are defined by Willner et al. (2019) as semi-dry grasslands with a large proportion of steppe species with a Siberian-Pontic-Pannonian distribution. Furthermore, there were patches of wet meadows with *Molinia arundinacea* in scattered, small areas on the meadow surfaces.

The apparent species richness of the meadow steppes, at least in parts, attracted attention from the very first field visits. Through discussions with local botanists, it became clear that the hay meadows were a rarity in the region due to their large size and their relatively good state of preservation. Another point that seemed interesting was that there was no literature for Romania on *Molinia* meadows with the species *Molinia arundinacea*, which is often considered a subspecies of *Molinia caerulea* and not mentioned separately (see Figure 2).

Figure 2: Meadow vegetation with *Molinia arundinacea* and *Gentiana pneumonanthe* in one of the meadows in which *Phengaris* spp. are present (Borşa commune, 15.08.2013)

At that time, there was only one phytosociological study covering parts of the study area, a PhD thesis about the flora and vegetation of the interfluve between the Nadăş and the Borșa valley by Pop (1985), including Borșa commune south of the river Borșa and one of the hay meadows in question (see also Pop 1996). The phytosociological publications by Soó (1927, 1947, 1949) cover an area around Cluj-Napoca south of Borșa commune, thus do not directly include the study area. In contrast, other meadows located only 7-11 km as the crow flies from the study area of this thesis are very well known and researched botanically, namely the Hay Meadows of Cluj (*Fânațele Clujului*) nature reserve, see for example Hayek (1916), Soó (1927), Bujorean (1933) and Soó (1947).

In this nature reserve, at about the same time as the syntopic *Phengaris* spp. occurrence was discovered, some of the meadow steppes traditionally managed as hay meadows had been identified as a world record site for vascular plant species richness at the small scale (Dengler et al. 2012; Wilson et al. 2012). On 0.1 m^2, Dengler et al. (2012) found 43 vascular plant species and on 10 m^2, 98 species, which was later increased to 106 species by Roleček et al. (2019) and finally to 115 species on 10 m^2 by Roleček et al. (2021), all at the same location.

The vegetation of the site belongs to a type of semi-dry basiphilous grasslands, which is found only in some regions of Europe, namely the Transylvanian Plateau, the White Carpathians, the Ukrainian Carpathians, Western Estonia and Southern Öland, and which seem to have a higher plant diversity than comparable grasslands in other parts of Europe (Merunková et al. 2012; Dengler et al. 2014; Roleček et al. 2014). These semi-dry grasslands often are assigned to the phytosociological association *Brachypodio pinnati-Molinietum arundinaceae* (Illyés et al. 2007; Roleček et al. 2014; Roleček et al. 2019) with *Molinia caerulea* agg., including *Molinia arundinacea*.

The fact that the hay meadows where *Phengaris* spp. occur also contain basiphilous semi-dry grassland vegetation and communities with *Molinia arundinacea*, the obvious high plant species richness, as well as the geographical proximity to the world record site, gave rise to the question whether these hay meadows might also belong to this particularly species-rich type of semi-dry basiphilous grasslands (see Figure 3).

Through an applied nature conservation project running at the same time (Paulini 2012), attention was drawn, on the one hand, to the threats to the hay meadows posed by the abandonment of mowing and an increase in sheep grazing, as well as to their special land tenure structure: they consists of over hundred small ownership parcels of around 0.3 or 0.6 ha, something which was thought likely to have a direct influence on conservation efforts.

Apart from their outstanding recognised lepidopterological and presumed botanical importance, the hay meadows with *Phengaris* spp. were also a typical example of the situation of many traditional hay meadows in Transylvania, threatened by land use change (see Chapter 1.4). This led to an extension of the thesis focus from single vegetation types to a holistic view on the traditional hay meadows as an element of the Transylvanian cultural landscapes. For this purpose, the core research approach was supplemented with interdisciplinary aspects. Before presenting the objectives of this thesis, however, the importance of traditional hay meadows and semi-natural grasslands in general and in Romania in particular shall be explained.

Figure 3: Species-rich semi-dry grassland (meadow steppe) in one of the surveyed hay meadows with *Rhinanthus rumelicus, Anthericum ramosum, Stachys officinalis, Leucanthemum vulgare, Trifolium montanum,* etc. (Dăbâca commune, 24.06.2016)

1.2 Importance of hay meadows and semi-natural grasslands

Hay meadows are unsown grasslands which are cut from time to time, once or twice a year, receive no or little manure and serve for the production of hay or green fodder (not silage) for farm animals (Dierschke and Briemle 2008; Luick et al. 2012; Oppermann et al. 2012).

This is a low to medium intensity management characterized by the low use of external inputs (Baldock et al. 1994). This extensive to semi-extensive (at the most semi-intensive) land use (Schumacher 1995; Dierschke and Briemle 2008) generates semi-natural vegetation, that is, grasslands and other vegetation types which are partly shaped by human influence, generally over long time periods, but which maintain also many natural features (Luick et al. 2012). Other examples of semi-natural vegetation include litter and water meadows, wooded pastures and rough pastures. Semi-natural vegetation is also the most important type of High Nature Value farmland, a term often encountered in European policies discussions (Beaufoy et al. 2012).

Semi-natural grasslands were generated over many centuries by ordinary farming activities (Oppermann and Paracchini 2012); as an 'unintentional by-product', one might say (Poschlod and Schumacher 1998; Schumacher 2005). As changes towards more intense farming occurred, semi-natural grasslands were often abandoned, replaced and isolated bit by bit. The remaining semi-natural grasslands are thus an important part of the European natural and cultural heritage.

Semi-natural grasslands, and especially hay meadows, belong to the most species-rich communities in Europe (Poschlod and WallisDeVries 2002). A high plant species richness of semi-natural grasslands can be linked to a high diversity of other species groups, as Batáry et al. (2010) could show in the case of bee species and insect-pollinated plants. Often, plant species richness and bird diversity of semi-natural grasslands are correlated positively (e.g. Vessby et al. 2002).

Semi-natural meadows are an important habitat for a range of species which are adapted to their management regime. Many of these typical meadow species are highly specialized, rare or endangered. Red data lists often include typical meadow plants, such as orchids (e.g. *Anacamptis morio*, *Orchis mascula*), *Arnica montana* and wet meadows species such as *Iris sibirica* and *Gentiana pneumonanthe* (see Figure 4). Endangered bird species often found in wet meadows include the corncrake (*Crex crex*) and the great snipe (*Gallinago media*).

Figure 4: *Iris sibirica* in one of the study hay meadows (Dăbâca commune, 19.05.2013)

Semi-natural grasslands provide important public goods and ecosystem services, which often are higher here than in agriculturally improved grasslands, with the exception of the quantity of food provided through livestock raising (Bullock et al. 2011; Paracchini and Oppermann 2012).

The aforementioned high wild species diversity offers genetic resources that could be used to breed improved cultivars better adapted to climate change. Another ecosystem service important in the context of climate change is the storage of carbon, which seems to be higher at intermediate levels of grassland management compared to intensive - and extensive - management levels (Ward et al. 2016). Furthermore, the emission of nitrous oxide (N_2O) and other greenhouse gases is often higher from intensively farmed than from extensively farmed grasslands (Flechard et al. 2007; Skiba et al. 2013).

Our food supply depends on crops pollination and pest control, which can be enhanced through the so-called 'spillover' of bees, bumble bees, hoverflies and other groups from semi-natural grasslands towards farmed land (Tscharntke et al. 2005; Öckinger and Smith 2007; Bullock et al. 2011).

Eventually, semi-natural meadows contribute to the structural beauty and peculiarity of the cultural landscapes, for example through their often spectacular flowering displays (Nowak and Schulz 2002), and provide public goods such as recreation, tourism, education or ecological knowledge (Bullock et al. 2011). Like most semi-natural grasslands, traditionally farmed meadows are a result of centuries of human influence on the landscape (Luick et al. 2012). Therefore, they conserve the traces of our past and of the richness of different management forms throughout Europe (Oppermann and Paracchini 2012), for example different forms of stacking the hay as well as different cutting dates often based on traditional holidays.

1.3 Current situation of meadows and conservation attempts

In many parts of Europe, there has been a dramatic decline of the traditionally farmed meadows during this and the last century, affecting both, their quantity and quality, as the following examples show:

- Britain has lost around 98 % of its hay meadows since 1930 (Gamble and St. Pierre 2010; Knowles 2011). For instance, the 'northern or upland hay meadows' (*Anthoxanthum odoratum – Geranium sylvaticum* grassland) have been reduced to an area of about 900 hectares in the entire United Kingdom (Bullock et al. 2011; Pinches et al. 2013).
- Sweden lost 99,7% of its hay meadows between 1870 and 2010 (Dahlström et al. 2013).
- The remaining area of lowland hay meadows in German federal states is for example about 110 ha in Schleswig-Holstein and 760 ha in Mecklenburg-Vorpommern (Riecken et al. 2006).
- Almost all meadow plant communities are regarded as endangered in Germany, for example the *Geranio sylvatici-Trisetetum* (critically endangered), nutrient-poor *Arrhenatheretum elatioris* meadows (endangered) or the *Molinietum caeruleae* (critically endangered) (Rennwald 2000). Meadow stands with the complete typical species composition are encountered only rarely (Rennwald 2000; Nowak and Schulz 2002).

Most of the remaining species-rich meadow sites in Northern, Western and Central Europe depend on nature conservation activities and are protected through various conservation instruments. These range from protection measures for typical meadow species and habitats in national laws on environment conservation, to the central instrument of the European Union for wildlife conservation, the Habitats Directive (Council of the European Communities 2013), which includes several protected habitat types of farmed meadows (e.g. habitat type 6410 '*Molinia* meadows', 6510 'Lowland hay meadows' and 6520 'Mountain hay meadows').

Conservation measures linked to agriculture are especially important for protecting low-input grasslands including meadows, which after all depend on regular farming. The agri-environment schemes of the national Rural Development Programmes are such instruments, which compensate farmers financially for the loss of income and/or additional costs of environmentally and wildlife-friendly farming. Many countries have designed programmes targeted at the conservation of species-rich meadows, often including specifications of cutting dates, top-ups for non-mechanized mowing and so on.

While the agri-environment programmes in many cases do have a positive impact on the environment and biodiversity, there are also many records of failed delivery (Kleijn and Sutherland 2003; Stoate et al. 2009; Batáry et al. 2015) and in some cases they may even have negative effects on biodiversity, for example through uniform cutting dates (Knowles 2011); they must be well-designed and thoroughly-evaluated.

1.4 Semi-natural meadows and grasslands in Romania

In Transylvania, like on other regions of the former Eastern Bloc countries, large areas of semi-natural grasslands as well as traditional land use systems have survived until today due to the agricultural policy and farming structure during and after communist times (Ruşdea et al. 2005; Schmitt and Rákosy 2007; Dahlström et al. 2013; Sutcliffe 2013). For example, in Romania, 34% of the utilised agricultural area, that is about 4.8 million hectares, have been classified as High Nature Value farmland by Paracchini et al. (2008). However, the amount of international literature about semi-natural vegetation in the New Member States of the EU, including Romania, is very low compared to its high natural value (Sutcliffe et al. 2015).

To some extent, in Romania semi-natural grasslands are being maintained by small-scale farming. There are still huge numbers of small farms in Romania: out of around 2.9 million farms, around 2.6 million farms had less than 5 hectares agricultural area in 2020 (Eurostat 2023). If they are still actively farming, subsistence- and semi-subsistence farmers need hay from their meadow parcels for winter keep for their cattle and graze their livestock on the common pasture of the village, thus maintaining not only semi-natural meadows and pastures but also traditions and knowledge about low-intensity farming (Dahlström et al. 2013).

On-site evidence as well as regional studies show the existence, at least until recently, of large areas of species-rich hay meadows in Romania, especially in the hilly and mountain regions (e.g. Knowles 2011; Paulini et al. 2012; Dahlström et al. 2013). Additionally, the figures from the Article 17 reporting of the EU Habitats Directive give some ideas about the large extent of semi-natural meadows in Romania. For example, the area size of lowland hay meadows in the reporting period 2013-2018 was in

Romania 6700 km^2, compared to 1536 km^2 in Germany and 1435 km^2 in the Czech Republic (European Environment Information and Observation Network 2023).

However, the Romanian hay meadows and semi-natural grasslands in general are under a high threat of the imminent loss of both quality and quantity unless effective countermeasures are taken. Several studies expect an accelerated loss of biodiversity in most of the New Members States of the EU, due to major changes in the farming structure (e.g. Stoate et al. 2009; Sutcliffe et al. 2015). As for the traditional hay meadows, the ongoing changes lead in many cases to the abandonment of mowing due to a decline in the keeping of cattle and therefore a reduction in the need for hay. The abandoned meadows get overgrown by shrubs and forest or transformed into sheep pastures (Demeter and Kelemen 2011; Paulini et al. 2012).

Especially the expansion of sheep farming has become a common problem for the semi-natural grasslands of Romania in general. Roman et al. (2020) for instance show that more than 50 % of the permanent grassland of Romania is strongly affected and degraded, most of it by overgrazing. The developments of the last decades give rise to fears that much of the valuable grassland in Romania exists on paper only.

1.5 Definition of the thesis objectives

When the research for this thesis started in 2009, the following facts were known about the hay meadows in Dăbâca and Borșa communes:

- There existed large meadow surfaces with semi-natural, in part very species-rich vegetation.
- There was an unique syntopic occurrence of five *Phengaris* taxa.
- The vegetation types might belong to extremely species-rich meadow steppes.
- There were plant communities with *Molinia arundinacea,* which had not been described for Romania up to that point.
- There existed a particular pattern of land tenure.
- There had been a long temporal continuity of meadow use.
- Mowing was to some extent still present as part of the small-scale farming.
- At the same time, large parts of the meadows were unmown and scrub encroachment and sheep grazing had increased, with still unexplored effects on the meadow vegetation and plant diversity.

The rarity of semi-natural meadows in Europe, even, in general, in Romania, as well as the acute threat at that time to that element of the cultural landscape by land use change seemed to demand both ecological research and the implementation of protection measures for the ‘*Phengaris*-meadows’. The basis for this should be a baseline survey of the vegetation.

Experiences from an applied conservation project for the hay meadows managed by the thesis author had revealed furthermore that successful conservation measures could only be developed based on knowledge of the land use history and the land tenure structure.

Thus, the overall goal of this thesis is to better understand the traditional hay meadows of the study area from a vegetation-ecological point of view, and to collect information necessary for their protection. In addition to ecological and phytodiversity data, this includes aspects of land tenure and land use change. This detailed and interdisciplinary approach aims to show, by way of example, which aspects are important to consider for a successful conservation of the high biodiversity of Transylvania's cultural landscapes. Finally, based on the collected data, recommendations for conservation strategies shall be outlined.

After this introduction and description of the study area in Chapter 2, the thesis is divided into four parts:

Chapter 3 - Vegetation survey: Identification and description of the grassland vegetation types harbouring host plants of several *Phengaris* taxa, the *Molinia arundinacea* meadows and the basiphilous semi-dry grasslands.

Chapter 4 - Land use survey: Investigation of the land tenure structure and the land use history; description and quantification of some ongoing land use changes.

Chapter 5 - Phytodiversity survey: Verification of the assumption that the semi-dry grasslands of the meadows reach very high vascular plant richness values. Analysis of how cessation of mowing and sheep grazing alter the semi-dry grasslands and their plant diversity.

Chapter 6 - Conclusions and outlook: The results of Chapters 3 to 5 are discussed against the background of the agricultural and legal framework; conservation strategies are recommended.

The data for this thesis was collected in the years 2009-2013. However, the analysis and discussion of the results is also based on current scientific publications and includes recent developments in the study area.

2 Study area

2.1 Geographical location

The study area is located in Northwest Romania, in the historical region of Transylvania, and belongs to the county of Cluj (see Figure 5). It is situated on the Someş Plateau (*Podişul Someşan*) in the north-western part of the Transylvanian Plateau (*Podişul Transilvaniei*).

Figure 5: The location of the study area within Romania
Source of the map showing national borders, the historical region Transylvania, and Romanian counties: Andrein (https://commons.wikimedia.org/wiki/File:Transylvania.svg), https://creativecommons.org/licenses/by-sa/4.0/legalcode

The Someş Plateau borders on the Transylvanian Plain (*Câmpia Transilvaniei*), separated by the valley of the *Someş Mic* (see Figure 6). The lower parts of the Someş Plateau are called Hills of Cluj and Dej (*Dealurile Clujului si Dejului*) (see Figure 6).

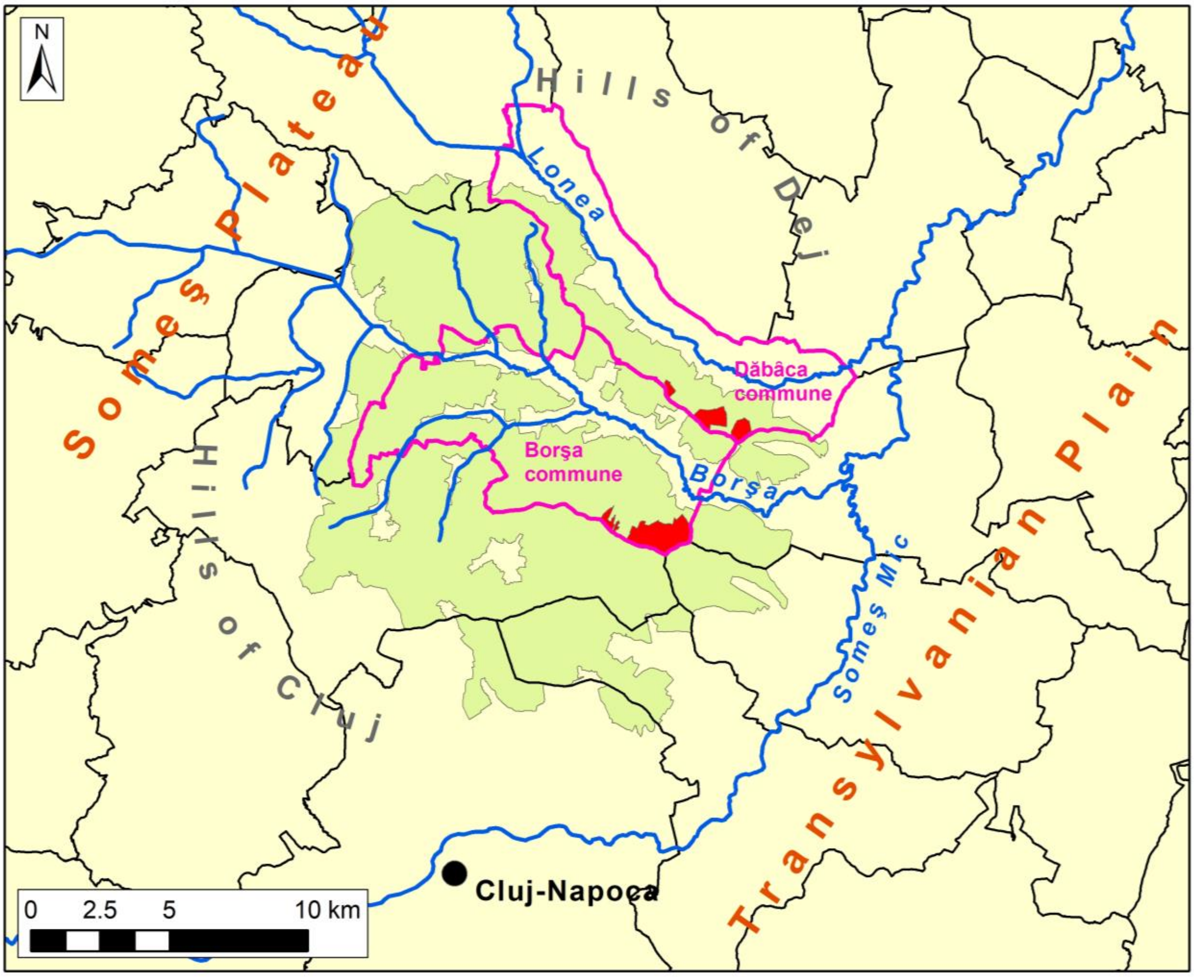

Figure 6: The location of the study area in the Hills of Cluj and Dej
Red polygons: the study hay meadows; green polygon: the Eastern Hills of Cluj Site of Community Importance; black lines: borders of communes; pink lines: borders of Dăbâca and Borșa communes; blue lines: rivers (only the rivers *Someş Mic, Lonea* and *Borșa* and some of their tributaries are shown)

The areas on which this thesis is focussed are five hay meadows located in the communes of Dăbâca and Borșa, in the centre of the Hills of Cluj and Dej (see Figure 6). The communes, including the hay meadows, are partly situated in the Eastern Hills of Cluj Site of Community Importance (ROSCI0295) (see Figure 6). They are located close to Cluj-Napoca which, with around 325,000 inhabitants, is the second largest city in Romania. The communes are accessible via the A-road DN 1C (Cluj-Napoca-Dej) and municipal roads which branch off it. The distance between Cluj-Napoca and the centres of Borșa and Dăbâca villages is in both cases approximately 35 km.

Three of the study meadows (Lord’s Meadow, Village Meadow and Great Meadow) are called *utilised hay meadows* in this thesis, because they were still partly mown at the time of data collection. They are the focus of the phytosociological and land use studies (see Figure 7). In addition, two nearby units which featured similar geomorphological and historical conditions, but which had already been converted into permanent sheep pastures at the time of data collection (Meadow Hill and Jacob’s Meadow) were selected to enable a comparison between mown and grazed meadows. These meadows are called *former hay meadows* in this thesis (see Figure 7).

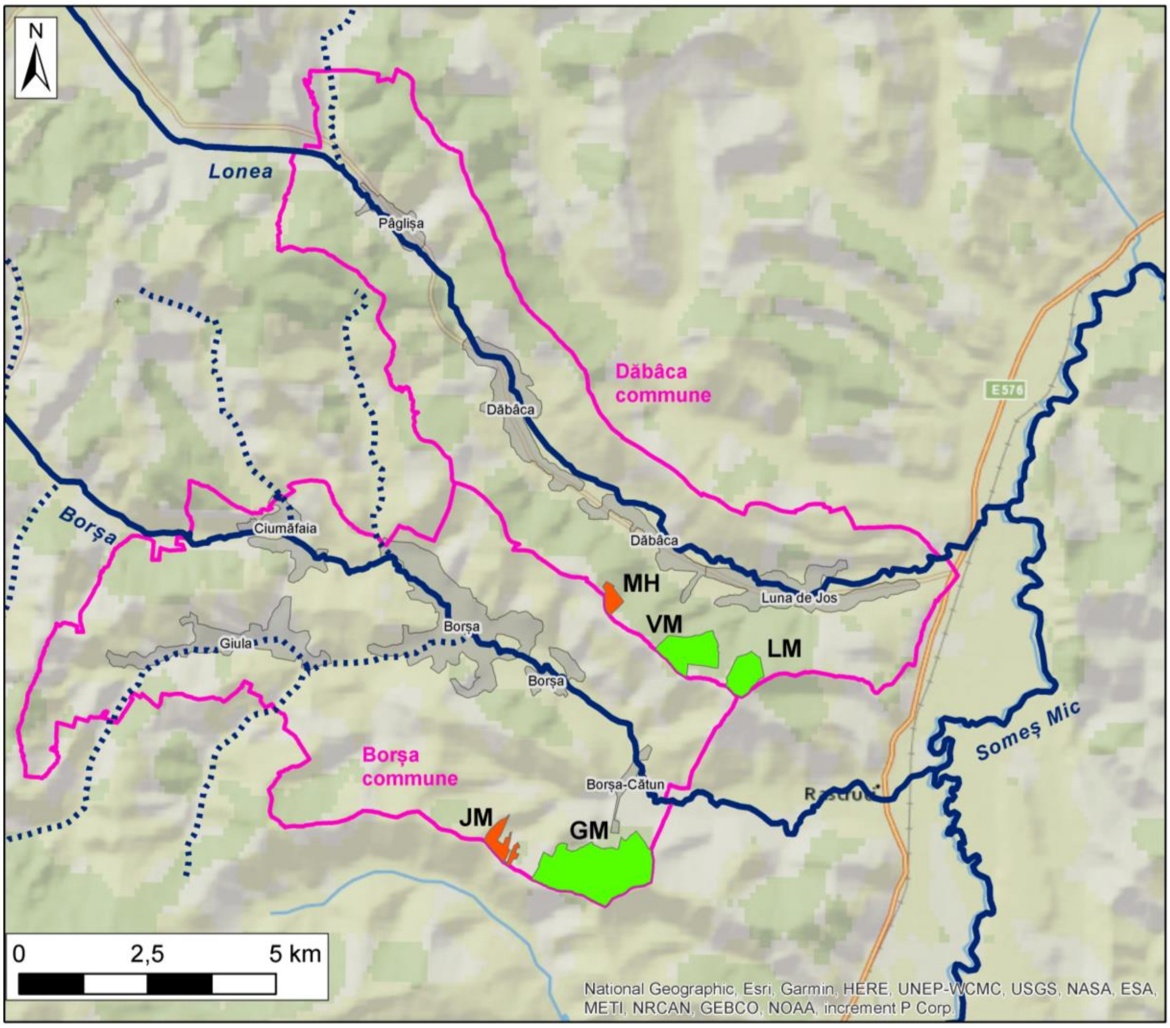

Figure 7: The hay meadows in the communes Borșa and Dăbâca
LM: Lord’s Meadow; VM: Village Meadow; GM: Great Meadow; MH: Meadow Hill; JM: Jacob’s Meadow. Green polygons: *utilised hay meadows*; orange polygons: *former hay meadows*; grey polygons: villages; pink lines: borders of Dăbâca and Borșa communes; blue lines: rivers (only the rivers *Someş Mic, Lonea* and *Borșa* and some of their tributaries are shown). The source of the topographic map is indicated in the lower right corner of the map.

Dăbâca commune covers 5025 ha and has 1437 inhabitants in three villages (status 2021, Institutul Naţional de Statistică 2023). The villages are in the valley of the river *Lonea*, a left bank tributary of the *Someş Mic*, which runs from northwest to southeast through the centre of the commune (see Figure 7). The height above sea level ranges from 280 m in the *Lonea* valley to 550 m on the hilltops. The owners of the meadow plots usually originate from Luna de Jos village, which has 693 inhabitants, but there are also some from Dăbâca village, which has 651 inhabitants.

Borșa commune covers 6162 ha and has 1511 inhabitants in four villages (status 2021, Institutul Naţional de Statistică 2023). The villages are located in the valleys of the river *Borșa* and its tributaries, which runs from northwest to southeast through the commune and is another left bank tributary of the *Someş Mic* (see Figure 7). The height above sea level ranges between 300 m in the valleys and 500 m on the hilltops. The owners of the meadow plots usually originate from the villages Borșa-Cătun (54 inhabitants) and Borșa (1167 inhabitants).

2.2 Climate

At the closest weather station to the study area, Cluj-Napoca (413 m a.s.l), the mean annual temperature between 1971-1990 was 8.2°C and mean annual precipitation over the same period was 548 mm (Deutscher Wetterdienst 2023). The highest monthly mean temperature is reached in July (18.2°C), the lowest in January (-3.4°C), and the most precipitation occur in the months of June, July, May and August (Deutscher Wetterdienst 2023) (see also the climate diagram in Figure 8). The precipitation maxima are predominantly caused by the influence of the dominant westerly (Sunder-Plassmann 2016). There are around 2000 hours of sunshine per year (Deutscher Wetterdienst 2023).

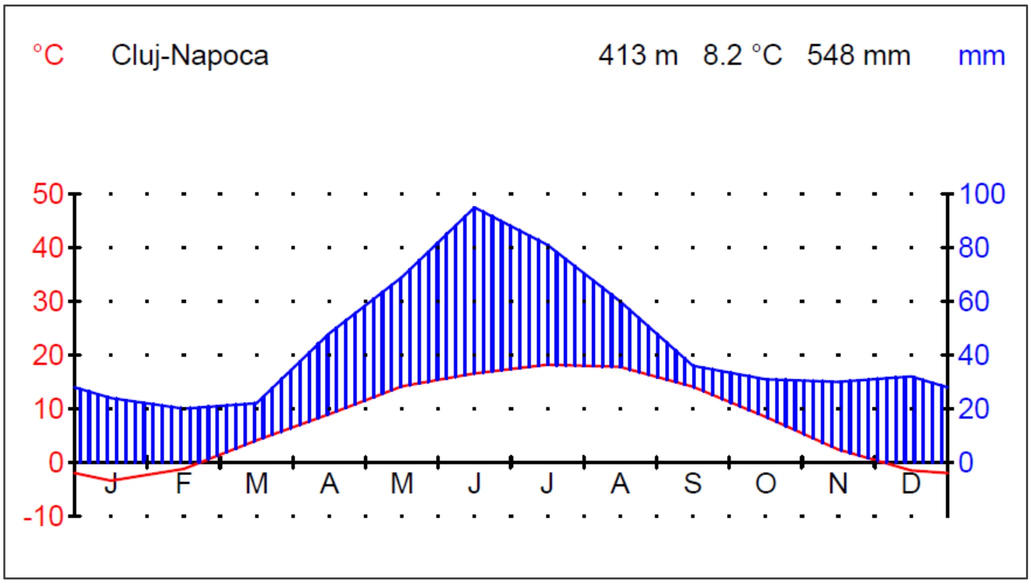

Figure 8: Climate diagram for Cluj-Napoca weather station for the period 1971-1990
Data source: Deutscher Wetterdienst 2023. The diagram was created with the software Klima 0.9 Thierer (2000).

According to the Köppen-Geiger climate classification system, the study area belongs to the cold or boreal climate zone (D), the humid climate type (f) and the subtype with warm summers (b). This classification is based on the following characteristics: the average month temperature is over 10°C in at least four months (May-September), the warmest month July averages below 22 °C and the coldest month January averages below 0°C / 3°C (Kun et al. 2004; Peel et al. 2007). In the climate classification system of Troll and Paffen (1964), the study area belongs to the subcontinental climate of the cool-temperate zones.

The average annual temperature shows an increasing trend during the last decades. Thus, the average annual temperature for the 20-year period 1991-2010 is 9.2°C, one degree higher than for the period 1971-1990 (Tutiempo Network 2023).

The mean annual precipitation for the period 1970 to 2008 as measured at the hydrometric station Borşa range between around 350 mm and 900 mm (Societatea Lepidopterologică din România 2016). The mean value for the period is slightly higher than that for the weather station at Cluj-Napoca (up to 600 mm) and shows a slight downward trend over the last decades.

The high variation in annual mean precipitation and the occurrence of torrential rains are important for understanding the geomorphological processes of the study area (Sunder-Plassmann 2016). Severe storm events occur mainly in the months June to August (Irimuş et al. 2009) and can bring precipitation of 70 to 110 mm over a 24 hour period (Moraru et al. 2015). According to Surdeanu and Sorocovschi (2005), the environmental risks in the wider study area include erosion through torrential rains, landslides, but also droughts.

The predominantly northern aspect of the hay meadows, which reduces the intensity of solar radiation, plays a significant role in their local climate. This affects for example soil temperature, evapotranspiration rate or snow cover (Sunder-Plassmann 2016).

2.3 Geology, relief and soils

The Transylvanian Plateau is a sedimentary basin consisting of Tertiary strata (Földvary 1988). The middle Miocene sedimentation stage of the *Sarmatian* covers the eastern part of Borșa and Dăbâca communes, including the study hay meadows. It is characterized by formations of carbonate-rich clays, including marly clays, clayey and sandy marls, sandstones, conglomerates and tuffs (Pop 2001; Badea et al. 2006; Societatea Lepidopterologică din România 2016; Sunder-Plassmann 2016). The river beds (e.g. of the rivers *Someş Mic*, *Borșa* and *Lonea*) are filled with quaternary deposits of sand and gravel (Societatea Lepidopterologică din România 2016).

The landscape of the Hills of Cluj and Dej has been formed by the fluvial network, consisting in the main of left tributaries of the *Someş Mic* river (Pop 2001). The streams, which developed after the subsidence of the Transylvanian Plateau, have eroded their paths into the weak geological strata (Pop 2001; Societatea Lepidopterologică din România 2016), resulting in a sequence of hills and valleys (see Figure 9).

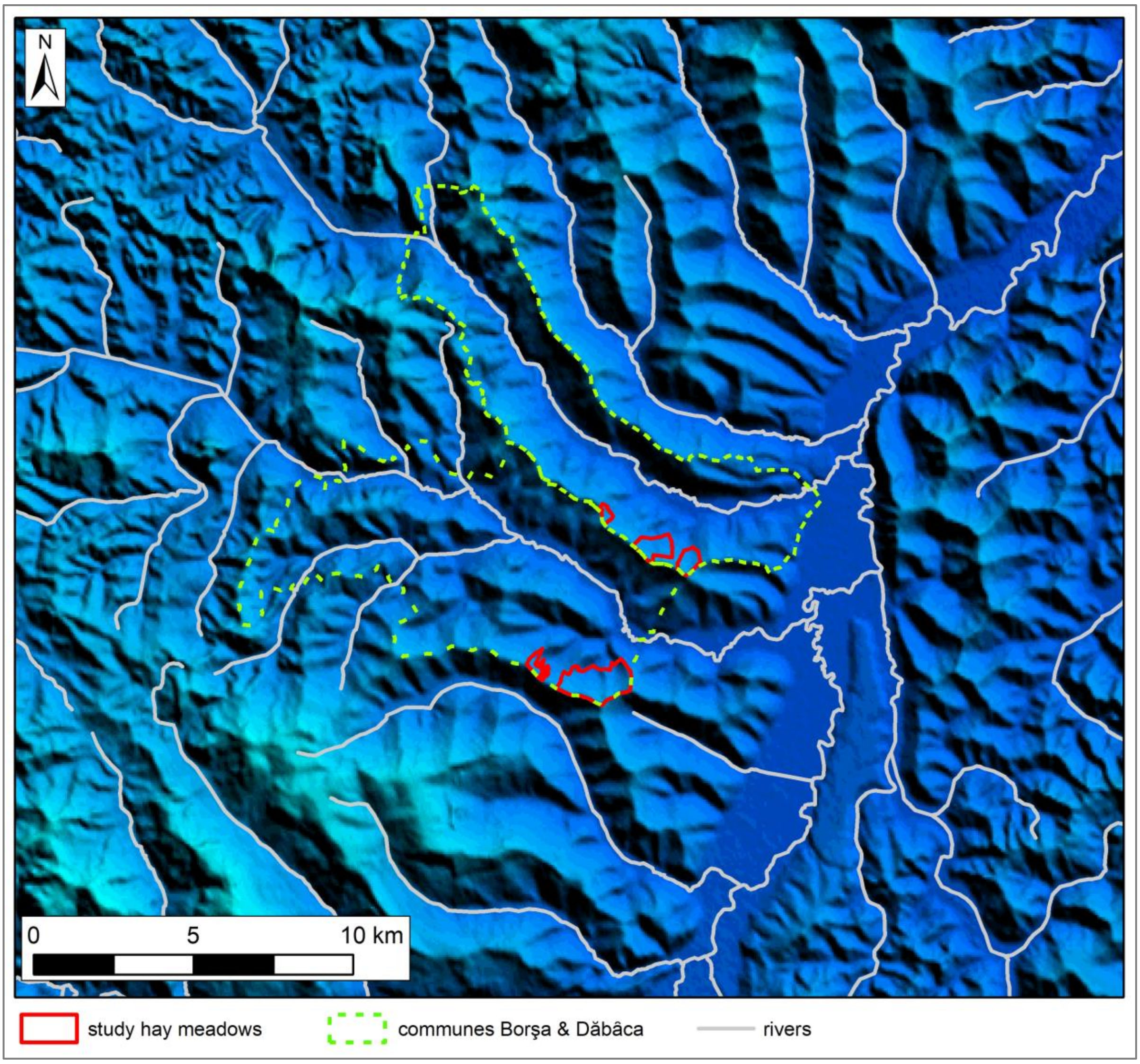

Figure 9: Digital elevation model of the study area
Source of the relief map: processed SRTM data (version 4.1) by Jarvis et al. (2008)

Thus, the study area is characterized by a sequence of NW-SE-orientated hill ridges on around 450-500 m a.s.l., alternating with valley bottoms of around 280-350 m a.s.l. The resulting north- and south-facing hillslopes differ clearly in their microclimatic conditions. The study hay meadows are mainly north-facing, in smaller parts also east, northeast- or northwest-facing.

The study meadows are characterised by a complex relief consisting of small plateaus, erosion gullies, concave and convex forms with a generally very high level of slope morphodynamics (see Figure 10). The underlying processes from the past are known for the Lord's Meadow. Here, the upper and middle slope was most probably formed by complete slumping at the end of the Last Glacial Period. Furthermore, dislocation of solid material by surface erosion occurred, probably intensified by an increase of anthropogenic influence through episodical burning of the grass vegetation during spring (Sunder-Plassmann 2016). Current processes in all study meadows are for example rotational slumping, caused by alternating water-permeable and -impermeable sediment layers, as well as mass displacement due to the constant creeping of the ground cover (G. Sunder-Plassmann, personal communication, February 2023).

Figure 10: Complex small-scale relief of the Lord's Meadow (Dăbâca commune, 16.08.2013)

The information on the soils of the study hay meadows come from different sources: the soil map of Romania 1:200,000 by Florea et al. (1963-1993), a more detailed map (scale 1:10,000) of the soil types and other soil properties available for the commune of Borșa (Oficiul pentru Studii Pedologice şi Agrochimice Cluj 1960s /1970s) and the management plan for the SCI (Societatea Lepidopterologică din România 2016). Furthermore, there exists a detailed pedological study for the Lord's Meadow by Sunder-Plassmann (2016).

In general, the following conditions have had an influence on the soil formation in the Lord's Meadow and presumably also on the other study meadows (G. Sunder-Plassmann, personal communication, February 2023):

- unconsolidated, carbonate-rich marls as parent material
- concentration of the precipitations in late spring / early summer, with frequent occurrence of torrential rains in this period (see also Chapter 2.2)
- the already mentioned pronounced morphodynamic processes on the hillslopes, leading to a mosaic of substrate ablation, translocation and accumulation
- a long history of anthropogenic influence on vegetation cover during the Holocene (see also Chapter 2.6)

According to the sources named above, the zonal soil types of the study meadows are chernozems and phaeozems (see Figure 11). The chernozems can be shallow in places, and in this case are indicated as regosols in the soil map of Florea et al. (1963-1993). Furthermore, vertisols occur as intrazonal soil types.

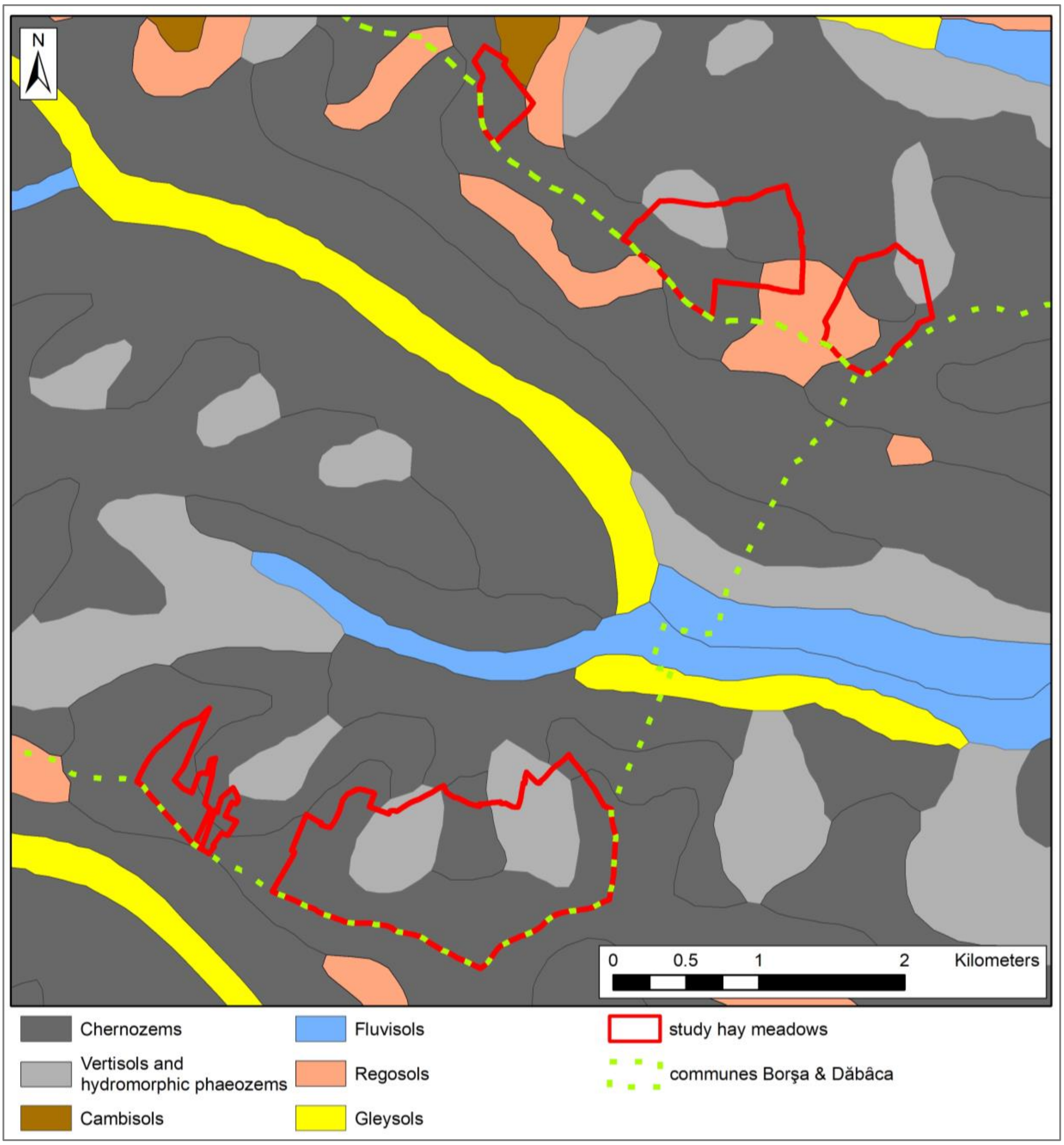

Figure 11: Soil map of the study hay meadows
Source of the soil map: Soil map of Romania 1:200,000 by Florea et al. (1963-1993); original soil units have been grouped together and adapted to the World Reference Base for Soil Resources (IUSS Working Group WRB 2022)

Chernozems, the zonal soil type of the tallgrass steppes, are soils with a thick, black Ah-horizon generally located directly above the C-horizon (Zech et al. 2014), which develop from unconsolidated carbonate-rich parent material, e.g. loess or marl. They are characterized by a favourable pore size distribution, a high usable field capacity, a high humus richness, a high biological activity during the humid months, a high bioturbation rate through an active soil fauna, as well as high nutrient supply and availability (Zech et al. 2014).

Phaeozems, the zonal soil type of the forest steppes, have very similar biological, physical and chemical properties to the chernozems. The diagnostic difference to the chernozems is the lack of secondary carbonates in the first 50 cm under the lower limit of the Ah-horizon (Zech et al. 2014).

Vertisols are soils rich in swelling clay minerals. They shrink when dry, often with formation of cracks, and swell when the conditions become wet again. Under wet conditions the soils are characterized by poor drainage, low air capacity and a low usable field capacity (Zech et al. 2014; Sunder-Plassmann 2016). In the dry season the usable field capacity is also low due to a high water tension (Sunder-Plassmann 2016). The soils have high nutrient reserves, some of which, however, are poorly available to plants (Zech et al. 2014).

The following characteristics of the soils in the Lord's Meadow are listed by Sunder-Plassmann (2016) as being particularly important. First, the high clay content of the soils, which varies depending on whether the soils are located in accumulation and translocation areas, where the clay mineral formation mainly takes place, or ablation areas, where the least thick soil profiles with the lowest clay contents are found (Sunder-Plassmann 2016). The high clay content leads to stagnic properties of the soils, i.e. temporary water-logging and reducing conditions, which were identified for all soil profiles in the Lord's Meadow (Sunder-Plassmann 2016). Further effects of high clay content on plants were described in the paragraph on vertisols.

Second, the exceptionally high and deep humus content of the soils, for which the various reasons are listed by Sunder-Plassmann (2016). This characteristic of the soils significantly increases their water-binding capacity and structural stability. Furthermore, it also makes the soils an exceptionally large carbon sink, which must be preserved in the face of global warming (Sunder-Plassmann 2016).

Third, the soils are subject to intensive bioturbation by soil mammals and *Lumbricidae* and the high density of ants on the site. The extremely rich soil biology leads to intensive mixing activity and the generation of a loose and stable soil structure, which has a significant impact on soil properties (Sunder-Plassmann 2016).

Regarding the properties of the substrate that affect vegetation productivity, on the one hand there are positive factors, such as marl as a parent rock, high bioturbation, and high relief dynamics, which at most sites lead to a re-accumulation of nutrients in the topsoil. On the other hand, the interaction of the high clay content (and thus a low usable field capacity) with the highly seasonal climate has a negative effect on productivity. Especially on steep, clay-rich sites, drought stress sets in more frequently and relatively early due to the high water tension. Furthermore, increased drought stress occurs on the less clay-rich but more exposed sites of the upper slope, as there is no supplemental water here (G. Sunder-Plassmann, personal communication, December 2016).

At the sites in the Lord's Meadow covered by *Molinia* meadows, where stagnant water and slope water supply provide plant-available water for a longer period of time, productivity is likely to be higher, despite the highest clay contents, than at the sites covered by semi-dry grassland communities (G. Sunder-Plassmann, personal communication, December 2016).

2.4 Vegetation cover of the study area

Figure 12 shows the result of a land cover and grassland survey on the level of phytosociological alliances carried out in the communes of Borșa and Dăbâca in the years 2010 and 2011 by Bărbos (2012), at the same time as the data collection for this thesis. The methodology has been described by Paulini et al. (2011). Around 5740 ha, that is, 51 % of the total communal area, were covered by grasslands, which could be considered on the whole as semi-natural (Bărbos 2012). The most common vegetation units in terms of area are presented in the following.

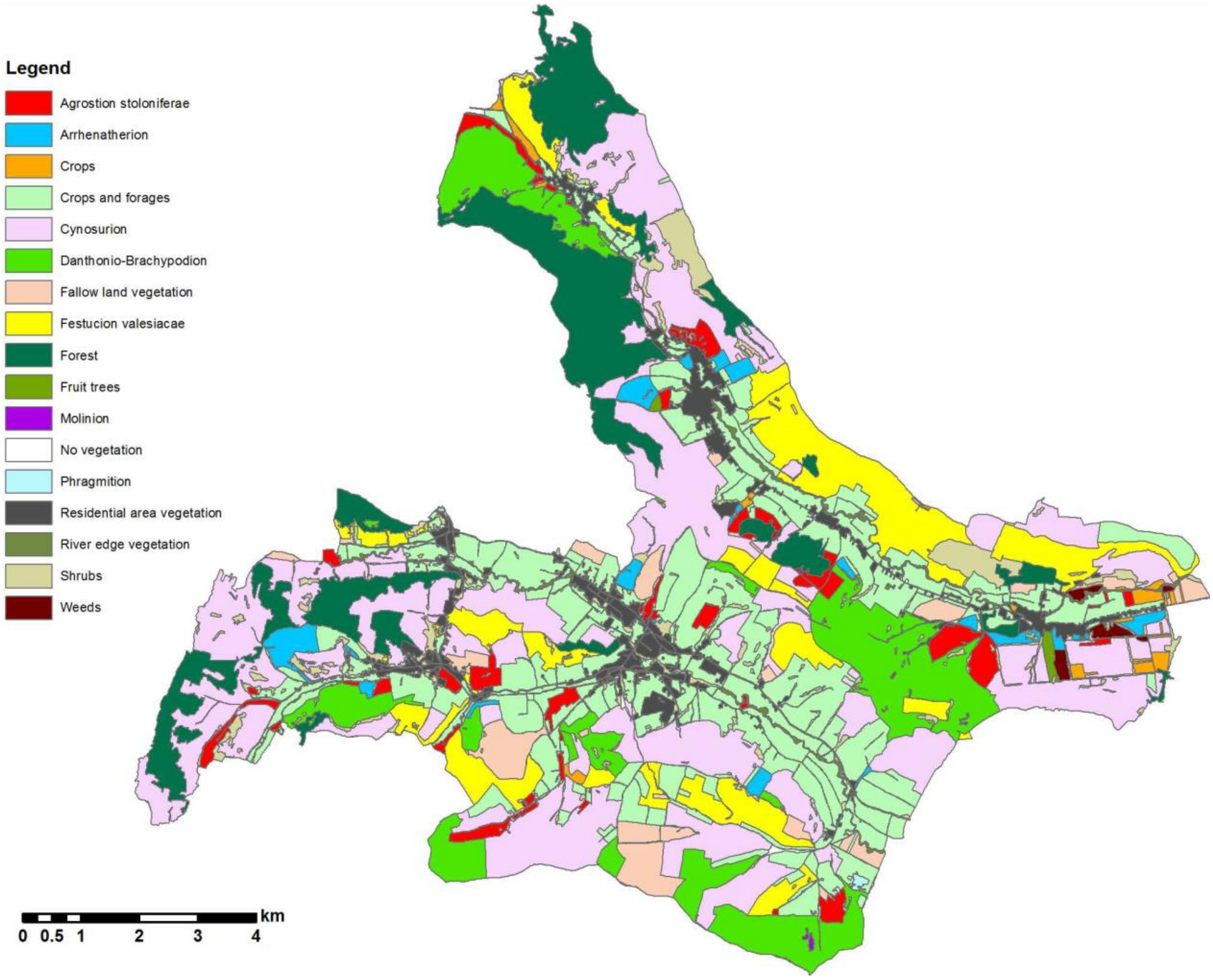

Figure 12: Map of the land cover and vegetation in Borșa and Dăbâca communes in the year 2011, with detailed information about the grassland types (phytosociological alliances) Synonyms of alliance names: *Agrostion stoloniferae = Deschampsion cespitosae* Horvatić 1930; *Danthonio-Brachypodion = Cirsio-Brachypodion pinnati* Hadač et Klika in Klika et Hadač 1944; from: Bărbos (2012), page 13

Around 3430 ha, that is, 60 % of the grassland area belonged to agricultural grasslands of the class *Molinio-Arrhenatheretea*, mainly to the alliance of mesotrophic to eutrophic mesic pastures *Cynosurion cristati* (see Figure 12). This type of grassland was used as pasture or hay meadow and could be found on many surfaces, ranging from those which were arable until the 1990s to long-standing and more recent pastures.

A small area (190 ha, 3 %) was covered by mesic meadows of the *Arrhenatherion elatioris* (see Figure 12). These meadows were distributed in several patches over the two communes and were situated mostly near the villages. They were used as hay meadows (Paulini et al. 2011; Bărbos 2012).

The order of wet grasslands, *Molinietalia caeruleae*, was represented by two alliances and accounted for 6 % of the grassland area (340 ha). Almost the entire share belonged to the floodplain meadows of the *Deschampsion cespitosae* (syn.: *Agrostion stoloniferae*), which often were found in the lower part of north-facing slopes and were used as hay meadows or pastures (see Figure 12).

According to this survey, around 5.4 ha, that is, 0.1 % of the total grassland surface, belonged to intermittently wet meadows of the alliance *Molinion caeruleae*. They were occurring in small patches in the traditional hay meadows on north-facing slopes, usually within a matrix of semi-dry grassland, except one case where they were located in a mesic meadow. Within the vegetation survey in this thesis, the area of the *Molinion caeruleae* in the study meadows alone was estimated to be higher, namely 7 - 8.5 ha (see Chapter 3.3.4.4). In any case, the *Molinion* meadows occupied a small surface compared to the total grassland area.

Around 2300 ha, that is, 40% of the grassland area was covered by dry and semi-dry basiphilous grasslands of the class *Festuco-Brometea*. Around half of these grasslands (1130 ha) belonged to communities of the alliance *Festucion valesiacae*, mostly located on the south-facing slopes. These grasslands occurred on traditional grazing areas, but also on former arable land used at the time of data collection as pastures (see Figure 12).

Communities of semi-dry grasslands of the alliance *Cirsio-Brachypodion pinnati* (syn.: *Danthonio-Brachypodion*) covered around 1180 ha, that is, 21% of the grassland area, and occurred mainly on the north-facing slopes (see Figure 12). They often could be found in places which had been used traditionally as hay meadows, including the surveyed meadows, but also in traditional grazing areas. In most cases these grasslands had not been used as arable for at least 60 years.

Only around 12 % of the communal area of Borșa and Dăbâca were covered by forests (Paulini et al. 2011). The forests were mainly located in the western part of the communes, while the eastern part, where the study hay meadows are located, was almost free of forest (see Figure 12).

According to Pop (1996), most of the forests of the Hills of Cluj belong to the mesophilous Transylvanian oak-hornbeam forests represented by the association *Lathyro hallersteinii-Carpinetum* Coldea 1975. The association is dominated by *Quercus petraea* and *Carpinus betulus*, with a weakly developed shrub layer of

Crataegus monogyna, *Coryllus avellana*, *Acer campestre* and *Tilia cordata* (Pop and Coldea 1987; Pop 1996). It is included in the habitat type of Community interest 'Dacian oak & hornbeam forests' (91Y0) (Societatea Lepidopterologică din România 2016).

According to the management plan of the SCI 'Eastern Hills of Cluj' the habitat type 'Pannonian-Balkanic turkey oak – sessile oak forests' (91M0) is the most widespread forest type in the SCI, represented by the association *Quercetum petraeae-cerris* Soó (1957) 1969 (Societatea Lepidopterologică din România 2016). According to Wallnöfer (2003), these are forests dominated by *Quercus petraea* and *Quercus cerris,* with *Potentilla alba* in the herb layer. Pop (1996) also mentions the association *Carpino-Quercetum cerris* Klika 1938 as occuring in the Hills of Cluj.

Another forest type reported to occur in the SCI is the habitat of Community interest 'Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*' (91E0) along the watercourses, represented by several associations. The characteristic species are *Salix fragilis*, *Salix alba* and *Alnus glutinosa* (Societatea Lepidopterologică din România 2016).

The most common scrub association named by Pop (1996) for the Hills of Cluj is the *Pruno spinosae-Crataegetum monogynae* (Soó 1927) Hueck 1931. According to Doniţă et al. (2005), the association is included in the habitat type of Community interest 'Subcontinental peri-Pannonic scrub' (40A0*). The dominant shrub species are *Prunus spinosa*, *Crataegus monogyna*, *Rosa canina*, *Ligustrum vulgare*, *Pyrus pyraster* and *Cornus sanguinea* (Pop 1996). In the study area, scrubs could be found for example on forest edges, boundary ridges, verges and waysides.

2.5 Potential natural vegetation

According to the map of the potential natural vegetation of Romania drawn up by Ivan et al. (1993), the eastern part of the Hills of Cluj, including the area of the study hay meadows, belongs to mesophilous Transylvanian oak-hornbeam forests of *Quercus petraea* and *Carpinus betulus* with *Lathyrus hallersteinii* (see Figure 13). Directly to the west of the study area the potential natural vegetation according to Ivan et al. (1993) is the thermophilous Pannonian-pre-Carpathian forests of *Quercus petraea* and *Quercus cerris* with *Potentilla alba* and *Vicia cassubica*. Thus, the forest remnants in the communes correspond to the named forest types of the potential natural vegetation (see previous chapter).

In a south-easterly direction from the study area, separated by the valley of the *Someş Mic*, the natural vegetation of the Transylvanian Plain (Ivan et al. (1993) is the Transylvanian forests of *Quercus robur* and *Quercus petraea* in a complex with extra-zonal steppe communities (*Stipa tirsa, Carex humilis, Astragalus peterfii*) (see Figure 13).

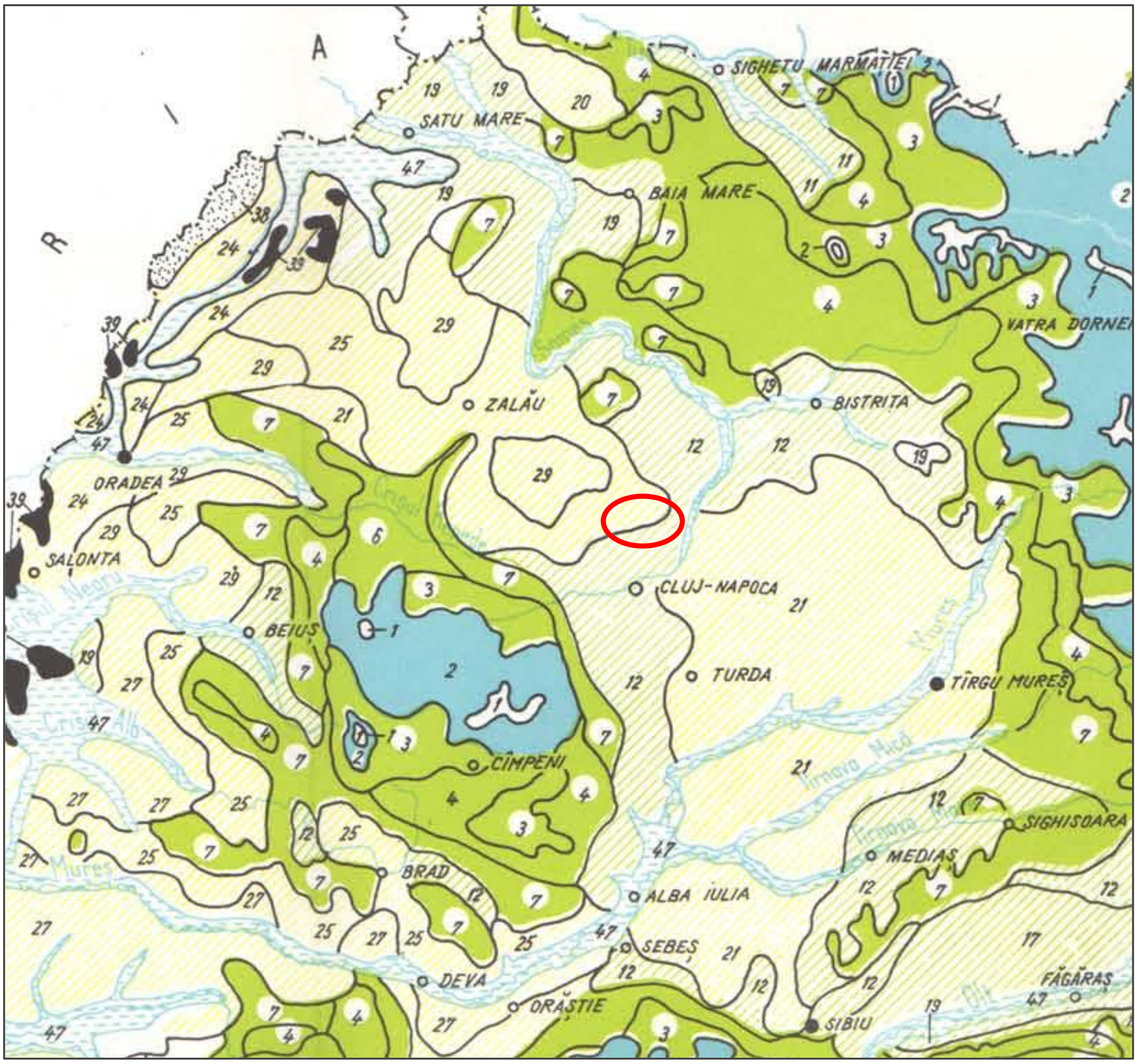

Figure 13: Detail from the map of the potential natural vegetation of Romania by Ivan et al. (1993)
The red oval shows the approximate position of the communes Borşa and Dăbâca.
Explanation of selected units: 25 - thermophilous Pannonian-pre-Carpathian forests of *Quercus petraea* and *Quercus cerris*; 29 - Danubian-Balkanic forests of *Quercus cerris*;
12 - mesophilous Transylvanian forests of *Quercus petraea* and *Carpinus betulus*;
21 - thermophilous Transylvanian forests of *Quercus robur* and *Quercus petraea* in complex with extra-zonal steppe communities

An interesting and much-debated aspect related to the natural vegetation is whether the Transylvanian Basin belongs (at least in part) to the vegetation zone of forest-steppes. Eurasian forest-steppes usually are considered to be a transitional zone between the closed-canopy temperate forests and the temperate treeless steppes, extending intermittently from Hungary to East Asia (Feurdean et al. 2015; Erdős et al. 2020). A more complex definition by Erdős et al. (2018) includes elements of physiognomy (mosaical vegetation complex of arboreal and herbaceous components), climate conditions (semi-arid to semi-humid) and complex biotic and abiotic interactions.

According to the bioclimatological classification by Kun et al. (2004), the potential vegetation of the Transylvanian Basin would not be uniform, featuring several vegetation zones with gradual transitions between them. These would include a forest zone in the north and east, a forest-steppe zone in the southwest, as well as a transitional zone between forest and forest-steppe in the central and western part. The study are would be located in the forest zone, bordering to the transition zone between forest and forest-steppes (see Figure 14).

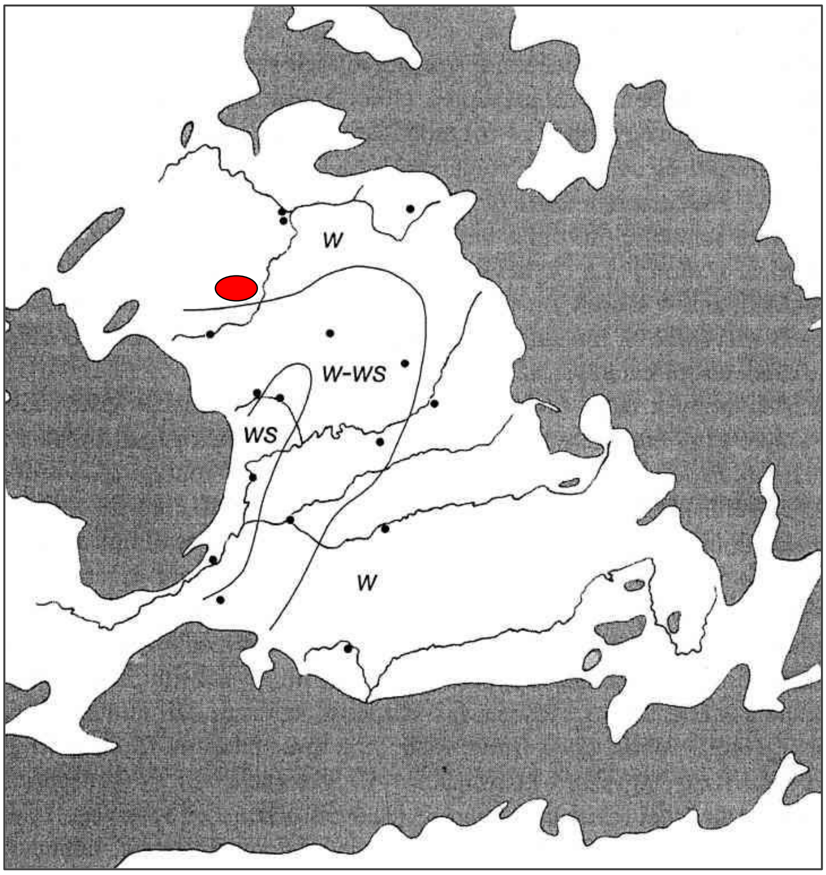

Figure 14: Bioclimatological vegetation zones of the Translyvanian Basin by Kun et al. (2004)
The red oval shows the approximate position of the communes Borşa and Dăbâca. W: forest; W-WS: forest/forest-steppe; WS: forest-steppe

However, Feurdean et al. (2015) emphasise that the biogeography of the forest-steppes in Europe is nowadays rather shaped by cultural and less by natural factors, leading to the occurrence of forest-steppes in regions where local environmental factors would favour forest. According to the map in their publication, the study area would be located within the forest-steppe zone.

Similarly, Soó already mentions 1927 that the south-eastern part of the Hills of Cluj was originally a wooded hill region and would now be an artificial steppe zone. In this context, the possibility of chernozem formation from former forest soil under grassland vegetation in a relatively short time (300-400 years), described by Soó (1927), is also worth mentioning.

2.6 Continuity of open land vegetation

The discussion about the current assignment of the Transylvanian Basin to the forest-steppe zone is closely linked to the vegetation history of this area, especially to the question of whether, to name the extremes, it was once in the Holocene covered by a closed forest cover or whether there is a post-glacial continuity of forest-steppe vegetation. On this depends the continuity or age of the nowadays occurring natural and semi-natural grasslands; a long continuity could be a reason for the high biodiversity of some of the grasslands in the region (e.g. Feurdean et al. 2015).

Feurdean et al. (2015) could show by means of an integrated palaeoecological record from Lake Ştiucii (around 14-18 km east of the study meadows) that the main forest clearing phase of the grasslands in the region already took place in the Middle Bronze Age (3700 cal. yr BP). This caused a biome shift from forest to forest-steppe (Feurdean et al. 2015).

However, even in the preceding mid-Holocene, the forest cover never would have been completely closed, which would have made grassland persistence throughout the Holocene possible (Feurdean et al. 2015). The reasons for this would have been a warm and dry climate, frequent fires, herbivore pressure and early Neolithic settlements (Feurdean et al. 2018). The northward exposure of the slopes with their relatively cool and humid meso-climate makes it likely that the study *utilised hay meadows* were forested during the early and middle Holocene (Sunder-Plassmann 2016), however, possibly with a not entirely closed tree cover as mentioned above.

After the main forest clearing phase starting in the Middle Bronze Age, there were some further phases of grassland expansion, often associated with increased burning activity, but presumably also favoured by the introduction of iron scythes after 2600 cal. yr BP (Feurdean et al. 2015). During periods of strong decline in tree cover, the region could be considered a grassland biome. An increase in tree cover only occurred between 700 and 200 cal. yr BP and during the first decades of the 21st century, as will be explained below (Feurdean et al. 2015).

In the pre-socialist period (1860-1950), the proportion of grassland within a radius of 50 km around Lake Ştiucii was about 30-50 %, as Feurdean et al. (2017) could show. This indication is supplemented by the data given by Paulini et al. (2011) regarding the share of arable and permanent grassland in the communes of Borșa and Dăbâca for the beginning and end of the communist period (see Figure 15): The share of grassland of the entire agricultural area decreased from around 40 % at the end of the 1960s to around 30 % at the end of the 1980s (Paulini et al. 2011).

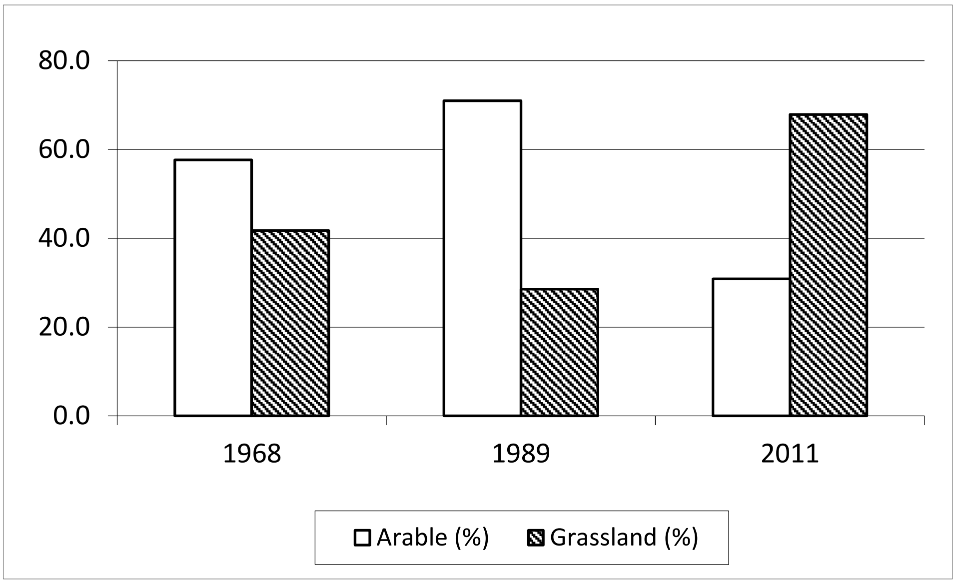

Figure 15: Share of arable and permanent grassland in the total agricultural area in the communes of Borșa and Dăbâca 1968, 1989 and 2011
From: Paulini et al. (2011), page 22. Sources: 1968: cadastre map 1:25,000, Agency of Cadastre and Land Registration Cluj; 1989: interviews with experts; 2011: field survey

Twenty years later, in 2011, 70 % of the agricultural area of the communes was permanent grassland (see Figure 15), which illustrates the high level of abandonment of arable cropping during the two decades after the fall of communism (Paulini et al. 2011). This was, among others, due to the lack of equipment and financial resources of the many small-scale farmers to whom the land had been restituted. For the post-socialist period, Feurdean et al. (2017) also observed large areas of new grassland on former arable in the surveyed 50 km radius centred on Lake Ştiucii.

An important aspect of these land cover fluctuations is that there are grassland units, which have not been converted to arable since at least the 1960s, as Paulini et al. (2011) could show. These are mostly traditional common pastures and traditional hay meadows. Furthermore, Feurdean et al. (2017) could show, that of the grasslands present in 2010 in the study radius around Lake Ştiucii, 60% were present as grassland in 1985, but only 8% in 1860. The utilised *hay meadows* of this study are part of latter category, as explanations in Chapter 4.3.1.2.3 will show.

2.7 *Phengaris* taxa in the hay meadows

All five European taxa of the genus *Phengaris* (=*Maculinea*) have been observed in the study hay meadows: *Phengaris arion* Linnaeus, 1758, *Ph. teleius* Bergsträsser, 1779, *Ph. nausithous* Bergsträsser, 1779, and *Ph. alcon* Denis & Schiffermüller, 1775 (see Figure 16). The taxon *Phengaris alcon* is represented in the study area by two ecotypes: *Ph. alcon 'cruciata'* and *Ph. alcon 'pneumonanthe',* which are named after their host plants, following Timuş et al.(2013b). Although an equivalence might be suspected, *Phengaris alcon 'cruciata'* is not equated here with *Phengaris* (=*Maculinea*) *rebeli* Hirschke, 1904.

Figure 16: *Phengaris alcon* in the Lord's Meadow (Dăbâca commune, 13.06.2009, picture: Natalia Timuş)

The butterflies of the genus *Phengaris,* in English 'large blues', are parasitic myrmecophilous butterflies with a complex life-cycle, which depend on specific host ants of the genus *Myrmica* as well as specific host plants for oviposition and feeding by the first instars of the caterpillars. For every *Phengaris* species there are particular combinations of ant and plant species preferred (Thomas et al. 1989; Johst et al. 2006; Rákosy and Vodă 2008; Timuş et al. 2013b; Tartally et al. 2019).

The host plants for the large blues occurring in mesic to wet meadows and marshes are *Sanguisorba officinalis* for *Phengaris teleius* (see Figure 17) and *Ph. nausithous* (see Figure 18), as well as *Gentiana pneumonanthe* for *Ph. alcon 'pneumonanthe'*. In the patches of semi-dry and dry grasslands on their fringes the host plants are *Thymus* spp. and *Origanum vulgare* for *Phengaris arion* and *Gentiana cruciata* for *Ph. alcon 'cruciata'* (Rákosy and Vodă 2008).

A common feature of the large blue plant-ant systems is their high specificity of habitat requirements, linked to low-intensity agricultural use and partly also specific mowing management. Thus, changes in land use have led to a rapid decline of many *Phengaris* populations and extinctions in several European countries (Thomas 1980; Wynhoff 1998; Tartally et al. 2019). These developments are reflected by the inclusion of the *Phengaris* taxa in numerous regional to international red lists. Furthermore, both *Phengaris nausithous* and *Ph. teleius* are listed in Annexes II and IV and *Phengaris arion* in Annex IV of the Habitats Directive (Council of the European Communities 2013).

Figure 17: Marked *Phengaris teleius* on *Sanguisorba officinalis* in the Lord's Meadow (Dăbâca commune, 30.07.2009, picture: Natalia Timuş)

Figure 18: Marked *Phengaris nausithous* on *Sanguisorba officinalis* in the Lord's Meadow (Dăbâca commune, 30.07.2009, picture: Natalia Timuş)

Besides the high conservation value, the occurrence of five *Phengaris* taxa in the study area is also of elevated scientific value, due to several reasons:

- It is most probably the only case in Europe where five *Phengaris* taxa occur together in the same habitat (Timuş 2014), that is, are syntopic in the sense of Rivas (1964).
- It is the only known syntopic occurrence of *Phengaris alcon 'cruciata'* and *Ph. alcon 'pneumonanthe'*, whose taxonomic classification as species or ecotype has not yet been definitively clarified (Timuş et al. 2013b; Czekes et al. 2014).
- It is assumed by Rákosy et al. (2010) that the *Phengaris nausithous* populations in the study area belong to the subspecies *Phengaris nausithous kijevensis* Sheljuzhko, 1928, which may differ from the nearest western population of *Phengaris nausithous* in Western Hungaria (Hollós et al. 2012).

The populations of the large blues in the study area have been surveyed since 2009, especially those of *Phengaris nausithous*, *Ph. teleius* and *Ph. alcon*. This includes studies focussing on adult butterfly phenology, demography, mobility, and spatial distribution (e.g. Vodă et al. 2010, Timuş et al. 2011, Timuş et al. 2013b, Timuş 2014), studies about parasitism (Timuş et al. 2013a, Timuş 2014; Csata et al. 2017), host ants (Tartally et al. 2008a; Tartally et al. 2008b), taxonomy (Rákosy et al. 2010) and oviposition strategy (Czekes et al. 2014).

2.8 Population structure and agriculture

The population figures of the communes of Borșa and Dăbâca during the period 1850 to 2021 show a steady increase until the 1940s / 1950s, followed by a decline which continued until the most recent data point, 2021 (see Figure 19). Thus, in 2021, the population of Borșa commune (1511) was only 32 % of that in the 1940s and 1950s while the corresponding figure for Dăbâca commune (1437) is 41 %. The decline in population has already resulted in the dying of one of Borșa commune's villages (Borșa-Crestaia), which had around 140 inhabitants in the 1950s and has been abandoned completely during the last decades.

The information regarding the situation of agriculture was mainly obtained through an agro-economic study in the communes of Borșa and Dăbâca carried out in the years 2010-2011 (Mihai and Jitea 2011a, 2011b, 2011c; Paulini et al. 2011). The study included a questionnaire survey of a sample of 79 agricultural households in Borșa and Dăbâca communes and three larger commercial farms in Borșa commune (Mihai and Jitea 2011a). The situation described here is therefore that of about a decade; this was the context which shaped the agricultural situation of the hay meadows at the time of the vegetation survey.

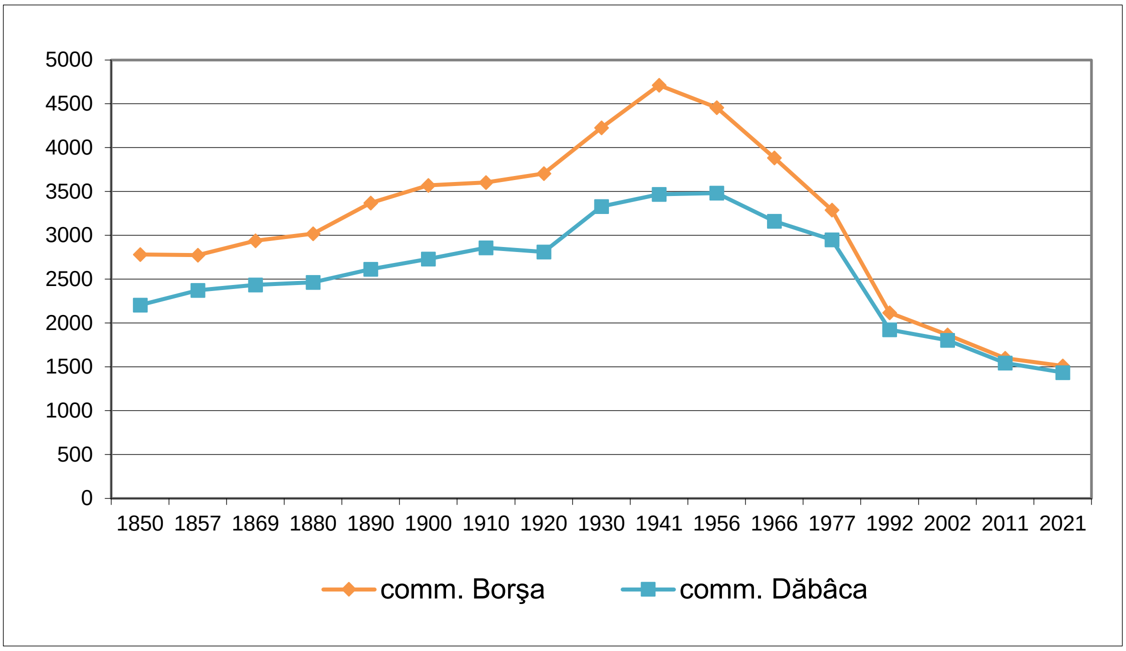

Figure 19: Population of the communes of Borșa and Dăbâca 1850-2021
Data sources: Varga E. (1999-2023), Institutul Naţional de Statistică (2011, 2023)

In 2010, in Borșa commune (1600 inhabitants at that time), there were 650 small family run agricultural holdings (Romanian: *gospodărie*), two registered commercial farms and one self-employed farmer (Romanian: *persoană fizica autorizată*), while Dăbâca commune (1543 inhabitants) had 542 small agricultural holdings, no registered commercial farms and three self-employed farmers working in agriculture (Mihai and Jitea 2011a).

Of the 79 sampled small agricultural holdings, around one third were subsistence farms (standard gross margin below 1,200 Euros/year), which produced mainly for the household consumption. The majority of the holdings, i. e. around 60 %, were semi-subsistence farms with a standard gross margin between 1,200 and 9,600 Euros/year, for which market participation was more important. Eventually, 7 % of the family run holdings in Borșa and 10 % in Dăbâca had the size of a professional farm (Mihai and Jitea 2011b; Paulini et al. 2011).

The family run agricultural holdings used on average an agricultural area of 7-8 ha, which mainly consisted of arable land (average 3.4 ha/household) and permanent meadows and pastures (average 2.8 ha/household), partitioned in many parcels (Mihai and Jitea 2011b; Paulini et al. 2011). The arable was split in 7-8 parcels on average per holding and the grassland in 3-5 parcels per holding. The largest arable area owned by a holding was 18 ha in Borșa and 17 ha in Dăbâca commune, the largest permanent grassland area was 14 ha in Borșa and 70 ha in Dăbâca commune.

Only around 7-8 % of the family run holdings owned a tractor at the beginning of the 2010s (Mihai and Jitea 2011b). This low percentage illustrates the low mechanization level of agriculture in the study communes and the financial strain for the small farmers who didn't own a tractor and had to contract others for this service. In contrast, the commercial farms in Borșa had almost no expenses for work performed by third parties (Mihai and Jitea 2011c).

Family holdings traditionally have a broad range of agricultural activities to ensure their self-sufficiency; the production is mainly for their own consumption. Usually, a family farm in the study communes held a broad range of livestock: one or more dairy cows, other cattle, sheep, which usually spent the period between spring to autumn in the flocks on the communal sheep pastures, pigs, poultry, and sometimes horses. In 2010, around half of the interviewed farmers stated that they owned some sheep.

In 2010, in Dăbâca commune there were 268 head of cattle, of which 170 were dairy cows, and in Borșa commune, 811 cattle, of which 460 were dairy cows. In Borșa commune, around half of the cattle and of the dairy cows belonged to the three commercial farms (Mihai and Jitea 2011c). Considering the fact that the family households may own more than one cattle beast or dairy cow per farm, it is estimated that only around 10% to 25% of the 650 holdings in Borșa and 542 holdings in Dăbâca owned dairy cows and/or other cattle at that time.

The total numbers of livestock recorded were clearly lower than what had formerly been kept in the communes (see Table 1); cattle numbers entered a decline after the regime change in 1989. One reason for this was the dismantling of the collective farms. Dairy farming by the family households was not profitable for several reasons: the small milk price, the lack of infrastructure for milk collection, low livestock numbers per household and therefore high levels of inconvenience and lack of economies of scale, as well as low levels of cooperation between the farmers.

Dairy sheep farming on the other hand experienced a period of growth (see Table 1), again due to multiple reasons: the sheep were managed for large parts of the year by a professional sheep-keeper, with economies of scale and low demands on the individual households. Furthermore, there was additional grazing area available compared to the former common sheep pastures (abandoned arable land, abandoned hay meadows, rented pastures) as well as a constant demand and market for sheep cheese. Furthermore, the sheep-keepers had the wherewithal and capacity to invest and enlarge their flocks.

Table 1: Number of cattle and sheep in the communes of Dăbâca and Borșa in selected years

	Year	**1895**	**1948**	**1971**	**1992**	**1995**	**1999**	**2009**	**2010**
Dăbâca	Cattle (C)	1370	1479	1848	885	733	819	305	268
	Sheep (Sh)	2893	3786	3233	1930	3335	2650	3100	3764
	Ratio Sh/C	*2.1*	*2.6*	*1.7*	*2.2*	*4.5*	*3.2*	*10.2*	*14.0*
Borșa	Cattle (C)				1043		780		811
	Sheep (Sh)				5762		7226		6027
	Ratio Sh/C				*5.5*		*9.3*		*7.4*

Empty cells: No data available. Sources: 1895: agricultural census (Rotariu et al. 2004); 1948: agricultural poll (Pintilie and Pintilie 2001); 1971: agricultural census (Pintilie and Pintilie 2001); 1992 - 2009: Locality Fact Sheet (report of statistical data provided by the communes to the Ministry of Agriculture and Rural Development); 2010: General Agricultural Census of the National Institute of Statistics (Direcţia Regională de Statistică Cluj 2010)

This new livestock situation had consequences for the grasslands in the study area: the need of hay from the meadows for dairy cattle had declined and the communal cattle pastures were undergrazed, while the demand for sheep pastures had increased. The consequences for the study hay meadows are discussed in Chapter 4.3.3.

With an average of 157 ha used agricultural area, the three commercial farms in Borșa commune were substantially larger than the family holdings. Their main activity at that time was cattle dairying with around 80 dairy cows and 140 total heads of cattle per farm. The largest share of the land they worked was arable (average of 73 %), growing fodder crops as well as maize.

The average milk yield per cow (litres/head/year) ranged between 5000 l and 5800 l (family households: 3900 l); the annual amount of milk sold annually between 370,000 l and 500,000 l. The milk was sold by all three commercial farms individually to the large dairy company Napolact with an acquisition price of 1.19 RON per litre (around 0.26 Euros/litre). The family households received only around half the milk price paid to the three commercial farms. The managers of all three farms saw cattle breeding as the main development possibility for their commune, similar to the family farmers (Mihai and Jitea 2011c).

2.9 Description of the study hay meadows

In this chapter, the five study meadows are described in more detail, regarding their geography, delimitation, Romanian and English toponyms and short land use history. The Romanian toponyms of the meadows are well-established place names, while the English denominations have been derived from them by the thesis author.

The delimitation of the meadows used in this thesis is based mainly on aerial and satellite images, but also on cadastral maps, communal borders, observations in the field and statements of local farmers. While oral tradition, landscape elements and cadastral maps determine the approximate location of the meadows, the setting of exact limits is based on subjective decisions on the part of the thesis author.

2.9.1 Dăbâca commune

The two *utilised hay meadows* Lord's Meadow and Village Meadow are located in the southeast of Dăbâca commune, where it meets Borșa and Bonțida communes (see Figure 20). They belong to the territory of the village Luna de Jos. To the northwest follows the *former hay meadow* Meadow Hill, which belongs to the village of Dăbâca.

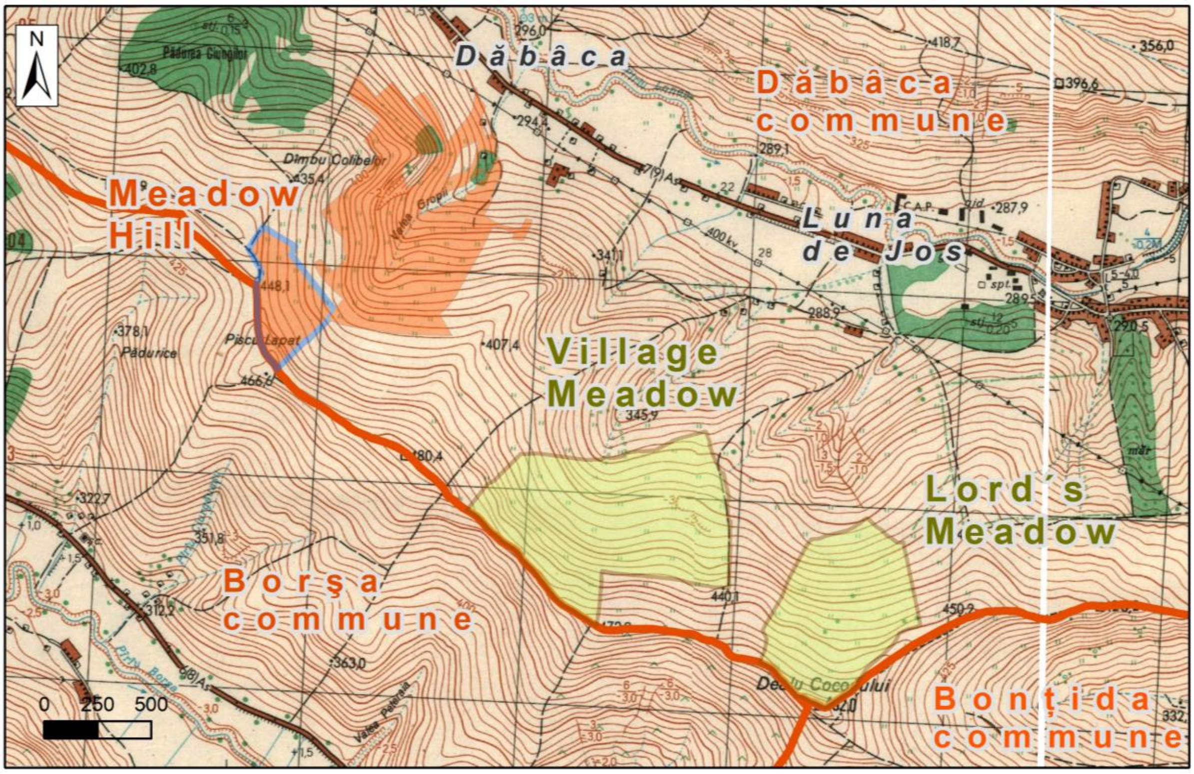

Figure 20: Topographic map of the study hay meadows in Dăbâca commune
Green polygons: *utilised hay meadows*, orange polygon: *former hay meadow,* blue outline: surveyed part of the Meadow Hill. Source of topographic map: Military Topographic Maps L-34-048-A-b and L-34-048-B-a, scale 1:25,000 (Direcția Topografică Militară 'General de divizie Constantin Barozzi'; period of publication: 1974-1992)

2.9.1.1 The Lord's Meadow

The Lord's Meadow is located below the *Dealu Cocoşului* peak (492 m a.s.l.) on the upper and middle slope of a side valley of the *Lonea* River (see Figure 20). The slope has an amphitheatre-like shape, resulting in a northern aspect in the centre and north-east and north-west aspects on the slopes on either side. The hay meadow has a maximum width (west-east) of 750 m, a maximum length (north-south) of 800 m, and an altitude difference of about 115 m (see Figure 21). Its surface area is 42 ha. Further down the slope, the side valley periodically carries water.

Most of the boundaries of the Lord's Meadow correspond well to landscape elements: a path on the hill crest in the south, a hill ridge in the south-east, and hedgerows in the north and on the western slope shoulder (see Figure 22). Only in the case of the eastern delimitation, which was taken from cadastral maps from the late communist period, a clear topographical boundary is not present in the landscape (see Figure 23).

Figure 21: Google Earth image of the Lord’s Meadow (white outline)
Red lines: communal borders. The Google Earth image is from 10 October 2016 (Google, © 2023 CNES / Airbus).

Figure 22: The Lord's Meadow: western upper part (Dăbâca commune, 06.09.2012)

Figure 23: The Lord's Meadow: eastern upper part (Dăbâca commune, 16.08.2013)

The Romanian toponym *Fânaţul Domnesc* was used by all the inhabitants and officials consulted. The Romanian word *fânaţul* means 'the hay meadow' and *domnesc* means 'lordly' or 'manorial'. The English name Lord's Meadow is derived from these meanings.

The Lord's Meadow has been used as a hay meadow from at least 1878 until the 1950s. From the 1950s to 1990, the meadow was used as pasture for dairy cows, then again for hay production, with gradual abandonment of use as a meadow from 1990 onwards. Parallel to the abandonment of mowing, the frequency of sheep grazing increased. The meadow is divided in numerous ownership plots. More details on the land tenure and use history can be found in Chapter 4.3.

2.9.1.2 The Village Meadow

The Village Meadow is located on the upper and middle slope of the next side valley of the *Lonea* River westward from the Lord's Meadow. Further down the slope, the side valley periodically carries water (see Figure 20).

Most of the shape and contour of the Village Meadow is based on the limits of the meadow unit in the cadastral map from 1878 (see also Chapter 4.3.1). An exception is the south-eastern boundary, which originates from the communism period, when part of the original Village Meadow was converted into arable (see Figure 24 and Figure 25). Apart from the western boundary, which was taken from the 1878-map, all the delimitations are reflected in landscape features: a path on the hill crest and the boundary with the former arable to the south, a field path to the east and a narrow hedge to the north.

Figure 24: Google Earth image of the Village Meadow (white outline)
Red lines: communal borders. The Google Earth image is from 10 October 2016 (Google, © 2023 CNES / Airbus).

Figure 25: The Village Meadow: south-eastern part (Dăbâca commune, 11.08.2013)
On the right side of the picture the border with the former arable is visible.

The eastern part of the hay meadow is north-facing and has a less inclined slope than the NE-facing western part (see Figure 25 and Figure 26). The eastern part does not extend to the hill ridge and lies at an elevation of about 440 m a.s.l. to 375 m a.s.l., while the western part extends to the ridge at about 460 m a.s.l. The meadow has a maximum width (west-east) of 1200 m and a maximum length (north-south) of 750 m; its size is 67 ha.

Figure 26: The Village Meadow: western part (Dăbâca commune, 14.09.2012)

The Romanian toponym *Fânaţul Sătesc* was used by all consulted locals and officials and can be considered as a counterpart of the Lord's Meadow, as *sătesc* means 'belonging to the village'. As with the Lord's Meadow, the meaning of the toponym can also be explained by the historical ownership relations (see Chapter 4.3.1).

The Village Meadow has been used continuously as a hay meadow from at least 1878 until the present day, though mowing has been abandoned on some plots since the 1990s, especially in the western part of the meadow. The meadow is divided in numerous ownership parcels. More details on the land use and tenure history can be found in Chapter 4.3.

2.9.1.3 The Meadow Hill

The *former hay meadow* called Meadow Hill used to be one of the largest continuous hay meadow areas of Dăbâca village and is located northwest of the Village Meadow (see Figure 20). The delimitation of the meadow is based on the cadastral maps from the 1960s/1970s. The name 'Meadow Hill' is a translation of the Romanian place name *'Dâmbul Fânaţelor'*, which was mentioned by local farmers.

The meadow is located on the slopes of a valley named *Valea Gropii* whose non-permanent watercourse runs into the *Lonea* River (see Figure 20). The vegetation relevés were carried out in one 14 ha sub-area of the Meadow Hill, located on the upper slope and facing east to north-east. The south-eastern corner of this part borders onto the hilltop called *'Piscu Lapat'* (466.6 m a.s.l.) and the lowest elevation is at 395 m a.s.l. (see Figure 20 and Figure 27).

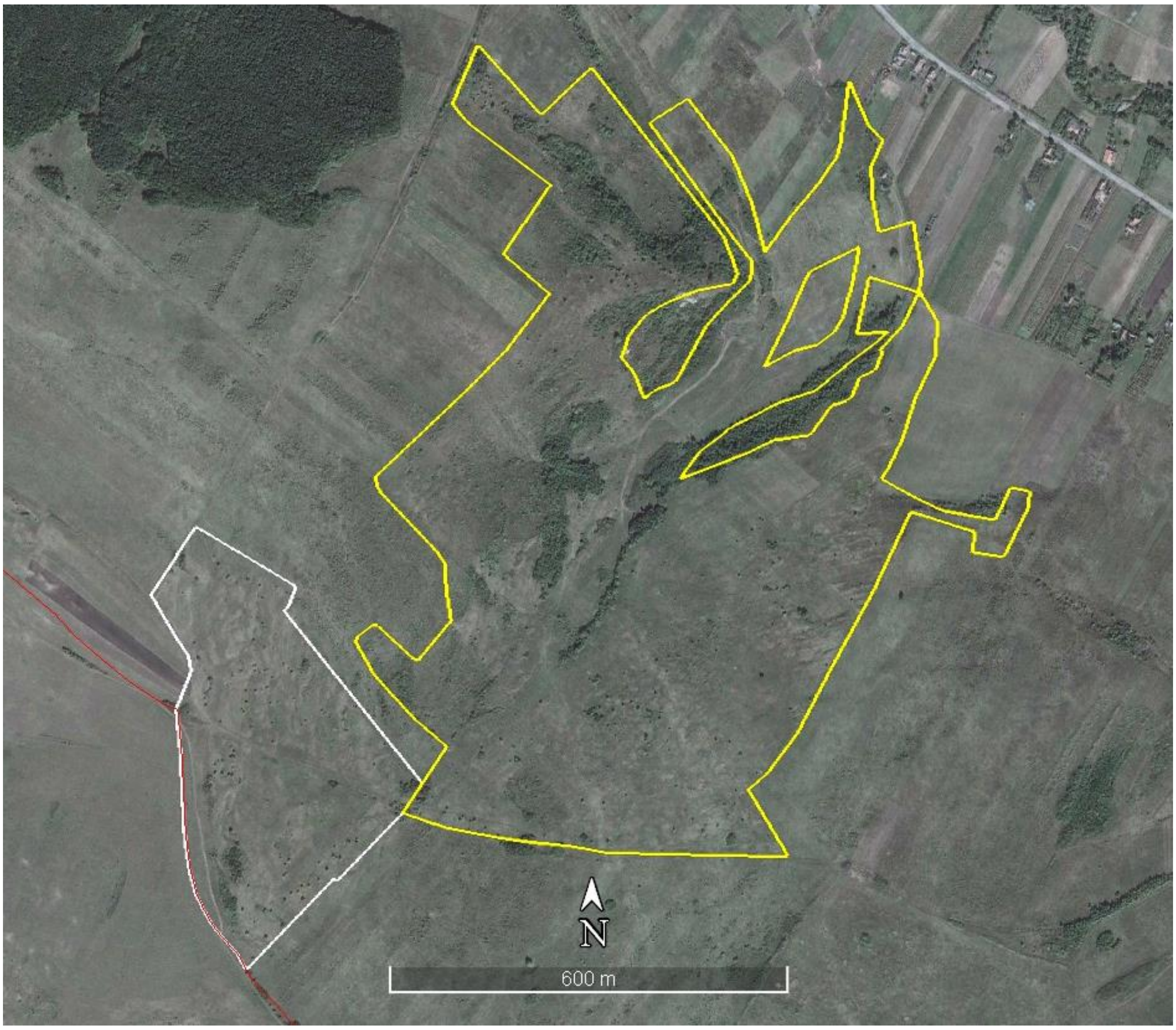

Figure 27: Google Earth image of the surveyed upper part (white outline) and lower part (yellow outline) of the Meadow Hill
Red lines: communal borders. The Google Earth image is from 21 September 2011 (Google, © 2023 Maxar Technologies).

This small meadow polygon has a maximum width (west-east) of 380 m and a maximum length (north-south) of 620 m. It is delimitated by the hill crest in the southwest and (former) arable areas in the other directions, which at the time of data collection were mainly covered with new permanent grasslands on the abandoned arable (see Figure 27). Nowadays (year 2023), a large part of the entire meadow, including the small polygon, is converted into arable, which also extends to the surrounding areas to the east and west.

How far back the use of the Meadow Hill as hay meadow goes is not known. The earliest known mention as hay meadow is from the 1960s/1970s cadastral maps. A gradual abandonment of mowing from the 1990s onwards is presumed, as happened in the Village and Lord’s Meadows. According to the statement of a local shepherd in 2013, the upper part of the Meadow Hill has been mainly used as a permanent sheep pasture since 2009, because mowing had been almost completely abandoned (see Figure 28). In 2014, for the last time a mown plot was observed in the upper part of Meadow Hill and since the year 2015 the area has been gradually converted into arable land.

Figure 28: The upper part of the Meadow Hill (Dăbâca commune, 11.08.2013)
In the foreground a *Molinia arundinacea*-stand, the light-coloured dots in the background are *Eryngium campestre*. In the middle part of the picture a flock of sheep is visible.

2.9.2 Borșa commune

The third *utilised hay meadow* surveyed in this thesis, called the Great Meadow, is located in the south-eastern corner of Borșa commune, and borders on the three communes Bonțida, Jucu de Sus and Chinteni (see Figure 29). The *former hay meadow* Jacob's Meadow lies to the north-west of the Great Meadow.

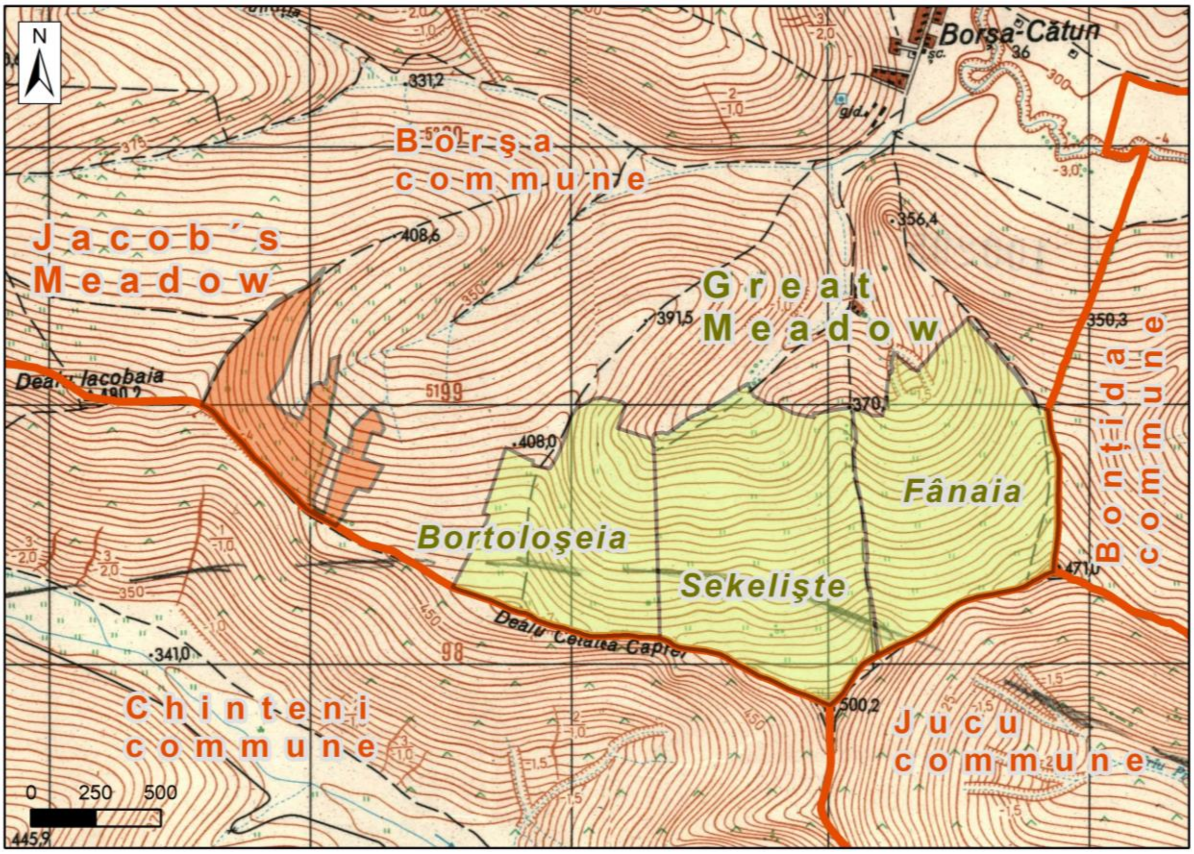

Figure 29: Topographic map of the study hay meadows in Borșa commune
Green polygon: *utilised hay meadows*, orange polygon: *former hay meadow*. Source of topographic map: Military Topographic Map L-34-048-A-d, scale 1:25,000 (Direcția Topografică Militară 'General de divizie Constantin Barozzi'; publication period: 1974-1992)

2.9.2.1 The Great Meadow

The Great Meadow is made of three attached parts with very similar landscape structure, but three different local toponyms: *Bortoloşeia, Sekelişte* and *Fânaia* (see Figure 29). These local names have been used by all the consulted inhabitants and officials in Borșa commune and appear on several cadastral maps. Due to its having the largest extent of all meadows, the novel English name Great Meadow is being introduced in this thesis for all three parts together, which are considered one land use unit.

The Great Meadow is located on the upper and middle slopes of two side valleys of a short tributary of the *Borșa* River (see Figure 29). The valleys are separated by a slope shoulder with dirt path, which separates *Fânaia* in the east from *Sekelişte* in the west. *Sekelişte* and *Bortoloşeia* are not delimited from each other by clear geographical features. As with the Lord's Meadow, the valleys have the concave form of an amphitheatre, facing north in the centre and north-west or north-east on the shoulders of the bowl. The Great Meadow is about 200 ha in size, up to 2250 m wide (west-east) and up to 1100 m long (north-south). The highest point is 500.2 m a.s.l. on the ridge at the southern border of *Sekelişte*, the lowest point is about 325 m a.s.l.

The southern and eastern boundaries of the Great Meadow follow geographical and municipal boundaries (see Figure 29), while the northern and western boundaries are mainly based on the 1970s cadastral maps, which for the most part correspond to the part which is actually used as hay meadow (see Figure 30).

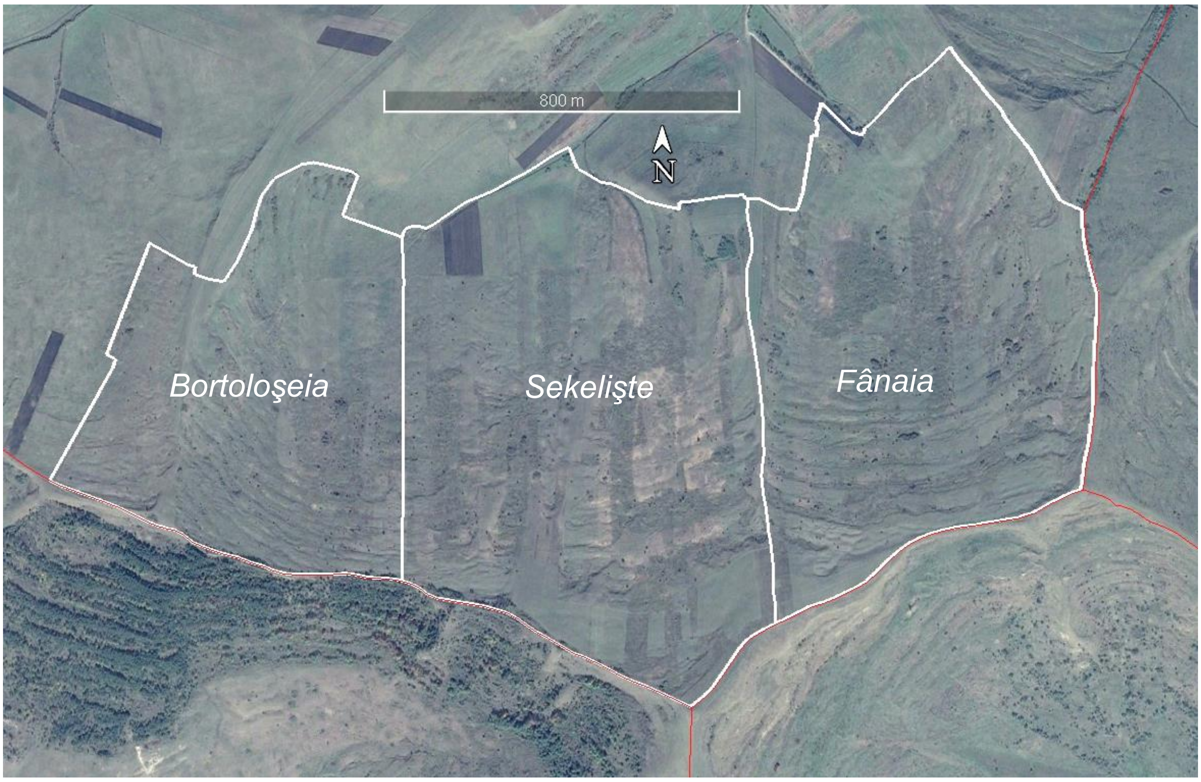

Figure 30: Google Earth image of the Great Meadow (white outline)
Red lines: communal borders. The Google Earth image is from 5 October 2013 (Google, © 2023 CNES / Airbus).

Like the Village Meadow, the Great Meadow was used continuously as a hay meadow from at least 1883 until 1990. Since then, it has been a mosaic of mown and unmown plots (see Figure 31). During the last years, the frequency of sheep grazing increased. The meadow is divided in numerous ownership plots. More details on the land use and tenure history can be found in Chapter 4.3.

Figure 31: The Great Meadow: view from W to E on the *Sekelişte* and *Bortoloşeia* sections (Borșa commune, 06.08.2011)

2.9.2.2 Jacob’s Meadow

The *former hay meadow* named Jacob’s Meadow is the next bigger area formerly used as a hay meadow to be found west of the Great Meadow in Borșa commune (see Figure 29). The delimitation of the meadow polygon is based on cadastral maps from the 1970s. According to those maps, the area which was used as a hay meadow at that time consisted of a large western (around 21 ha) and a narrow eastern part (around 4 ha), separated by what was at that time an arable field (see Figure 29 and Figure 32). The vegetation survey has been carried out in the main western part.

Jacob’s Meadow is situated on the upper and middle slope of the next side valley westward from the Great Meadow (see Figure 29). The meadow also has an amphitheatre shape, this time with north-east as the main exposure and east to north exposed margins. The main meadow polygon has a maximum width (west-east) of about 600m and a maximum length (north-south) of about 700m. It is delimited by the hill ridge to the southwest and west and a line of trees and shrubs to the east (see Figure 32), while the northern border seems not to be reflected by a geographical feature. The hill ridge is at an altitude of about 450 m a.s.l. and the lowest point at about 380 m a.s.l.

Figure 32: Google Earth image of Jacob’s Meadow (white outline)
Red lines: communal borders. The Google Earth image is from 5 October 2013 (Google, © 2023 CNES / Airbus).

The place name *Iacobaia Sătească* was mentioned by town hall employees and locals. The name ‘*Iacobaia*’ appears also in other toponyms for areas surrounding the meadow (*Dealu Iacobaia*, *Dosu Iacobăii*, *Faţa Iacobăii*) and may be derived from the name *Iacob*. The Romanian word *sătească* means ‘belonging to the village’, like in the Romanian place name ‘*Fânaţul Sătesc*’ for the Village Meadow.

The area was said to be a former hay meadow by town hall employees and is also marked on a cadastral map from the 1970s as a hay meadow. In 2013, a local shepherd stated that grazing in Jacob’s Meadow had started before 1989 and that mowing had stopped completely by 1998 except for one plot, at which point the meadow was finally converted into a permanent sheep pasture. A sheep farmer has been settled just beyond the northern boundary of the meadow since at least 2011, gradually adding sheepfolds, shepherds’ huts, simple farm buildings and a vegetable garden (see Figure 33). Like the *utilised hay meadows*, Jacob’s Meadow is also divided into numerous ownership plots.

Figure 33: View from S to N on the main part of Jacob’s Meadow with the buildings and infrastructure of a sheep farm adjacent to the meadow (Borșa commune, 06.08.2013)

3 Vegetation and flora of the hay meadows

3.1 Introduction

This vegetation survey aims to identify the most important grassland vegetation types of the study meadows (Lord's Meadow, Village Meadow and Great Meadow) and to sketch their structure and ecological characteristics. Additional information shall help to develop adequate management measures for the hay meadows.

The selection of the surveyed vegetation types was based on the priorities outlined in Chapter 1. Vegetation types harbouring the host plants of the butterfly species *Phengaris teleius*, *Ph. nausithous* and *Ph. alcon 'pneumonanthe'* were prioritized, since these were the best studied *Phengaris* species in the area and, referring to the first two species, the main reason for the designation of the Natura 2000 site. Their host plant species, *Sanguisorba officinalis* and *Gentiana pneumonanthe*, occur in or near stands with *Molinia arundinacea*.

Stands with *Molinia arundinacea* were a focus of this survey for the following further reasons: a lack of information on *Molinia* meadows with this species in Romania, which is often considered a subspecies of *Molinia caerulea*, and underrepresentation of basophilic *Molinion* meadows in the phytosociological literature of Romania in general. For instance, the central association of the alliance, the *Molinietum caeruleae* Koch 1926, is not listed in the phytosociological synopses of Romanian vegetation by Coldea et al. (2012) and Sanda et al. (2008).

A further priority of the vegetation survey were the species-rich meadow steppes, with the intention of verifying whether they belonged to similar plant communities like the meadow steppes of the world record site in the Hay Meadows of Cluj nature reserve (see Chapter 1).

During the first field walks, the occurrence of the species *Serratula coronata* L. was detected (synonym: *Serratula wolffii* Andrae), mostly in the Great Meadow, where the tall forb species seemed to co-occur with *Calamagrostis epigejos*. Since this was a new location of the rare species for Romania (S. Bădărău, personal communication, August 2009), another focus was put on the vegetation stands with *Serratula coronata*.

To complement the information about the meadow vegetation, some relevés were also made in non-priority grassland vegetation types. Furthermore, the relevés made for the phytodiversity study (see Chapter 5) in the *former hay meadows* were also included in the analysis.

It is important to note that the study meadows, besides having their predominant grassland vegetation, are also characterised by woody plants, particularly *Crataegus monogyna*, *Prunus spinosa*, *Rosa canina*, *Cornus sanguinea, Pyrus pyraster and Salix cinerea*. These occur either as solitary shrubs or trees, clumps of shrubs scattered over the meadow surface, or as more or less dense shrubby plant formations in the areas affected by scrub encroachment or at the margin of the meadows. The woody plant communities were not surveyed in this thesis.

3.2 Methodology

3.2.1 Vegetation sampling

3.2.1.1 Overview

For the identification of the vegetation types the phytosociological approach (Braun-Blanquet-school) was chosen, since this is the most comprehensive and consistent methodology for vegetation classification as well as the mainstream classification scheme in Europe (Dengler et al. 2008).

Field work was carried out in the summer months of 2009, 2011, 2012 and 2013 by the thesis author and colleagues (for detailed information on the surveyors see Annex 2). For the data analysis 102 phytosociological relevés were used, containing 320 vascular plant species. Some of these relevés (n = 44) are additionally part of nested diversity plot series (see Chapter 5).

From the total number of 102 relevés, 86 relevés were carried out in three *utilised hay meadows*, which were still partly mown at the time of data collection: 28 in the Lord's Meadow, 24 in the Village Meadow (both Dăbâca commune) and 34 in the Great Meadow (Borșa commune). Additionally, 16 relevés were made in the *former hay meadows*, which were used as permanent pastures at the time of data collection: nine in the upper part of the Meadow Hill (Dăbâca commune) and seven in Jacob's Meadow (Borșa commune) (see description of the meadows in Chapter 2.9).

The sample plots were square-shaped phytosociological relevés. The plot size traditionally used for phytosociological grassland relevés in Romania is 25 m^2 or 100 m^2, see for example the most frequently used plot sizes in the Romanian Grassland Database: 100 m^2 – 22 %, 25 m^2 – 21 % and 10 m^2 – 4 % (Vassilev et al. 2018). Here, the size of 25 m^2 was chosen for the phytosociological relevés (n = 64), except for the relevés which belong to the nested diversity plot series, where the size of 10 m^2 was used (n = 38). In the phytosociological analysis the difference in relevé size was not considered (see discussion in Chapter 3.4.2).

3.2.1.2 Selection of the plots

The selection of the plots within the grassland vegetation of the meadows was in most cases targeted (preferential) towards certain species:

- The *Phengaris* host plants *Sanguisorba officinalis* and/or *Gentiana pneumonanthe* and/or of the species *Molinia arundinacea*
- Diagnostic species for steppe meadows, that is, species composition with high cover values of *Brachypodium pinnatum* and/or *Festuca stricta* subsp. *sulcata,* and occurrence of one or more other species like *Trifolium montanum, Centaurea scabiosa, Ranunculus polyanthemos* and *Scabiosa ochroleuca*
- *Serratula coronata*

For the 44 relevés included into the nested diversity plot series, land use was an additional criterion (see Chapter 5.2.1). Further selection criteria for all the plots were homogenous vegetation physiognomy, floristic homogeneity, as well as homogeneity of the visual site conditions (Dierschke 1994; Tremp 2005).

In addition, six relevés in the *utilised hay meadows* were made in other vegetation types occurring on small surfaces of the meadows: four relevés in wet meadows and two in dry grasslands with *Stipa tirsa* and *Stipa capillata*. The preferential selection method is discussed in Chapter 3.4.1).

3.2.1.3 Collected species data

For all vascular plant species, the cover values per plot have been estimated using the shoot-presence approach (vertical projection). For the estimation, three different cover scales have been used by different surveyors:

- abundance / cover estimation based on categories of the Braun-Blanquet scale (Dierschke 1994) for 33 relevés: r: 1 individual with small cover value; +: cover < 1%; 1: cover 1 – 5 %; 2: cover 5 – 25 %; 3: cover 25 – 50 %; 4: cover 50 – 75 %; 5: cover 75 – 100 %
- abundance / cover estimation based on categories of the Londo scale (Londo 1976; Dierschke 1994) for 25 relevés: r: 1 individual with small cover value; .1: cover < 1 %; .2: cover 1 – 3 %; .4: cover 3 – 5 %; 1: cover 5 – 15 %; 2: 15 – 25 %; 3: 25 – 35 %; 4: 35 – 45 %; 5: 45 – 50 %; 5+: 50 – 55 %; 6: 55 – 65 %; 7: 65 – 75 %; 8: 75 – 85 %; 9: 85 – 95 %; 10: 95 – 100 %
- cover estimation in percentage values (Dierschke 1994) for 44 relevés

For the phytosociological analysis, all values have been converted into cover values based on the Braun-Blanquet scale due to the specification of the data processing software (details about the conversion in Chapter 3.2.4.1). Additionally, for each vascular plant species, the layer was specified using the following rules:

- Herbaceous plants were assigned to the herb layer.
- The specimen of the six phanerophyte species *Crataegus monogyna, Rosa canina, Prunus spinosa, Salix cinerea, Cornus sanguinea* and *Rosa micrantha* measuring less than 50 cm were assigned to the juvenile layer and measuring more than 50 cm were assigned to the shrub layer.
- The species *Lembotropis nigricans, Cytisus albus, Rosa gallica, Dorycnium pentaphyllum* subsp. *herbaceum, Genista tinctoria, Teucrium chamaedrys, Thymus pulegioides* subsp. *pannonicum* and *Rubus caesius* were always assigned to the herb layer.

The taxonomy of vascular plants follows the Euro+Med PlantBase (Euro+Med 2006+), except for *Festuca pratensis* Huds. and *Festuca arundinacea* Schreb., which are listed as *Schedonorus pratensis* (Huds.) P. Beauv. and *Schedonorus arundinaceus* (Schreb.) Dumort. in the Euro+Med PlantBase. In the following cases, subspecies which are considered species according to Săvulescu (1952-1976) were not considered separately:

- *Centaurea scabiosa* L. includes *Centaurea scabiosa* subsp. *spinulosa* (Spreng.) Arcang. (synonyms: *Centaurea apiculata* subsp. *spinulosa* (Spreng.) Dostál, *Centaurea spinulosa* Spreng.).
- *Euphorbia esula* L. includes *Euphorbia esula* subsp. *tommasiniana* (Bertol.) Kuzmanov (synonym: *Euphorbia virgata* Waldst. & Kit.).

3.2.1.4 Collected header data

For all relevés (n = 102), the total cover of vascular plants was estimated, and the species richness was calculated. Additionally, the following parameters of vegetation structure were estimated (or measured with a tape measure where indicated) for a part of the relevés:

- Cover of bare ground (n = 44)
- Cover of bryophyte, lichen, and litter layer (n = 44)
- Litter depth (n=41) (measured at standardized points, median of at least 6 values)
- Average and maximum height of herb layers (n = 38)
- Average height of lower and upper herb layer (n = 43) (measured, one value / plot)

The cover of bare ground, the cover of the bryophyte, lichen and litter layer and the litter depth were only determined for the diversity relevés, and therefore mean values can only be specified for three communities (see the subchapters 'Structure and species composition'). The recorded parameters on the height of the herb layers differed between the phytosociological and diversity relevés; the results are also discussed in the mentioned subchapters.

Furthermore, the following environmental parameters were recorded:

- The geographic coordinates (n = 100), height above mean sea level (n = 97) and aspect (n = 83) were determined with a GPS device.
- The inclination was estimated (n = 92).
- The soil texture of the topsoil was determined by haptic tests in the field (AG Boden 1996) (n = 38, only for the diversity relevés).

3.2.2 Occurrence, habitat codes and conservation value

The occurrence of the plant communities in the study hay meadows was described qualitatively according to observations, except for the *Molinietum caeruleae* in the Lord's Meadow, for which more detailed information can be provided based on a mapping of the species *Molinia arundinacea* carried out in 2010 with a GPS device in the field.

Additional information on the occurrence of the plant communities in Romania, the habitat codes and national / European conservation value were obtained from literature.

3.2.3 Data storage

The vegetation relevés were stored in databases using the programs EXCEL 2019 (Microsoft Corp. 2018) as well as TURBOVEG version 2.140b (Hennekens and Schaminée 2001).

3.2.4 Data analysis

3.2.4.1 Phytosociological classification

For the phytosociological vegetation classification, the program JUICE version 7.1 (Tichý 2002) was used. The relevé data was imported from TURBOVEG using adapted categories of the Braun-Blanquet scale indicated in Table 2, considering only cover values.

Table 2: Adapted cover scale used in the program JUICE

Braun-Blanquet values	r	+	1	2	3	4	5
Estimated cover (%)	0.01 – 0.1	0.2 – 1	2 – 5	6 – 25	26 – 50	51 – 75	76 – 100

For the standardization of relevé data, occurrences of species in the different layers (shrub, herb and juvenile layer) were combined (Dengler et al. 2012). Additionally, taxa determined only on genus level or coarser, as well as taxa with uncertain determination (*‘confer*’ in field name), were excluded from the analyses, except for the determination of the species richness (Jansen and Dengler 2010).

For the classification of the relevé table, the program TWINSPAN (‘Two way Indicator Species Analysis’) was used (Hill 1979, cited in Berg and Magnes 2019), which is integrated into JUICE. It is the most commonly used program for numerical classifications of vegetation relevés (Berg and Magnes 2019).

The ‘Two way Indicator Species Analysis’ is a hierarchical divisive classification technique (Roleček et al. 2009). In the first step, the TWINSPAN algorithm places the sites along the first axis of correspondence analysis (CA), then the sites are divided into two clusters by splitting the first CA axis near its middle (Roleček et al. 2009). After a mechanism of refinement, the process can be repeated at will and each of the two, four, etc. clusters is divided again according to the same principle (Roleček et al. 2009; Berg and Magnes 2019).

To obtain good results using TWINSPAN, the same conditions as for a correspondence analysis must be given, i.e. the gradient in the gradient analysis must be long enough and there must be one effective ecological main factor (Berg and Magnes 2019).

In TWINSPAN, only presence-absence-values of the species are used; however, through the principle of ‘pseudospecies cut levels’, the cover values of the species are included in the calculation to a certain extent (Berg and Magnes 2019). In order to achieve this, TWINSPAN internally creates ‘pseudospecies’ for species that exceed the specified coverage thresholds.

The specific procedure for the classification of the 102 relevés was the following: first, a preliminary detrended correspondence analysis (DCA) was performed to verify the axis length, which proved to be long enough (3.7 SD) (Lepš and Šmilauer 2003). After testing different possibilities, a TWINSPAN classification with the following analysis parameters was carried out because it resulted in the best interpretable classification of the relevé table:

- 3 pseudospecies cut levels with thresholds 0, 5, 25
- Minimum group size: 2
- Maximum level of division: 3 (resulting in 8 groups)

Subsequently, another group with two relevés was separated with manual editing; the group is characterized by species of high indicator value (the only two relevés with *Stipa tirsa*, *Stipa capillata*, *Festuca valesiaca* and *Salvia nutans*; see Chapter 3.3.10). In addition, two relevés were moved from one group to another due to the indicator species combination.

In the end, nine vegetation groups were obtained, each with a different number of relevés (from 1 to 36). An overview of the results and a detailed description of the vegetation types is given in Chapter 3.3.

3.2.4.2 Identification of diagnostic species

After the classification, the diagnostic species were identified for each of the nine groups and the relevé table was sorted manually according to these diagnostic species as well as their fidelity value.

In phytosociology, the term ‘diagnostic species’ is traditionally applied to differential and character species (Dengler et al. 2008). Diagnostic species are based on the concept of fidelity (german: *‘Treue*’), i.e. species with high fidelity can be considered diagnostic (Chytrý 2007a). Fidelity is defined as the concentration of occurrence or abundance of species within the given syntaxon (Dengler et al. 2008). In the past, arbitrary measures of fidelity were used, while the use of statistical fidelity measures has increased more recently (Dengler et al. 2008).

In this analysis, three different fidelity criteria have been considered. The decisive criterion was the statistical fidelity criterion, i.e. species are considered diagnostic if they meet at least the statistical fidelity criterion. The statistical fidelity measure used in this analysis is the phi-(Φ)-coefficient of association, which is a statistical measure of association between categories (in this case species presence/absence) (Chytrý et al. 2002; Tichý et al. 2010). It is one of the standard measures which can be calculated by JUICE (Berg and Magnes 2019).

The phi-coefficient is independent of the size of the data set and takes values from – 1 to + 1 (Chytrý et al. 2002); for convenience these values are multiplied with 100 in JUICE (Tichý et al. 2010). Positive values indicate that the species and the vegetation unit co-occur more frequently than would be expected by chance, with larger values indicating a greater degree of joint fidelity. The value 100 indicates that the species and the vegetation unit are completely faithful to each other (Chytrý et al. 2002), and the value 0 indicates no relation between the target species and the target vegetation unit (Tichý et al. 2010).

Species are considered diagnostic at a subjective phi-coefficient level so as to obtain an appropriate number of diagnostic species. Frequently used thresholds are 20 (Aćić et al. 2015) or 25 (Chytrý 2007a; Dengler et al. 2012). In this study, species with phi-coefficient values of at least 20 are considered diagnostic and species with phi-coefficient values of at least 45 are considered highly diagnostic. Only significant phi-coefficient values were considered; the statistical significance was calculated by Fisher's exact test (level of significance $p > 0.05$) in JUICE (Chytrý et al. 2002; Tichý and Chytrý 2006).

Since the groups obtained by the TWINSPAN classification differ considerably in the number of relevés (from 1 to 36), a standardisation of the relevé group size was applied in JUICE (Tichý and Chytrý 2006).

In addition to the statistical fidelity values, the frequency class and percentage frequency were also considered, to complement the results with the two following 'classic' fidelity criteria:

- Difference of frequency class: For diagnostic species, constancy differences between the considered group and other groups should be at least two frequency classes (Dierschke 1994) (e.g., V/IV vs. II, I, 0; III vs. I, 0; II vs. 0).
- Difference of percentage frequency: A species can be considered differential for a syntaxon when in has at least double the percentage frequency compared to another syntaxon of the same rank, provided that the observed difference in frequency is not coincidental (Bergmeier et al. 1990; Dengler 2003).

3.2.4.3 Assignment to syntaxonomical units

For the assignment of the vegetation groups to syntaxonomical units, the identified diagnostic species have been compared with indications in the phytosociological literature, focusing specifically on character and differential species. Other important indications for identifying the matching syntaxon (an association in most cases) are constant and dominant species, the total species composition, and information on site conditions, vegetation structure and range of the syntaxa.

If a group could not be assigned to an already existing syntaxon, it was named after a dominant species and referred to as dominance or informal community (see Chapters 3.3.5 and 3.3.7). The vegetation table with 102 relevés in nine groups was sorted manually based on the diagnostic species and affiliation to syntaxonomical groups.

The main syntaxonomical literature sources used were for the vegetation of Romania Coldea et al. (2012), Coldea et al. (1997), and Sanda et al. (2008) and for the vegetation of Europe Mucina et al. (2016), Leuschner and Ellenberg (2017), and Willner et al. (2019). The comparison of the obtained vegetation types with the vegetation of the White Carpathians was mainly based on the publications of Chytrý (2007b), including Hájková et al. (2007) and Chytrý et al. (2007), and Jongepierová (2008), including Škodová et al. (2008).

3.2.4.4 Ellenberg indicator values and DCA

Ellenberg indicator values provide approximate evidence for the ecological site conditions of the identified plant communities, based on the species composition of the relevés (Ellenberg et al. 2001). The indicator values for vascular plants were taken from the program JUICE (Tichý et al. 2011), which are based on Ellenberg et al. (1992)

For the species not included in the mentioned list, indications were completed from the Hungarian flora by Borhidi (1995) (34 of 320 species). For 12 species, no information on the Ellenberg indicator values could be found. Mean unweighted Ellenberg indicator values for relevés were calculated in JUICE and, based on these results, mean indicator values for the vegetation types.

A detrended correspondence analysis (DCA) was carried out to find the most important ecological gradients based on the floristic composition of the relevés. The DCA was performed in JUICE version 7.1 (Tichý 2002) using the software R version 3.6.1. (R Core Team 2019). The cover values were transformed by square root transformation, and down-weighting of rare species was used; the Ellenberg indicator values (unweighted) were displayed as vectors (Berg and Magnes 2019).

3.3 Results

3.3.1 Overview of the results

In the following, the most important results of the vegetation study are presented for all vegetation types together, while Chapters 3.3.2 to 3.3.10 show more detailed results on the individual plant communities.

3.3.1.1 Phytosociological results and occurrence in the hay meadows

The hierarchical divisive classification TWINSPAN of 102 relevés and subsequent manual editing has resulted in nine vegetation types with different numbers of relevés (from 1 to 36), which are also referred to as plant communities or, if applicable, as associations.

In the following, the results of the syntaxonomical assignment will be outlined, while the detailed syntaxonomical deduction of the plant communities is explained in the subchapters ‘Syntaxonomy and diagnostic species’ for each vegetation type, where a selection of the diagnostic species is also presented. Furthermore, the sorted phytosociological table is shown in Annex 1.

The nine identified grassland communities belong to three different phytosociological classes: reed and tall-sedge marshes *(Phragmito-Magnocaricetea)*, agricultural grasslands *(Molinio-Arrhenatheretea)* and base-rich semi-dry and dry grasslands *(Festuco-Brometea)*.

Six of the nine plant communities have the rank of phytosociological associations; one vegetation type has been identified as a dominance community (*Calamagrostis epigejos*-community, see Chapter 3.3.5), and two vegetation types are informal communities (*Festuca pratensis*-community, see Chapter 3.3.7, and *Cirsium furiens-Brachypodium pinnatum*-community, see Chapter 3.3.9). Figure 34 shows the names of the identified associations and communities and their placement in the syntaxonomic system.

Class:	*Phragmito-Magnocaricetea* Klika in Klika et Novák 1941
Order:	*Magnocaricetalia* Pignatti 1953
Alliance:	*Magnocaricion gracilis* Géhu 1961
Association:	*Caricetum vesicariae* Chouard 1924 (1 relevé)
Class:	*Molinio-Arrhenatheretea* Tx. 1937
Order:	*Potentillo-Polygonetalia avicularis* Tx. 1947
Alliance:	*Potentillion anserinae* Tx. 1947
Association:	*Mentho longifoliae-Juncetum inflexi* Lohmeyer ex Oberdorfer 1957 nom. invers. (3 relevés)
Order:	*Molinietalia caeruleae* Koch 1926
Alliance:	*Molinion caeruleae* Koch 1926
Association:	*Molinietum caeruleae* Koch 1926 (16 relevés)
Community:	*Calamagrostis epigejos*-[Molinietalia caeruleae]-community (10 relevés)
Class:	*Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947
Order:	*Brachypodietalia pinnati* Korneck 1974 nom. conserv. propos.
Alliance:	*Cirsio-Brachypodion pinnati* Hadač et Klika in Klika et Hadač 1944
Association:	*Brachypodio pinnati-Molinietum arundinaceae* Klika 1939 (10 relevés)
Community:	*Festuca pratensis*-[Cirsio-Brachypodion pinnati]-community (8 relevés)
Association:	*Polygalo majoris-Brachypodietum pinnati* Wagner 1941 (36 relevés)
Community:	*Cirsium furiens-Brachypodium pinnatum*-[Cirsio-Brachypodion pinnati]-community Dengler et al. 2012 (16 relevés)
Order:	*Festucetalia valesiacae* Soó 1947
Alliance:	*Festucion valesiacae* Klika 1931 nom. conserv. propos.
Suballiance:	*Stipenion lessingianae* Soó 1947
Association:	*Danthonio-Stipetum stenophyllae* Ghişa 1941 (2 relevés)

Figure 34: Identified syntaxa and their placement in the syntaxonomic system

The nomenclature for the classes, orders and alliances follow Mucina et al. (2016); for the associations and communities the nomenclature follows different authors indicated in the respective chapters.

The course of the classification by TWINSPAN is illustrated by a dendrogram in Figure 35 and described in the following:

- In the first division step, four communities of moist to wet grasslands were separated from four communities of semi-dry grasslands of the alliance *Cirsio-Brachypodion pinnati*.
- In the second step, the *Mentho-Juncetum inflexi* and *Molinietum caeruleae* were divided from the *Caricetum vesicariae* and the *Calamagrostis epigejos*-community.
- On the side of the semi-dry vegetation, the second division step divided the *Brachypodio-Molinietum arundinaceae* and the *Festuca pratensis*-community from the *Polygalo-Brachypodietum pinnati* and the *Cirsium furiens*-community (including the *Danthonio-Stipetum stenophyllae*).
- The third step resulted in the final division, with subsequent manual separation of the *Danthonio-Stipetum stenophyllae* from the *Cirsium furiens*-community.

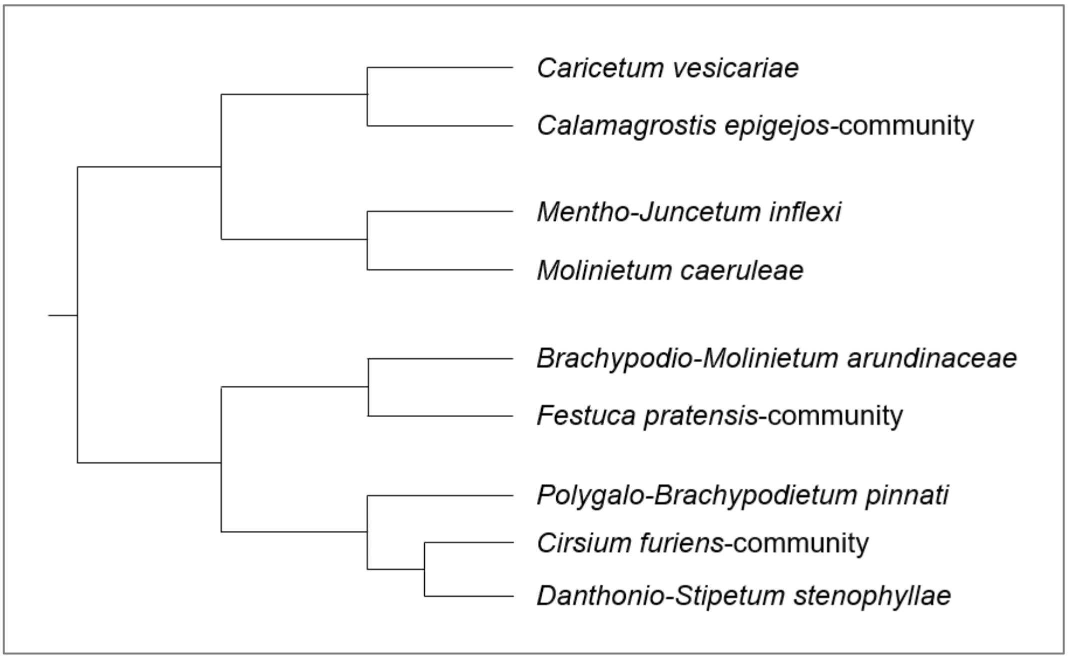

Figure 35: Dendrogram of the TWINSPAN classification of the relevés
The program does not specify distance measures. The *Danthonio-Stipetum stenophyllae* was separated manually from the *Cirsium furiens*-community.

The location of the 102 relevés with display of the group affiliation is shown for the Lord's Meadow in Figure 36, for the Village Meadow in Figure 37, for the Meadow Hill in Figure 38 and for the Great Meadow and Jacob's Meadow in Figure 39.

Qualitative information about the location and the area covered by the plant communities is provided in the respective subchapters 'Occurrence of the plant community in the study hay meadows'. Furthermore, the mapping results of the *Molinia arundinacea* stands are presented in Chapter 3.3.4.4.

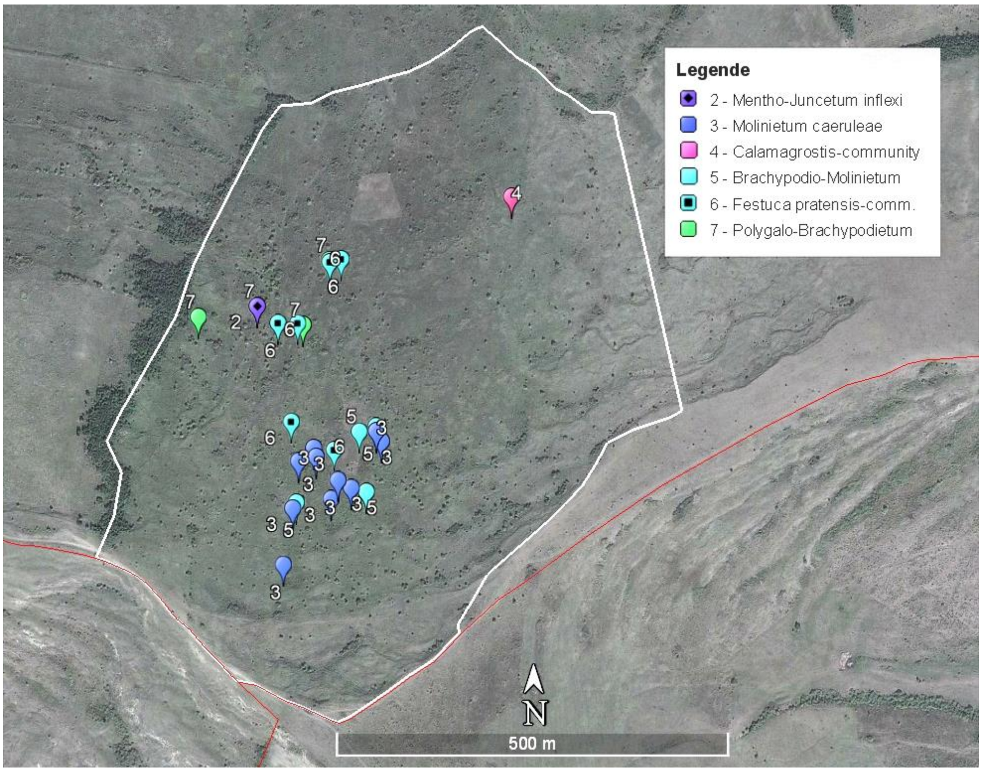

Figure 36: Locations of the relevés with plant community affiliation in the Lord’s Meadow (white outline; Dăbâca commune)
Red lines: communal borders. The Google Earth image is from September 2011 (Google, © 2023 Maxar Technologies).

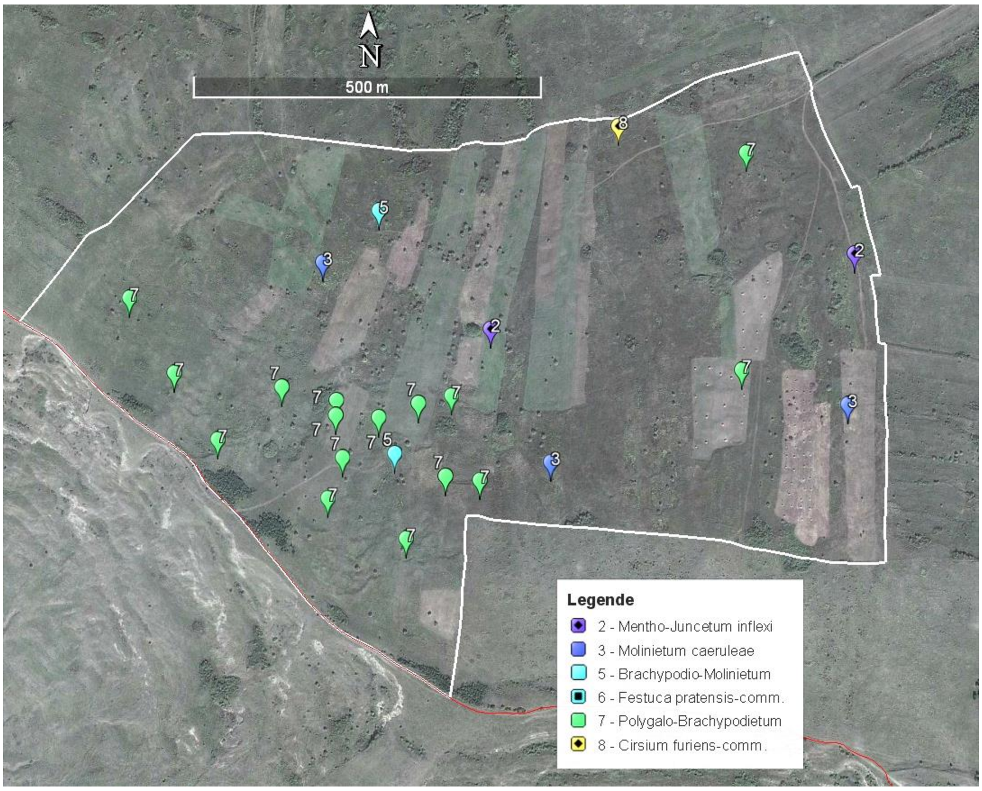

Figure 37: Locations of the relevés with plant community affiliation in the Village Meadow (white outline; Dăbâca commune)
Red lines: communal borders. The Google Earth image is from September 2011 (Google, © 2023 Maxar Technologies).

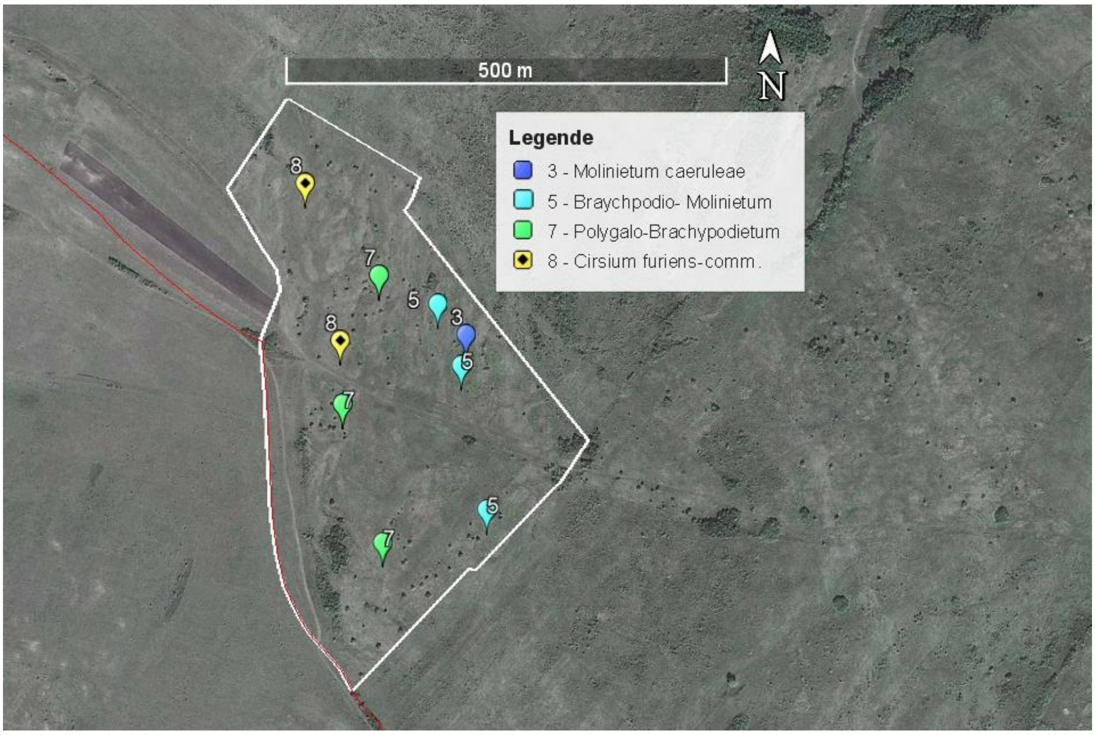

Figure 38: Locations of the relevés with plant community affiliation in the Meadow Hill (white outline; Dăbâca commune)
Red lines: communal borders. The Google Earth image is from September 2011 (Google, © 2023 Maxar Technologies).

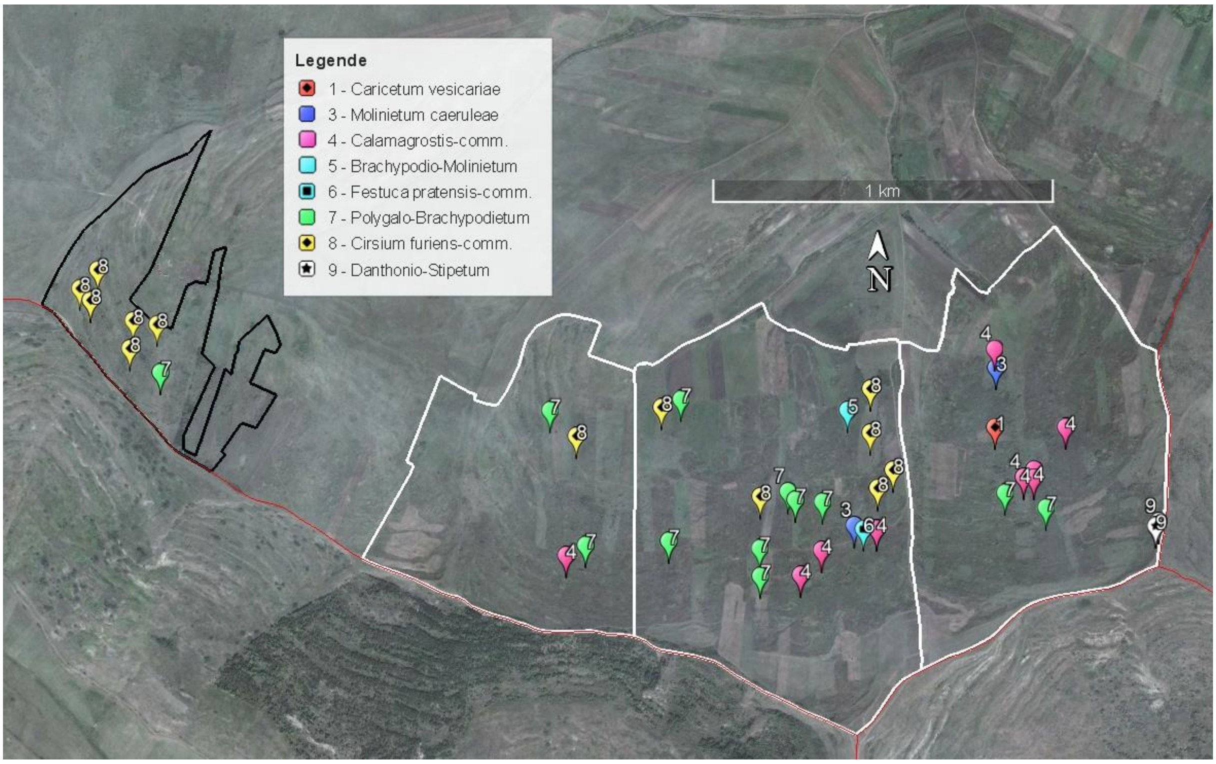

Figure 39: Locations of the relevés with plant community affiliation in the Great Meadow (white outline) and Jacob's Meadows (black outline) (Borșa commune)
Red lines: communal borders. The Google Earth image is from September 2011 (Google, © 2023 Maxar Technologies).

3.3.1.2 Ellenberg indicator values

The mean Ellenberg indicator values (unweighted) of the nine identified plant communities, calculated from the mean values of the relevés, are shown in Table 3, Figure 40, and are also discussed in the subchapters 'Environmental and ecological conditions' for the single plant communities. For discussions about the use of the arithmetic mean for the Ellenberg indicator values, which are ordinal data, see Dierschke (1994), Ellenberg et al. (2001) and Chytrý et al. (2018).

Table 3: Unweighted mean Ellenberg indicator values of the plant communities

Plant community	**Light**	**Tempera-ture**	**Continen-tality**	**Reaction**	**Moisture**	**Nutrients**
Caricetum vesicariae	6.9	5.6	4.6	7.0	8.0	5.5
Mentho-Juncetum inflexi	7.1 ± 0.1	5.7 ± 0.1	4.2 ± 0.0	7.2 ± 0.2	6.8 ± 0.3	4.3 ± 0.4
Molinietum caeruleae	7.2 ± 0.2	5.8 ± 0.1	4.4 ± 0.2	7.3 ± 0.2	5.5 ± 0.4	4 ± 0.3
Calamagr. epigejos-comm.	7.2 ± 0.1	5.9 ± 0.1	4.8 ± 0.1	7.5 ± 0.2	5.4 ± 0.4	4.2 ± 0.3
Brachypodio-Molinietum	7.3 ± 0.1	5.9 ± 0.1	4.7 ± 0.1	7.5 ± 0.1	4.3 ± 0.2	3.4 ± 0.1
Festuca pratensis-comm.	7.3 ± 0.1	6.0 ± 0.1	4.6 ± 0.2	7.4 ± 0.1	4.3 ± 0.3	3.6 ± 0.2
Polygalo-Brachypodietum	7.2 ± 0.1	6.1 ± 0.1	4.9 ± 0.1	7.5 ± 0.1	3.8 ± 0.2	3.4 ± 0.2
Cirsium furiens-comm.	7.3 ± 0.1	6.0 ± 0.1	4.7 ± 0.2	7.6 ± 0.2	3.9 ± 0.2	3.4 ± 0.3
Danthonio-Stipetum	7.7 ± 0.0	6.5 ± 0.1	5.5 ± 0.1	7.8 ± 0.2	3.0 ± 0.1	2.9 ± 0.1

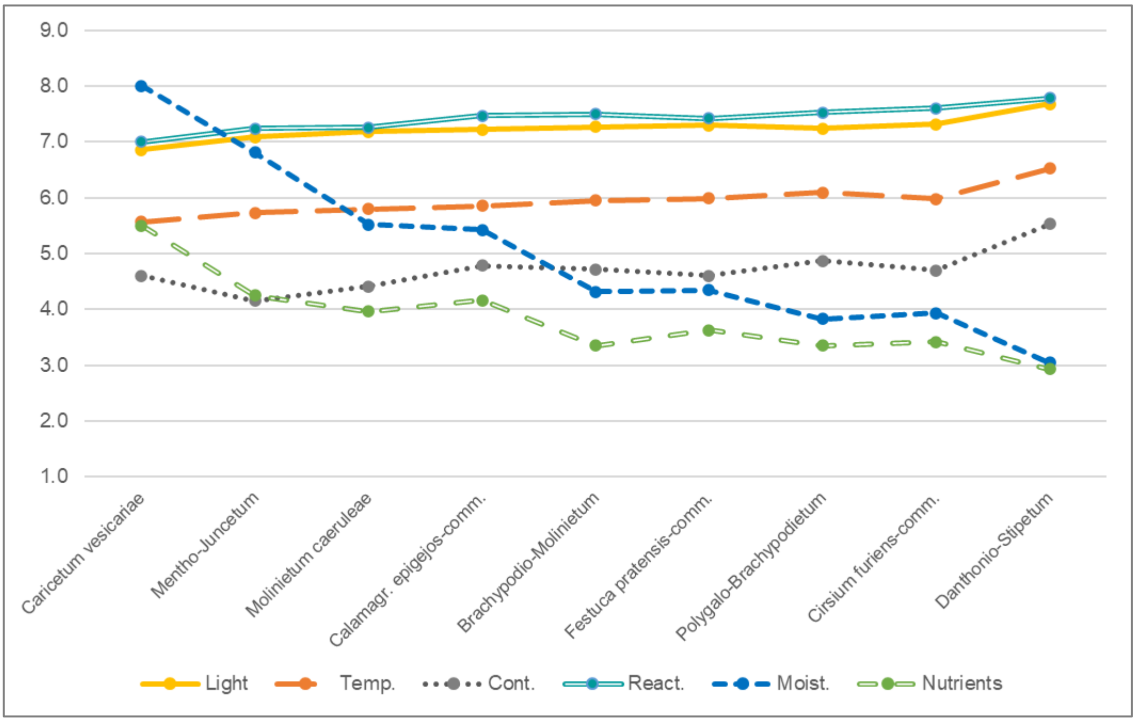

Figure 40: Diagram of the unweighted mean Ellenberg indicator values

The plant communities differ most in their ecological behaviour regarding soil moisture (range from 3.0 to 8.0) and the supply of mineral nitrogen (range from 2.9 to 5.5). The mean values of the other indicators (light, temperature, continentality, soil reaction) are within approximately one scale step per plant community. In the following, the results for the single Ellenberg indicator values are considered in more detail.

Since all studied plant communities are grasslands, the Ellenberg indicator for light varies little, as expected, and reflects a relatively high light requirement of the vascular plant species (Dierschke and Briemle 2008). The mean indicator values per plant community range between 6.9 (*Caricetum vesicariae*) and 7.3 for all vegetation types except the *Danthonio-Stipetum stenophyllae*, which has a value of 7.7. This means that the studied plant communities predominantly contain vascular plant species occurring generally in well lit places, but also in partial shade (Hill et al. 1999; Ellenberg et al. 2001).

The mean Ellenberg indicator value for temperature, which depends on the geographic range or altitudinal stage of the species (Ellenberg et al. 2001), ranges between 5.6 *(Caricetum vesicariae)* and 6.5 *(Danthonio-Stipetum stenophyllae)*. This means that the majority of the plant communities have an elevated occurrence of vascular plant species of temperate areas in the lowland to (sub)montane level (Ellenberg et al. 2001).

The mean indicator value for continentality ranges between 4.2 (*Mentho-Juncetum inflexi*) and 5.5 *(Danthonio-Stipetum stenophyllae)*. The continentality value 4 indicates a suboceanic occurrence of a species, the value 5 a weak suboceanic to weak subcontinental occurrence (Ellenberg et al. 2001). This means that, on average, the plant species in the vegetation types occur predominantly in this range, although there can be large deviations (values from 2 to 9 for single plant species).

The mean indicator value for soil reaction ranges between 7.0 *(Caricetum vesicariae)* and 7.8 *(Danthonio-Stipetum)*. This indicates the more frequent occurrence of plant species growing predominantly on soils with neutral to rather alkaline pH-value (Ellenberg et al. 2001), which can be explained by the fact that the parent rock is carbonate-rich marl (see Chapter 2.3).

The mean Ellenberg indicator value for moisture ranges between 3.0 (*Danthonio-Stipetum stenophyllae*) and 8.0 (*Caricetum vesicariae*) and has the largest range of all indicator values as previously mentioned. Many indicator species for dryness occur in the *Danthonio-Stipetum stenophyllae*, while the four plant communities assigned to the alliance of semi-dry grasslands *Cirsio-Brachypodion pinnati* (*Brachypodio-Molinietum*, *Festuca pratensis*-community, *Polygalo-Brachypodietum* and *Cirsium furiens*-community) have a mean moisture value of about 4, indicating soil moisture conditions between dry and damp.

The *Molinietum caeruleae* and the *Calamagrostis epigejos*-community, that is, the two plant communities assigned to the *Molinietalia caeruleae*, have a mean indicator value of about 5.5 (damp to slightly moist), while the mean moisture value of 6.8 for the *Mentho-Juncetum inflexi* and of 8.0 for the *Caricetum vesicariae* indicate moist and wet soil conditions, respectively.

The mean indicator value for mineral nitrogen i.e. nutrient availability ranges between 2.9 (*Danthonio-Stipetum stenophyllae*) and 5.5 (*Caricetum vesicariae*). Thus, the site conditions of the plant communities fall into the range between low nitrogen supply (3) and moderately high nitrogen supply (5).

3.3.1.3 DCA

The result of the detrended correspondence analysis (DCA) is shown in Figure 41. The gradient length of the first axis is 3.7 SD and the length of the second axis is 2.2 SD. That means that the minimum gradient length for a reasonable application of a DCA between 3 and 4 SD is fulfilled for the first axis (Lepš and Šmilauer 2003) and the DCA is therefore considered interpretable.

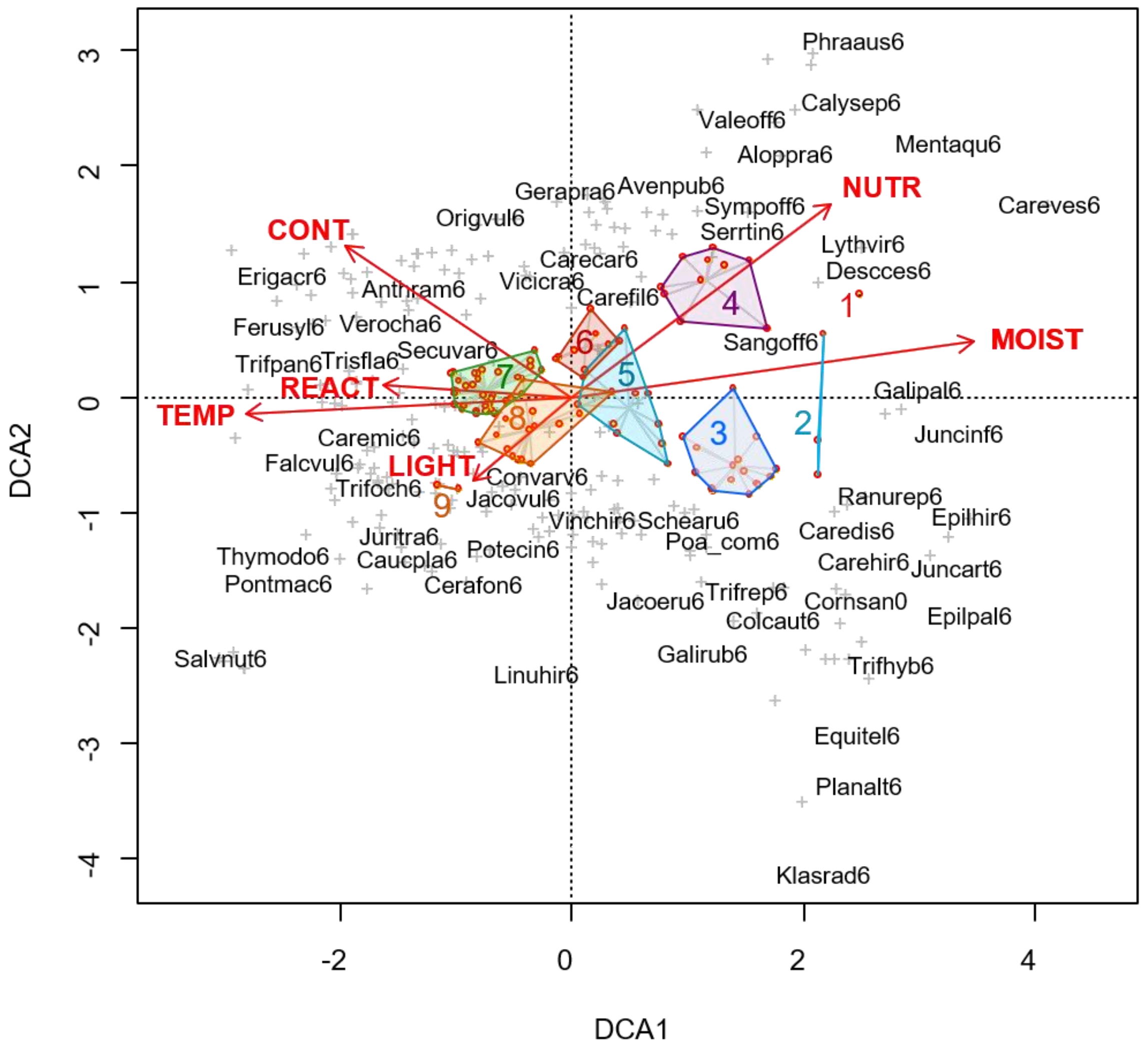

Figure 41: DCA biplot (1st and 2nd axis) with projected relevés (red-yellow circles), species (grey crosses and, for some species, black labels) and unweighted Ellenberg indicator values as vectors (red)
The cover values were transformed by square root transformation, and down-weighting of rare species was used. The plant communities are displayed with envelopes, spiderplots and centroids. Gradient length of 1st axis: 3.7 SD, 2nd axis: 2.2 SD; eigenvalue 1st axis: 0.45, 2nd axis: 0.19

Plant communities:

1 – *Caricetum vesicariae*
2 – *Mentho-Juncetum inflexi*
3 – *Molinietum caeruleae*
4 – *Calamagrostis epigejos*-community
5 – *Brachypodio-Molinietum arundinaceae*
6 – *Festuca pratensis*-community
7 – *Polygalo-Brachypodietum pinnati*
8 – *Cirsium furiens*-community
9 – *Danthonio-Stipetum stenophyllae*

Another important parameter of the DCA is the eigenvalue of each axis, which ranges between 0 and 1; an eigenvalue above 0.5 indicates that a high part of the variability of the data set is explained by this axis (Berg and Magnes 2019). The eigenvalues of the analysed data set are as follows: 1st axis 0.45 and 2nd axis 0.19. From this it was concluded that the first axis can explain a large part of the variability, while the second axis should not be used for interpretation.

The vector that represents the Ellenberg indicator values for moisture runs almost parallel to the first axis (see Figure 41). This confirms that soil moisture is the most important ecological gradient for the plant communities studied (see previous chapter). Pointing in the opposite direction of the moisture vector are the vectors representing the Ellenberg indicator values for soil reaction and temperature.

The four damp, moist or wet plant communities (*Molinietum caeruleae*, *Calamagrostis epigejos*-community, *Mentho-Juncetum* and *Caricetum vesicariae*), which are located on the right side of the first axis, have a somewhat larger distance to each other, while the four semi-dry communities of the *Cirsio-Brachypodion pinnati* (*Brachypodio-Molinietum*, *Festuca pratensis*-community, *Polygalo-Brachypodietum* and *Cirsium furiens*-community), which have a relatively central position in the ordination diagram, are located close to each other and partially overlap (see Figure 41). The clear distance of the *Danthonio-Stipetum* from the *Cirsium furiens*-community confirms the validity of the manual separation following the TWINSPAN classification.

Regarding the variability within the groups, it turns out that in the *Polygalo-Brachypodietum*, despite having the largest number of plots, the projected relevés are closest to each other. This shows that the *Polygalo-Brachypodietum* is one of the most ecologically homogeneous vegetation types.

3.3.1.4 Vegetation structure and species richness

In the following, some parameters on vegetation structure that were surveyed uniformly for (almost) all relevés are shown. Additional parameters are discussed in the subchapters ‘Structure and species composition’ for each vegetation type.

Table 4 shows the mean, minimum and maximum total cover of vascular plant species for each studied plant community. All average values are above 90 %, except the single relevé of the *Caricetum vesicariae* (80 %). The highest values are reached by the *Mentho-Juncetum* (99.3 %) and the *Molinietum caeruleae* (98.9 %), the lowest by the *Cirsium furiens*-community (92.6 %) and the *Danthonio-Stipetum* (92.5 %).

Table 4: Mean total cover of vascular plant species per plant community

Plant community	**Number relevés**	**Total cover (%)**		
		mean ± SD	min.	max.
Caricetum vesicariae	1	80	80	80
Mentho-Juncetum	3	99.3 ± 0.9	98	100
Molinietum caeruleae	14	98.9 ± 1.5	95	100
Calamagr. epigejos -comm.	10	94.3 ± 4.5	90	100
Brachypodio-Molinietum	10	95.3 ± 4.4	85	100
Festuca pratensis- comm.	8	97.6 ± 3.9	90	100
Polygalo-Brachypodietum	36	96.8 ± 4.1	80	100
Cirsium furiens- comm.	16	92.6 ± 4.7	85	100
Danthonio-Stipetum	2	92.5 ± 2.5	90	95
Sum no. relevés	100			

SD = standard deviation

Table 5 shows the mean vascular plant species richness for each plant community, either related to the 25 m²-relevés or the 10 m²-relevés (the latter highlighted in grey). Only the species richness of relevés with the same size can be compared to each other; the accuracy of the richness determination also differs between the purely phytosociological relevés (25 m²) and the relevés which were part of diversity nested plots (10 m²) (see Chapter 5).

Table 5: Mean vascular plant species richness per plant community

Plant community	**Number relevés**	**Plot size (m²)**	**Species richness**		
			mean ± SD	min.	max.
Caricetum vesicariae	1	25	7	7	7
Mentho-Juncetum	3	25	23 ± 3	19	25
Molinietum caeruleae	14	25	32 ± 5	25	43
Calamagr. epigejos -comm.	10	25	29 ± 4	23	36
Brachypodio-Molinietum	7	*10*	*56 ± 8*	*46*	*67*
Festuca pratensis- comm.	8	25	42 ± 10	30	56
Polygalo-Brachypodietum	15	25	43 ± 8	26	56
	21	*10*	*61 ± 10*	*41*	*81*
Cirsium furiens- comm.	14	*10*	*59 ± 9*	*48*	*76*
Danthonio-Stipetum	2	25	24 ± 1	23	25
Sum no. relevés	95				

SD = standard deviation

The highest mean richness values are reached by three communities of the *Cirsio-Brachypodion pinnati* alliance: the *Polygalo-Brachypodietum* (61 species / 10 m²), the

Cirsium furiens-community (59 species / 10 m^2), and the *Brachypodio-Molinietum* (56 species / 10 m^2).

The richness values of the purely phytosociological relevés can be compared for all communities except the *Brachypodio-Molinietum* and the *Cirsium furiens*-community. Here again, the *Cirsio-Brachypodion*-communities, that is, the *Polygalo-Brachypodietum* and the *Festuca pratensis*-community, have the highest richness values (around 42 species / 25 m^2).

The next highest mean richness value is found in the *Molinietum caeruleae* (32 species / 25 m^2), followed by the *Calamagrostis epigejos*-community (29 species / 25 m^2). The single *Caricetum vesicariae*-relevé had the lowest value with only 7 species on 25 m^2.

Table 6 shows the number and share of relevés per plant community in which the following six phanerophyte species occur: *Crataegus monogyna, Rosa canina, Prunus spinosa, Salix cinerea, Cornus sanguinea* and *Rosa micrantha*, regardless of their size. Of the 102 relevés, 54 relevés contain these phanerophyte species.

Table 6: Occurrence and cover of phanerophyte species

Plant community	**Number relevés**	**All considered phanerphytes**		***Crataegus monogyna***			***Prunus spinosa***	***Rosa canina***	***Salix cinerea***	***Cornus sanguinea***	***Rosa micrantha***
		no.	share (%)	no.	share (%)	cover	no.				
Caricetum vesicariae	1										
Mentho-Juncetum	3	1	*33*						1		
Molinietum caeruleae	16	7	*44*	6	*38*	2.2			1	1	
Calamagr. epigejos -comm.	10	4	*40*	3	*30*	1.0		1			
Brachypodio-Molinietum	10	7	*70*	6	*60*	2.8	3	1			
Festuca pratensis- comm.	8	2	*25*	2	*25*	1.0					1
Polygalo-Brachypodietum	36	17	*47*	16	*44*	1.2	3	4			
Cirsium furiens- comm.	16	16	*100*	14	*88*	0.9	9	8			
Danthonio-Stipetum	2										
Sum number relevés	102	54		47			15	14	2	1	1

Empty cell = zero; no. = number of relevés in which the species occurs; cover = mean cover related to the relevés with non-zero cover

The most frequent woody species recorded in the relevés is *Crataegus monogyna* (found in 47 of 102 relevés), which accounts for the largest proportion of phanerophytes in all communities by far, except in *Mentho-Juncetum inflexi.* Therefore, the share of relevés containing the species per community is shown, too. *Crataegus monogyna* is followed by the less frequent species *Prunus spinosa* (15 relevés) and *Rosa canina* (14 relevés). *Salix cinerea*, *Cornus sanguinea* und *Rosa micrantha* occur only in one or two relevés out of the total dataset.

In the *Cirsium furiens*-community, all relevés contain at least one of the six phanerophyte species. In the *Brachypodio-Molinietum arundinaceae,* 70 % of all relevés contain one or more phanerophytes, followed by the *Polygalo-Brachypodietum pinnati* with 47 %, the *Molinietum caeruleae* with 44 %, and the *Calamagrostis epigejos*-community with 40 % of the relevés.

The mean cover of the single phanerophyte species ranges between 0.1 % and 2.8 % of the relevé area, except in the *Mentho-Juncetum inflexi,* where *Salix cinerea* covered 15 % of the area (value of 1 relevé). In contrast to the proportion of relevés with phanerophytes, which is highest in the *Cirsium furiens*-community as mentioned above, the mean cover value is the lowest (0.9 %) in the *Cirsium furiens*-community, at least for *Crataegus monogyna*.

3.3.1.5 Environmental parameters

Table 7 shows the mean elevation above sea level of the relevés per plant community. The minimum and maximum values range from 364 to 468 m.a.s.l. The highest mean value is reached by the *Danthonio-Stipetum stenophyllae* with 462 m.a.s.l., and the lowest mean value by the *Caricetum vesicariae* with 395 m.a.s.l.

Table 7: Altitude of the relevés - mean for plant communities

Plant community	**Number relevés**	**Altitude (m a.s.l.)**		
		mean ± SD	min.	max.
Caricetum vesicariae	1	395	395	395
Mentho-Juncetum	2	400 ± 10	390	409
Molinietum caeruleae	14	435 ± 25	370	468
Calamagr. epigejos -comm.	10	418 ± 22	364	445
Brachypodio-Molinietum	10	432 ± 22	384	457
Festuca pratensis- comm.	7	433 ± 14	416	456
Polygalo-Brachypodietum	35	431 ± 18	377	461
Cirsium furiens- comm.	16	421 ± 23	374	450
Danthonio-Stipetum	2	462 ± 1	461	463
Sum no. relevés	97			

SD = standard deviation

Table 8 shows the median values of the estimated inclination of the plots per plant community. The *Caricetum vesicariae*, *Mentho-Juncetum inflexi* and *Calamagrostis epigejos*-community, that is, communities at wet to slightly moist sites, have the lowest values of inclination (median of 0°), which can be explained by their occurrence in flat areas or small depressions within the hill slope.

The next lowest inclination values (median of 1.5° or 2°) were found for the plant communities at slightly moist or semi-dry sites, such as the *Molinietum caeruleae*, *Brachypodio-Molinietum* and *Festuca pratensis*-community, while the *Polygalo-Brachypodietum* and *Cirsium furiens*-community have higher average inclination values (median of 5° and 7°). This indicates that stands of the latter plant communities are more frequently found on the inclined parts of the hillside.

Table 8: Inclination of the relevés - median for plant communities

Plant community	**Number relevés**	**Slope (degrees)**		
		median	min.	max.
Caricetum vesicariae	1			
Mentho-Juncetum	3	0.0	0.0	3.0
Molinietum caeruleae	10	1.5	0.0	3.0
Calamagr. epigejos -comm.	10	0.0	0.0	3.0
Brachypodio-Molinietum	10	2.0	0.0	10.0
Festuca pratensis- comm.	8	1.5	0.0	5.0
Polygalo-Brachypodietum	35	5.0	0.0	15.0
Cirsium furiens- comm.	15	7.0	1.0	12.0
Sum no. relevés	92			

The inclination has not been surveyed for the *Danthonio-Stipetum stenophyllae.*

Table 9 shows the aspect of the relevés for each plant community. The majority of the plots are north-facing (55 %) and only 5 % and 2 % of the plots are east- or west-facing, respectively. The remaining 37 % of the plots have an aspect of NNE, NE, ENE, NW or NNW. These values result from the main orientation of the hay meadow slopes towards the north, with possible deviations at the slope shoulders or in complex microrelief situations.

Table 9: Aspect of the relevés

Plant community	**Number relevés**	**N**	**NNE**	**NE**	**ENE**	**E**	**W**	**NW**	**NNW**
		360°	23°	45°	68°	90°	270°	315°	338°
Mentho-Juncetum	3	3							
Molinietum caeruleae	8	6	1					1	
Calamagr. epigejos -comm.	5	1						1	3
Brachypodio-Molinietum	10	6	2			1		1	
Festuca pratensis- comm.	7	7							
Polygalo-Brachypodietum	35	17	2	10	1	2		2	1
Cirsium furiens- comm.	15	6		5		1	2	1	
Sum no. relevés	83	46	5	15	1	4	2	6	4
Sum (%)	*100*	*55*	*6*	*18*	*1*	*5*	*2*	*7*	*5*

The aspect has not been surveyed for the *Caricetum vesicariae* and the *Danthonio-Stipetum stenophyllae.*

The soil texture of the topsoil was determined solely for the diversity relevés and therefore can be specified for the stands of the three communities *Brachypodio-Molinietum* (n = 6), *Polygalo-Brachypodietum* (n = 20), and *Cirsium furiens*-community (n = 12). Since the soil texture was determined only in the field and not in the laboratory, the results give only a rough indication of the soil texture: In 80 % of the plots clayey silt was found, mainly medium to highly clayey silt (Ut3, Ut4). In the remaining 20 % of the plots, silty clay was found, mainly highly silty clay (Tu4).

3.3.1.6 Habitat codes and conservation value

Table 10 shows the habitat codes for each plant community according to the Romanian classification (Doniţă et al. 2005) and the EUNIS-classifications of the European Union (European Environment Agency 2019; Chytrý et al. 2020). The EUNIS-codes for the *Festuca pratensis*-community and the *Cirsium furiens*-community were taken from the most similar plant communities. For the *Calamagrostis epigejos*-community no codes were assigned.

Table 10: Habitat codes of the plant communities

Plant community	**Romanian habitat code**	**EUNIS 2007 code (level 3)**	**EUNIS 2007 code (level 4/5/6)**	**EUNIS 2020 code (level 3)**
Caricetum vesicariae	(R5310 – Daco-danubian communities with *Carex elata*, *C. rostrata*, *C. riparia* and *C. acutiformis)*	D5.2 – Beds of large sedges normally without free-standing water	D5.2142 – Bladder sedge beds	Q53 - Tall-sedge bed
Mentho-Juncetum inflexi	R3709 - Danubian communities with *Juncus effusus*, *J. inflexus* and *Agrostis canina*	E3.4 - Moist or wet eutrophic and mesotrophic grassland	E3.46- Continental humid meadows / E3.441 – Tall rush pastures	R35 / R36 - Moist or wet mesotrophic to eutrophic hay meadow / pasture
Molinietum caeruleae	(R3710 - Dacian grasslands with *Molinia caerulea*)	E3.5 - Moist or wet oligotrophic grassland	E3.513 - Giant moorgrass swards	R37 - Temperate and boreal moist or wet oligotrophic grassland
Calamagrostis epigejos-community	-	-	-	-
Brachypodio-Molinietum, *Festuca pratensis*-community, *Polygalo-Brachypodietum*, *Cirsium furiens*-community	-	E1.2 - Perennial calcareous grassland and basic steppes	E1.233 - Dacio-Pannonic meadow-steppes (meso-xerophile grasslands of the Transylvanian basin and the foothills of the Apuseni mountains)	R1A - Semi-dry perennial calcareous grassland (meadow steppe)
Danthonio-Stipetum stenophyllae	R3407 - Ponto-pannonic grasslands of *Stipa stenophylla (S. tirsa)* and *Danthonia (provincialis) alpina*		E1.22- Arid subcontinental steppic grassland	R1B - Continental dry grassland (true steppe)

Romanian habitat code: Doniţă et al. (2005); EUNIS 2007 codes: European Environment Agency (2019); EUNIS 2020 codes: Chytrý et al. (2020); explanation of the brackets in the text

Where the Romanian habitat codes are in brackets, Doniţă et al. (2005) does not list the plant community considered explicitly. The *Caricetum vesicariae* was allocated to the Romanian habitat type R5310, which also includes the ecologically similar *Carex acuta* (synonym: *Carex gracilis*) as a possible dominant species. The *Molinietum caeruleae* was assigned to the habitat type R3710, which comprises the communities *Junco-Molinietum* Preising 1951, *Peucedano rocheliani-Molinietum coeruleae* Boşcaiu 1965 and *Molinio-Salicetum rosmarinifoliae* Magyar ex Soó 1933.

In Table 11, the conservation value of the plant communities is indicated based on the European Red List of Habitats by Janssen et al. (2016). Almost all plant communities in the relevés are considered vulnerable or endangered. Table 11 also shows the assignment of the communities to habitat types listed in Annex I of the Habitats Directive (European Environment Agency 2019). Six of the nine plant communities are protected by the Habitats Directive as habitat types 6410 (*Molinietum caeruleae*), 6210 (*Brachypodio-Molinietum arundinaceae*, *Festuca pratensis*-community, *Polygalo-Brachypodietum*, *Cirsium furiens*-community) and 6240 (*Danthonio-Stipetum stenophyllae).*

Table 11: Conservation value of the plant communities

Plant community	**European red list of habitats (Janssen et al. 2016)**	**Annex I of the Habitats Directive (Council of the European Union 2013)**	**Conservation value in Romania (Doniţă et al. 2005)**
Caricetum vesicariae	vulnerable (code C5.2: Tall-sedge bed)	-	moderate conservation value
Mentho-Juncetum inflexi	endangered (code E3.4a/b: Moist or wet eutrophic and mesotrophic hay meadow/pasture)	-	reduced conservation value
Molinietum caeruleae	endangered (code E3.5: Moist or wet oligotrophic grassland)	6410 - *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)	moderate conservation value
Calamagrostis epigejos -community	-	-	-
Brachypodio-Molinietum, *Festuca pratensis*- community, *Polygalo-Brachypodietum*, *Cirsium furiens*- community	vulnerable (code E1.2a: Semi-dry perennial calcareous grassland)	6210 - Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (* important orchid sites)	-
Danthonio-Stipetum stenophyllae	near threatened (code E1.2b: Continental dry steppe)	6240 - Sub-pannonic steppic grasslands	moderate conservation value

Information about the national conservation value of the plant communities can be provided only through a rough indication for the Romanian habitat types by Doniţă et al. (2005), since there is no true red list of plant communities or habitats for Romania yet. The information from Doniţă et al. (2005) is of limited value, however, as some of the plant communities do not have an exact correspondence in the listed habitat types and the conservation value seems questionable in some cases (such as the moderate conservation value of the *Molinion* meadows).

Table 12 shows the vascular plant species of national conservation concern in the relevés (endemic, vulnerable or rare). The assignment is based on three literature sources, since there is no generally valid red list of plant species for Romania: Dihoru and Dihoru (1994), Oltean et al. (1994) and Boşcaiu et al. (1994). Sixteen of the 320 vascular plant species are considered rare and/or vulnerable by at least one of the Romanian authors mentioned above, and two species are endemic to Romania (*Cirsium furiens* and *Jurinea transylvanica*).

Table 12: Vascular plant species of national conservation concern in the relevés: percentage frequency per plant community

Species	Status	Source	*Caricetum vesicariae*	*Mentho-Juncetum*	*Molinietum caeruleae*	*Calamagr. epigejos* -comm.	*Brachypodio-Molinietum*	*Festuca pratensis* -comm.	*Polygalo-Brachypodietum*	*Cirsium furiens*-comm.	*Danthontio-Stipetum*	Total
Adonis vernalis	v	D						13	67	6		25
Cirsium furiens (e)	k	D								25		4
Gentiana pneumonanthe	v	B			56		50	25	3			17
Gladiolus imbricatus	r	D						13				1
Iris aphylla	r	D				10						1
Iris sibirica	r; v	D; B			44	10	10					9
Jurinea transylvanica (e)	r	D, O								6		1
Klasea radiata	r	O			6							1
Mercurialis ovata	r	O							6			2
Nepeta ucranica	v; r	O; B							3			1
Rosa micrantha	r	O						13				1
Salvia nutans	v	D									100	2
Serratula coronata	r	D, O				70		13				8
Seseli peucedanoides	r	O				10		25	22	19		14
Teucrium montanum	r	D									50	1
Trinia kitaibelii	r	B								6		1
Veratrum nigrum	r	O							3			1
No. of species / comm.			0	0	3	4	2	6	6	5	2	

e = endemic, v = vulnerable, k = insufficiently known, r = rare; D = Dihoru and Dihoru (1994), B = Boşcaiu et al. (1994), O = Oltean et al. (1994); total = percentage frequency in the entire dataset of 102 relevés; no. of species / comm. = number of species of conservation concern per plant community

Some of these 16 species occur in one seventh (*Seseli peucedanoides*), one sixth (*Gentiana pneumonanthe*) or even one quarter (*Adonis vernalis*) of the relevés (see Table 12). However, most of the rare or vulnerable species have been found only in one or few relevés (e.g. *Gladiolus imbricatus*, *Nepeta ucranica*, *Trinia kitaibelii* and *Veratrum nigrum*). Separate studies are necessary to determine the actual occurrence of rare or endangered plant species in the hay meadows.

The plant communities with the highest numbers of species of national conservation concern are the *Polygalo-Brachypodietum* and the *Festuca pratensis*-community, each with six species, followed by the *Cirsium furiens*-community and the *Calamagrostis epigejos*-community with four species each (see Table 12).

In single relevés of the three communities *Polygalo-Brachypodietum, Cirsium furiens*-community and *Danthonio-Stipetum stenophyllae,* the species *Pontechium maculatum* has been found, which is protected by the Habitats Directive (Council of the European Communities 2013). *Iris aphylla*, recorded in one relevé of the *Calamagrostis-epigejos*-community and observed in several more places in the meadows (see Figure 42) may also be protected by the Habitats Directive if it is synonymised with *Iris aphylla* subsp. *hungarica* (see explanations in Annex 3).

Figure 42: *Iris aphylla* in the Lord's Meadow with *Adonis vernalis* in the background (Dăbâca commune, 02.05.2009)

3.3.1.7 Occurrence of *Phengaris* spp. host plant species

The host plant species of *Phengaris teleius* and *Ph. nausithous*, *Sanguisorba officinalis*, occurred in seven of nine plant communities in the study meadows (see Table 13). The highest frequency of the species was found in the *Molinietum caeruleae*-relevés (88 %), followed by the relevés of the *Festuca pratensis*-community (75 %), the *Mentho-Juncetum inflexi* (67 %), the *Calamagrostis epigejos*-community (50 %), and the *Brachypodio-Molinietum arundinaceae* (40 %) (see Table 13).

Table 13: Host plant species for *Phengaris* spp.: percentage frequency per plant community

Host plant species	*Phengaris* species	*Caricetum vesicariae*	*Mentho-Juncetum*	*Molinietum caeruleae*	*Calamagr. epigejos* -comm.	*Brachypodio-Molinietum*	*Festuca pratensis* -comm.	*Polygalo-Brachypodietum*	*Cirsium furiens*-comm.	*Danthontio-Stipetum*	Entire dataset
Sanguisorba officinalis	*Ph. nausithous, Ph. teleius*		67	88	50	40	75	14	13		37
Gentiana pneumonanthe	*Ph. alcon 'pneumonanthe'*			56		50	25	3			17
Gentiana cruciata	*Ph. alcon 'cruciata'*						50	6			6
Origanum vulgare					20			33	13		16
Thymus pulegioides subsp. *pannonicus*	*Ph. arion*					10		19	81	100	23
Thymus odoratissimus								3	6	50	3
No. of species / comm.		0	1	2	2	3	3	6	4	2	

The values shown are percentage values. Empty cells: zero; no. of species / comm.: number of host plant species per plant community

This means that *Sanguisorba officinalis* occurs both in plant communities of moist sites and in semi-dry grasslands, especially if the latter are characterised by alternating soil moisture. Occasionally, the species is found also in semi-dry grasslands with less pronounced alternating moisture (*Polygalo-Brachypodietum* and *Cirsium furiens*-community). In total, *Sanguisorba officinalis* occurs in 37 % of all relevés (see also Stoianov et al. 2012).

The host plant species of *Phengaris alcon 'pneumonanthe'*, *Gentiana pneumonanthe*, occurs at a lower frequency in the relevés (17 % of all relevés) and is also correlated to a smaller range of plant communities: mainly the *Molinietum caeruleae* (56 %), the *Brachypodio-Molinietum arundinaceae* (50 %), and the *Festuca pratensis*-community (25 %) (see Table 13).

The host plant species of *Phengaris alcon 'cruciata', Gentiana cruciata*, occurs in four of the eight relevés of the *Festuca pratensis*-community and in two of the 36 *Polygalo-Brachypodietum*-relevés. The preferential occurrence in these plant communities should be verified with more data, especially regarding the *Festuca pratensis*-

community. The frequency of *Gentiana cruciata* in all relevés amounts to 6 % (see Table 13).

Field observations also suggest that *Gentiana cruciata* has a different distribution pattern than *Gentiana pneumonanthe* in the north facing hay meadows; while the latter species has a more clustered occurrence in the plant communities mentioned above, *Gentiana cruciata* is irregularly distributed in the semi-dry grassland communities and their fringes and is likely less frequent than *Gentiana pneumonanthe*. In contrast, *Gentiana cruciata* is more frequent in the (semi)dry grasslands of the south-facing slopes.

Regarding *Phengaris arion*, three potential host plant species have been recorded in the relevés: *Origanum vulgare, Thymus pulegioides* subsp. *pannonicus* and *Thymus odoratissimus*. The thyme species occurred especially in the *Cirsium furiens*-community and the *Danthonio-Stipetum stenophyllae*, while *Origanum vulgare* has the highest frequency in the *Polygalo-Brachypodietum* (see Table 13).

The situation described so far refers to the occurrence of host plant species in the years 2009-2013, which in some cases has changed in the years since.

3.3.2 *Caricetum vesicariae* Chouard 1924

Vegetation type:	Tall-sedge community
Names:	
English:	Tall-sedge community of *Carex vesicaria*
Romanian:	Comunitate de rogoz înalt cu *Carex vesicaria*
German:	Blasenseggen-Rasen, Blasenseggen-Ried
Relevé type, size, year:	1 phytosociological relevé, 25 m^2, 2009
Location:	
Borșa:	Great Meadow

3.3.2.1 Structure and species composition

The vegetation type is described on the basis of a single phytosociological relevé carried out in the year 2009 in the Great Meadow. This consists of seven herb species and is dominated by *Carex vesicaria* with a cover value of 75-80 %. Both the species-poorness and the dominance of one sedge species, is typical for tall-sedge communities (Dierschke and Briemle 2008; Leuschner and Ellenberg 2017).

In addition to *Carex vesicaria*, *Iris pseudacorus* occurs with a cover value of up to 5%, as well as five other species (*Phragmites australis*, *Lysimachia nummularia*, *Cirsium canum*, *Lythrum salicaria, Inula salicina*) with a cover value of up to 1%.

The vegetation height has not been measured; however, *Carex vesicaria* can reach a height of 80 cm (Ciocârlan 2000). The total vegetation cover of the relevé equals 80%, which is low compared to all other vegetation types (see Table 4, page 61). Obviously, more relevés of this vegetation type must be made to provide reliable information on its typical species composition and structure in the study area.

3.3.2.2 Syntaxonomy and diagnostic species

Class:	*Phragmito-Magnocaricetea* Klika in Klika et Novák 1941[a]
Order:	*Magnocaricetalia* Pignatti 1953[b]
Alliance:	*Magnocaricion gracilis* Géhu 1961[c]
Association:	*Caricetum vesicariae* Chouard 1924[d]

Selected synonyms:

[a] *Phragmitetea* Tx. et Preising 1942
[b] *Magnocarici-Phragmitetalia* (Pignatti 1953) Succow 1974
[c] *Caricion gracilis-vulpinae* Bal.-Tul. 1965
[d] *Caricetum vesicariae* Br.-Bl. et Denis 1926

The nomenclature and selected synonyms regarding the class, order, and alliance come from Mucina et al. (2016); the nomenclature of the association follows Landucci et al. (2020). The synonym of the association was taken from FloraWeb (2000-).

Although the described vegetation type is represented by only one relevé, it can safely be assigned to the phytosociological association *Caricetum vesicariae* Chouard 1924, due to the high cover value of the association character species *Carex vesicaria* (Coldea et al. 1997). Furthermore, *Iris pseudacorus* was also identified as diagnostic species for this vegetation type (see Table 14 and Figure 43), and is considered a character species of the syntaxonomical units of tall-sedge communities, which include the *Caricetum vesicariae* (e.g., the *Caricenion gracilis* according to Sanda et al. 2008).

Table 14: Diagnostic species of the *Caricetum vesicariae* (total n = 2)

Association character species	*Carex vesicaria*
Magnocaricion gracilis / Magnocaricion elatae	*Iris pseudacorus*

The association *Caricetum vesicariae* was assigned to the alliance *Magnocaricion gracilis* Géhu 1961 in the classification of the European marsh vegetation (*Phragmito-Magnocaricetea*) by Landucci et al. (2020). However, often the alliance *Magnocaricion gracilis* Géhu 1961 is not separated from the *Magnocaricion elatae* Koch 1926 (e.g. in Leuschner and Ellenberg 2017), and then the *Caricetum vesicariae* is assigned to the *Magnocaricion elatae*.

Figure 43: *Iris pseudacorus* near the Great Meadow (Borșa commune, 29.05.2013)

3.3.2.3 Environmental and ecological conditions

The described vegetation stand occurs in a small depression within the meadow vegetation matrix, characterized by wet soil conditions, which are reflected by the high Ellenberg indicator value (unweighted) for soil moisture M = 8.0. Furthermore, four of the seven species occurring in the relevé indicate alternating soil moisture conditions (*Lysimachia nummularia, Cirsium canum, Lythrum salicaria* and *Inula salicina*) while *Carex vesicaria* and *Iris pseudacorus* are species indicating regular flooding (Ellenberg et al. 2001).

The Ellenberg indicator value (unweighted) for nitrogen supply N = 5.5 is also the highest of all studied plant communities and indicates moderately high nitrogen conditions.

3.3.2.4 Occurrence of the plant community in the study hay meadows

The relevé was made in a tall-sedge stand of small extent in the eastern part of the Great Meadow (see Figure 39, page 56). Tall-sedge communities dominated by other sedge species, for example *Carex vulpina,* have also been observed in the Village Meadow, where they have been found near a large *Phragmites australis*-stand, for example (see Figure 44). The tall-sedge communities form small stands in very wet parts of the studied hay meadows; the area covered and exact location have not been surveyed.

Figure 44: *Carex vulpina*-stand (dark green patch in the centre) in the Village Meadow (Dăbâca commune, 31.07.2009)

3.3.2.5 Occurrence of the plant community in Romania

The nearest occurrences of the association *Caricetum vesicariae* to the study area mentioned by Coldea et al. (1997) are in the Western Romanian Carpathians (Gilău Mountains, Vlădeasa Mountains). Pop et al. (1999-2000) mention a locality of *Caricetum vesicariae* in the north of Dej in Bistriţa-Năsăud county, an approximately 40 km straight-line distance from the study area. Whether the mentioned stands belong to shore vegetation of lakes and ponds or occur on waterlogged slopes is not mentioned.

Sanda et al. (2008) specify that the *Caricetum vesicariae* occurs sporadically in Romania in depressions and nutrient-rich swamps. Csergö and Demeter (2011b) list the association as one of the most frequent plant communities of eu-mesotrophic, temporary ponds in the Ciuc Basin (Eastern Carpathians).

3.3.2.6 Conservation value and protection status

On the European red list of habitats by Janssen et al. (2016), the tall-sedge beds, here with the EUNIS 2007 code C5.2, are indicated as vulnerable. However, the *Caricetum vesicariae* is not included in Annex I of the EU Habitats Directive (Council of the European Communities 2013). The *Caricetum vesicariae*-relevé considered in this study contains no vascular plant species of national conservation concern.

3.3.3 *Mentho longifoliae-Juncetum inflexi* Lohmeyer ex Oberdorfer 1957 nom. invers.

Vegetation type: Community of flooded grasslands and creeping plants

Names:

English: Community of flooded grasslands and creeping plants with *Juncus inflexus* and *Mentha longifolia*

Romanian: Comunitate de pajiști inundate și plante târâtoare cu *Juncus inflexus* și *Mentha longifolia*

German: Rossminzen-Blaubinsen-Rasen

Information relevés:

Type, size, year: 3 phytosociological relevés, 25 m^2, 2009

Surveyors: 3 different persons / teams

Location:

Dăbâca: Lord's Meadow (1), Village Meadow (2)

3.3.3.1 Structure and species composition

The following descriptions are based on three phytosociological relevés carried out in the year 2009. The surveyed parameters of vegetation structure are shown in Table 15. The vegetation stands have a well-developed upper layer of tall-growing plants consisting of species such as *Juncus inflexus*, *Mentha longifolia*, *Deschampsia cespitosa*, *Cirsium canum*, *Lythrum salicaria*, *Carex distans*, *Ranunculus acris,* and others, most of them rarely eaten by grazing animals (see Figure 45). The resulting structure resembles patchy meadows or tall forb vegetation.

Table 15: Data on vegetation structure for the *Mentho longifoliae-Juncetum inflexi*

Total cover (n = 3)	mean +/- SD	99.3 % +/- 0.9 %
	min. - max.	98.0 % - 100.0 %
Share of relevés with *Salix cinerea*		33.3 % (1 relevé)
Shrub cover (n = 1)		15%
Shrub hight (n = 1)	mean	0.6 m
	max.	0.6 m
Average hight of herb layers (n = 3)	mean +/- SD	67 cm +/- 24 cm
	min. - max.	50 cm - 100 cm
Max. hight of herb layers (n = 3)	mean +/- SD	120 cm +/- 59 cm
	min. - max.	60 cm - 200 cm

The second, lower vegetation layer is characterized especially by creeping plant species such as *Ranunculus repens*, *Lysimachia nummularia* and *Potentilla reptans*. Generally, the studied vegetation type is characterized by high cover values of rushes (*Juncus inflexus*, *J. articulatus*), sedges (e.g. *Carex distans*, *C. hirta*, *C. filiformis*) as well as mint species (e.g. *Mentha longifolia*, *M. arvensis*), clearly displaying the wet site conditions. In one relevé, *Salix cinerea* is occurring with a cover value of 15 % (height 0.6 m).

Figure 45: *Mentho-Juncetum inflexi* stand with *Juncus inflexus* and *Lythrum salicaria* in the Great Meadow (Borșa commune, 06.08.2011)

The total cover of vascular plants is consistently high in all three plots and shows the highest mean value of all studied vegetation types (99.3 +/- 0.9 %, see also Table 4, page 61). The average and maximum height of the herb layers shows a wider variety of values: The average height lies between 50 cm and 100 cm, while the maximum height lies between 60 cm and 200 cm (see Table 15 for the mean values).

3.3.3.2 Syntaxonomy and diagnostic species

Class: *Molinio-Arrhenatheretea* Tx. 1937
Order: *Potentillo-Polygonetalia avicularis* Tx. 1947[a]
Alliance: *Potentillion anserinae* Tx. 1947[b]
Association: *Mentho longifoliae-Juncetum inflexi* Lohmeyer ex Oberdorfer 1957 nom. invers.[c]

Selected synonyms from Dierschke (2012) and Mucina et al. (2016):
[a] *Polygono-Potentilletalia anserinae* Tx. 1947 nom. invers. propos.; *Agrostietalia stoloniferae* Oberd. in Oberd. et al. 1967
[b] *Lolio-Potentillion anserinae* Tx. 1947; *Agrostion stoloniferae* Görs 1966; *Eu-Agropyro-Rumicion* Westhoff et Den Held 1969
[c] *Juncus inflexus-Mentha longifolia*-association Lohmeyer 1953

The nomenclature regarding the class, order and alliance follows Mucina et al. (2016), the nomenclature of the association follows Dierschke (2012).

The vegetation type described here has been identified as the association *Mentho longifoliae-Juncetum inflexi* Lohmeyer ex Oberdorfer 1957 nom. invers., due to the identification of two association character species as diagnostic species, namely *Juncus inflexus* and *Mentha longifolia* (see Table 16). *Mentha longifolia* is also diagnostic for the *Molinietum caeruleae* and the species is often found on abandoned arable land in the study area, too (see Figure 46).

Figure 46: *Mentha longifolia* in an abandoned arable near the Village Meadow (Dăbâca commune, 04.08.2009)

Table 16: Fidelity values and preferential occurrence in plant communities of selected diagnostic species of the *Mentho longifoliae-Juncetum inflexi*

	Juncus inflexus	***Mentha longifolia***	***Juncus articulatus***	***Ranunculus repens***
	Fidelity values: perc (class) *fid*			
Mentho-Juncetum	100 (V) *fid 91***	67 (IV) *fid 50***	100 (V) *fid 94***	100 (V) *fid 68***
Molinietum caeruleae	19 (I)	44 (III) *fid 27**	13 (I)	44 (III) *fid 20**
Calamagr. epigejos -comm.		20 (I)		40 (II)
Brachypodio-Molinietum		10 (I)		
Festuca pratensis- comm.				
Polygalo-Brachypodietum				
Cirsium furiens -comm.				6 (I)
Braun-Blanquet-values	5, 3, +	3, 1, 0	3, 2, +	4, +
Coldea et al. (2012), p. 214*ff.* : table of *Potentillion anserinae*	C **association** *Mentho longifoliae-Juncetum inflexi*	C **association** *Mentho longifoliae-Juncetum inflexi*	accompanying species	C **alliance** *Potentillion anserinae* / **order** *Potentillo-Polygonetalia*
Dierschke (2012), p. 57: table of *Mentho longifoliae-Juncetum inflexi*	C **association** *Mentho longifoliae-Juncetum inflexi*	D **association** *Mentho longifoliae-Juncetum inflexi*	D **subassociation in** wet locations	C **class** *Molinio-Arrhenateretea*

Perc = percentage frequency; class = frequency class; *fid* = statistical fidelity; C = character species; D = differential species; empty cells = zero. The Braun-Blanquet-values are indicated for the *Mentho longifoliae-Juncetum inflexi*. The fidelity measure is the phi-(Φ)-coefficient of association. Species with phi-coefficient values of at least 20 are considered diagnostic (indicated by fid* and yellow colour); species with phi-coefficient values of at least 45 are considered highly diagnostic (indicated by fid** and green colour).

The association *Mentho longifoliae-Juncetum inflexi* was first provisionally described by Lohmeyer (1953) as *Juncus inflexus-Mentha longifolia*-association in a single relevé. The sequence of the species names was switched later on because of the higher importance of *Juncus inflexus* as a character species for the association (Dierschke 2012).

Regarding the syntaxonomical placement of the association *Mentho-Juncetum inflexi*, this study follows the classification of Dierschke (2012), which is identical with the grouping by Coldea et al. (2012), except for the choice of the synonyms: The association is assigned to the order of flooded grasslands and communities of creeping plants *Potentillo-Polygonetalia avicularis*, with the single alliance *Potentillion anserinae*, usually within the class of agricultural grassland *Molinio-Arrhenatheretea* (Leuschner and Ellenberg 2017). An alternative assignment of the *Mentho-Juncetum inflexi* is made by Hájková et al. (2007) for the Czech Republic, who place the association within the wet and nutrient-rich meadows of the *Calthion palustris* Tx. 1937.

The following species of the alliance *Potentillion anserinae* occur with high fidelity values in this vegetation type: *Juncus articulatus* and *Ranunculus repens* (see Table 17). There is one diagnostic species from the class *Molinio-Arrhenatheretea*, *Ranunculus acris,* and several character species of the order of wet grasslands (*Molinietalia caeruleae*): *Mentha arvensis, Cirsium canum, Lythrum salicaria* and *Deschampsia cespitosa*.

Table 17: Selected diagnostic species of the *Mentho longifoliae-Juncetum inflexi* (12 from a total of 13)

Association character species	*Juncus inflexus, Mentha longifolia*
Potentillion anserinae	*Juncus articulatus, Ranunculus repens*
Molinietalia caeruleae / Mol.-Arrhenatheretea	*Mentha arvensis, Cirsium canum, Lythrum salicaria, Deschampsia cespitosa, Ranunculus acris*
Magnocaricion gracilis / Magnocaricion elatae	*Carex vulpina, Carex riparia, Epilobium palustre*

Also worth mentioning is a certain resemblance between the *Mentho-Juncetum inflexi* and tall forb communities, especially where *Mentha longifolia* dominates (Sýkora 1982; Dierschke and Briemle 2008), see also the classification of the *Mentho longifoliae-Juncion inflexi* T. Müller et Görs ex de Foucault 2009 into an order of tall-herb wet meadow fringe vegetation by Mucina et al. (2016).

It is interesting to notice that *Agrostis stolonifera*, which in both phytosociological tables of Dierschke (2012) and Coldea et al. (2012) occurs as an alliance character species with high frequency values (classes IV and V), is missing from the three relevés classified here as *Mentho-Juncetum*. To check this peculiarity and to verify the diagnostic species and species composition of the *Mentho-Juncetum* in general, more relevés of this vegetation type need to be made in the hay meadows.

Finally, there are four diagnostic species which occur only in this vegetation type, each only in one relevé. They are characteristic species of the alliance *Magnocaricion gracilis* / *Magnocaricion elatae* (*Carex vulpina, Carex riparia* and *Epilobium palustre*) and the alliance *Senecionion fluviatilis* (*Epilobium hirsutum*).

3.3.3.3 Environmental and ecological conditions

The three analysed relevés have only a slight inclination (median: 0°), which indicates the occurrence of this vegetation type in flat areas within the hill slope. One relevé occurs next to a watering place for sheep as well as a path. This corresponds to the fact that the two most important ecological factors forming the *Mentho-Juncetum inflexi* are temporal waterlogging and disturbance by trampling or mechanical soil compaction (Dierschke and Briemle 2008; Dierschke 2012).

The Ellenberg indicator value for soil moisture M = 6.8 ± 0.3 (unweighted) for the studied relevés is the second highest value after the *Caricetum vesicariae* and reflects the favoured occurrence of species that grow in moist locations, often with strongly fluctuating groundwater and waterlogging (Dierschke and Briemle 2008).

The unbalanced water and air regime can be caused, for example, by flooding (e.g. of soil depressions) during high water, after rainfall, or by waterlogging. The fluctuation between limnic and terrestrial phases during the dry summer is typical for locations with *Potentillion anserinae* communities (Dierschke 2012). From the 13 diagnostic species of this vegetation type, eight species are indicators for alternating soil moisture: *Mentha longifolia, Ranunculus repens, Carex hirta, Mentha arvensis, Cirsium canum,* *Lysimachia vulgaris, Lythrum salicaria* and *Deschampsia cespitosa* (Dierschke and Briemle 2008).

The Ellenberg indicator value for nutrient availability N = 4.3 ± 0.4 (unweighted) of the three analysed relevés is the second highest value after the *Caricetum vesicariae* and reflects the favoured occurrence of species that grow in places with a moderate nitrogen supply (Dierschke and Briemle 2008). One reason for the higher nitrogen value than in most of the other studied plant communities could be nutrient input from grazing livestock.

The flooded grasslands of the *Potentillion anserinae* alliance often have various contact communities and undergo frequent spatio-temporal changes within their own community, but also in regards to the neighbouring communities (Dierschke 2012). In the studied meadows, the *Mentho-Juncetum inflexi*-stands are often found adjacent to *Molinietum caeruleae*-stands (see Figure 47).

Figure 47: *Mentho-Juncetum inflexi* stand (image centre) adjacent to an *Iris sibirica* dominance stand (on the right) and a *Molinietum caeruleae* stand (on the left) in the Village Meadow (Dăbâca commune, 06.08.2011)

3.3.3.4 Occurrence of the plant community in the study hay meadows

The three relevés of the *Mentho-Juncetum inflexi* were made in the Lord's Meadow (n = 1) and the Village Meadow (n = 2) (see Figure 36 and Figure 37, page 55). In general, the community occurred on rather small areas, and the surface of the *Mentho-Juncetum inflexi* was distinctly smaller than that of the *Molinietum caeruleae*-stands.

However, one of the factors promoting the characteristic species of flooded grasslands, soil disturbance by trampling, has increased since the relevés were made in 2009. Specific studies could reveal the present extent and distribution of the *Mentho-Juncetum inflexi* in all three hay meadows.

3.3.3.5 Occurrence of the plant community in Romania

According to Coldea et al. (2012), the *Mentho-Juncetum inflexi* is reported for several colline and montaneous zones in Romania on pond edges and brook sides. Both Coldea et al. (2012) and Sanda et al. (2008) give no more exact indications about the geographical distribution of the association. Pop et al. (1999-2000) do not mention the association at all in their overview about the vegetation of the County Cluj.

However, there are several regional and local studies which cover the *Mentho-Juncetum inflexi*, also for the region of this study. One example is the work about the flora and vegetation of the river *Someș* by Drăgulescu and Macalik (1999), who mention the association for the sector of the river *Someș Mic* between Gilău and Dej, which runs near the eastern border of Dăbâca commune (see Chapter 2.1).

Karácsonyi (2011) lists the association in his doctoral thesis about the flora and vegetation of the Hills of Tășnad (Counties Satu Mare, Bihor and Sălaj) in North-Western Romania, where it is apparently rather widespread. As the most frequent species he indicates *Juncus inflexus*, *Mentha longifolia*, *Ranunculus strigulosus*, *Angelica sylvestris*, *Caltha palustris*, *Scirpus sylvaticus* and *Symphytum officinale*.

Other examples of studies including the *Mentho-Juncetum inflexi* are located in North-Eastern Romania: for example, Blaj-Irimia (2008) studied the *Mentho-Juncetum inflexi* and three other associations of the *Molinio-Arrhenatheretea* in the *Vaslui* river basin (Vaslui County). Besides *Mentha longifolia* and *Juncus inflexus*, she mentions *Agrostis stolonifera*, *Inula britannica*, *Potentilla reptans* and *Ranunculus repens* as frequent species.

3.3.3.6 Conservation value and protection status

On the European red list of habitats by Janssen et al. (2016), moist or wet eutrophic and mesotrophic grasslands (code E3.4 a/b) are indicated as endangered. However, the *Mentho-Juncetum inflexi* is not included in Annex I of the EU Habitats Directive (Council of the European Communities 2013) and Doniţă et al. (2005) indicate a reduced conservative value for the corresponding habitat type in Romania.

The *Mentho-Juncetum inflexi*-relevés considered in this study contain no vascular plant species of national conservation concern.

3.3.4 *Molinietum caeruleae* Koch 1926

Vegetation type: Wet meadows of oligotrophic habitats

Names:

English: *Molinia* meadow (on calcareous soils), moor grass meadow
Romanian: Pajiște de *Molinia,* pajiște de iarbă albastră
German: Pfeifengras-Wiese

Information relevés:

Number: 16
Type, size, year: 14 phytosociological relevés, 25 m^2, 2009
2 diversity-relevés, 10 m^2, 2013
Surveyors: 5 different persons / teams

Locations:

Dăbâca: Lord's Meadow (10), Village Meadow (3), Meadow Hill (1)
Borșa: Great Meadow (2)

3.3.4.1 Structure and species composition

The following descriptions are based on 16 relevés carried out in the years 2009 and 2013 in four different meadows. The surveyed parameters of vegetation structure are shown in Table 18. The vegetation type is characterized by three herb layers: a high upper layer of around 2 m dominated by the tall growing *Molinia arundinacea*, followed by a second, middle layer which is characterized by a large number of forb species such as *Cirsium canum*, *Lysimachia vulgaris*, *Lythrum salicaria*, *Iris sibirica*, *Centaurea phrygia* and *Serratula tinctoria* as well as grass and sedge species such as *Agrostis stolonifera*, *Deschampsia cespitosa* and *Carex hirta* (see Figure 48).

Table 18: Data on vegetation structure for the *Molinietum caeruleae*

Total cover (n = 14)	mean +/- SD	98.9 % +/- 1.5 %
	min. - max.	95.0 % - 100.0 %
Share of relevés with *Crataegus monogyna*		38 %
Share of relevés with *Salix cinerea*		6 %
Share of relevés with *Cornus sanguinea*		6 %
Shrub cover (n = 1)		5%
Shrub hight (n = 1)	mean	0.5 m
	max.	0.7 m
Max. hight of herb layers (n = 6)	mean +/- SD	188 cm +/- 26 cm
	min. - max.	130 cm - 200 cm

The calculation of the maximum height of the herb layers is based on the data for only 6 out of 16 relevés, therefore the result should be considered preliminary. The values are relatively high due to the occurrence of many tall-growing species, not least the dominant *Molinia arundinacea*: the maximum height is 188 cm +/- 26 cm, ranging between 130 cm and 200 cm.

Figure 48: Upper and middle layer of a *Molinietum caeruleae* stand with *Molinia arundinacea, Lythrum salicaria, Lysimachia vulgaris* and *Sanguisorba officinalis* in the Village Meadow (Dăbâca commune, 29.07.2010)

Figure 49: Structure of a *Molinietum caeruleae* stand in the Village Meadow with *Molinia arundinacea, Cirsium canum, Lythrum salicaria,* etc. (Dăbâca commune, 03.08.2010)

The third, low herb layer consists mainly of forb species such as *Stachys officinalis, Galium boreale, Galium mollugo, Achillea millefolium, Ononis spinosa* subsp. *hircina* and the leaves of *Filipendula vulgaris* and *Sanguisorba officinalis*, as well as the sedge species *Carex filiformis* and *Carex distans* (see Figure 49).

The total cover of vascular plants is the second-highest of the studied vegetation types, with an average of 98.9 % ± 1.5 % and a range between 95 % and 100 % (surpassed only by the *Mentho-Juncetum* with 99.3 % ± 0.9 %). In seven of 16 relevés, phanerophytes are occuring (*Crataegus monogyna*, *Salix cinerea* and *Cornus sanguinea*), but only in one relevé are the *Crataegus monogyna* specimen taller than 0.5 m and thus attributed to the shrub layer (see Table 18).

Most of the relevés have been made in the Dăbâca meadows (13 of 16), especially the Lord’s meadow (10). Thus, the information about this vegetation type in the Village Meadow and the Great Meadow is incomplete and should be complemented by future studies.

3.3.4.2 Syntaxonomy and diagnostic species

Class:	*Molinio-Arrhenatheretea* Tx. 1937
Order:	*Molinietalia caeruleae* Koch 1926[a]
Alliance:	*Molinion caeruleae* Koch 1926[b]
Association:	*Molinietum caeruleae* Koch 1926[c]

Selected synonyms:

[a] *Molinietalia* Rübel 1933, *Deschampsietalia cespitosae* Horvatić 1958

[b] *Juncion acutiflori* Br.-Bl. in Br.-Bl. et al. 1947, *Eu-Molinion* Doing 1963, *Serratulo-Molinion* Doing 1963

[c] *Allio suaveolentis-Molinietum* Görs ex Oberdorfer 1983, *Iridetum sibiricae* Philippi 1960, *Molinietum medioeuropaeum* Oberdorfer 1957

The nomenclature and selected synonyms regarding the class, order, and alliance come from Mucina et al. (2016); the nomenclature and selected synonyms for the association were taken from Burkart et al. (2004).

The assignment of the vegetation type described here to the association *Molinietum caeruleae* Koch 1926 was made due to the close concordance of the diagnostic species found with the order, alliance and association character species described in literature (see next chapter) as well as based on the considerations listed further below.

3.3.4.2.1 Diagnostic species

There are two diagnostic species which are considered character species for the association *Molinietum caeruleae* Koch 1926**,** as well as the alliance *Molinion caeruleae* Koch 1962 (see Table 19). The first is *Iris sibirica* (see Figure 50), which is diagnostic for this vegetation type only. This species indicates fallow or late mown stands of the *Molinietum caeruleae* (Burkart et al. 2004). The second species, *Gentiana pneumonanthe,* is diagnostic for both this vegetation type and the

Brachypodio-Molinietum arundinaceae, similar to *Molinia arundinacea* (see Table 19 and Figure 51).

Table 19: Fidelity values and preferential occurrence in plant communities of selected diagnostic species of the *Molinietum caeruleae*

		Iris sibirica	***Gentiana pneumonanthe***	***Molinia arundinacea***	***Succisa pratensis***	***Plantago altissima***
		Fidelity values: perc (class) *fid*				
	Molinietum caeruleae	44 (III) *fid 51***	56 (III) *fid 41**	100 (V) *fid 62***	13 (I) *fid 34**	13 (I) *fid 34**
	Calamagr. epigejos -comm.	10 (I)		30 (II)		
	Brachypodio-Molinietum	10 (I)	50 (III) *fid 35**	80 (IV) *fid 46***		
	Festuca pratensis- comm.		25 (II)			
	Polygalo-Brachypodietum		3 (I)	3 (I)		
	Cirsium furiens- comm.			6 (I)		
	Braun-Blanquet-values	2,1,+	1,+,r	5,4,3,+	+	+
Romania	Coldea et al. (2012), p. 194 *ff.* : table *Filipendulion, Calthion* & *Molinion*	C **alliance** *Molinion caeruleae*	C **alliance** *Molinion caeruleae*	*M. caerulea* : C **alliance** *Molinion caeruleae*	C **order** *Molinietalia caeruleae*	-
Romania	Boşcaiu et al. (1964), p. 244-245: table *Molinietum caeruleae*	-	**association** *Molinietum caeruleae*	*Molinia caerulea* : **association** *Molinietum caeruleae*	**alliance** *Molinion caeruleae*	-
Romania	Resmeriţă (1969), p. 47-48: table *Molinietum caeruleae*	-	**association** *Molinietum caeruleae*	*Molinia caerulea* : **association** *Molinietum caeruleae*	**alliance** *Molinion caeruleae*	-
Romania	Boşcaiu (1965), p. 256-259, table *Peucedano rocheliani-Molinietum caeruleae*	**association** *Peucedano-Molinietum caeruleae*	**association** *Peucedano-Molinietum caeruleae*	*Molinia caerulea* : **association** *Peucedano-Molinietum caeruleae*	**alliance** *Molinion caeruleae*	-
Czech Republic / White Carpathians	Hájková et al. (2007), p. 210/211: *Molinietum caeruleae*	-	-	s. lat.: diagnostic, highly constant, highly dominant	diagnostic, constant	-
Czech Republic / White Carpathians	Havlová (2006), p. 93-95: diagnostic species in synoptic table of *Molinion caeruleae*	**association** *Molinietum caeruleae*	-	*M. caerulea* agg: **alliance** *Molinion caeruleae*	**alliance** *Molinion caeruleae*	-
Czech Republic / White Carpathians	Škodová et al. (2008), p.175-176: *Molinietum caeruleae*	occurs in *Molinietum caeruleae*	diagnostic	diagnostic, constant, dominant	-	-
Germany	Burkart et al. (2004), p. 78 *ff.* : table *Molinion caeruleae*	C **association** *Molinietum caeruleae* + C **alliance** *Molinion caeruleae*	C **association** *Molinietum caeruleae* + C **alliance** *Molinion caeruleae*	*M. arundinacea* ? / *M. caerulea* agg.: D **alliance** *Molinion caeruleae*	D / regional C **alliance** *Molinion caeruleae*	in text p. 48: C **alliance** *Deschampsion cespitosae*

Perc = percentage frequency; class = frequency class; fid = statistical fidelity; C = character species; D = differential species; empty cells = zero. The Braun-Blanquet-values are indicated for the *Molinietum caeruleae*. The fidelity measure is the phi-(Φ)-coefficient of association. Species with phi-coefficient values of at least 20 are considered diagnostic (indicated by fid* and yellow colour); species with phi-coefficient values of at least 45 are considered highly diagnostic (indicated by fid** and green colour).

Gentiana pneumonanthe is described by some Romanian authors as a character species of the acidophilous *Junco-Molinietum* (Borza and Raţiu 1970; Gergely et al. 1988). However, the Ellenberg indicator value for soil reaction is specified as 'indifferent' (x) by Rothmaler (2005) and 6 by Borhidi (1995), the latter indicating medium, slightly acidic to neutral sites (Dierschke and Briemle 2008). Furthermore, *Gentiana pneumonanthe* is often named as diagnostic species for the basiphilous

Molinietum caeruleae, for example in Romania by Boşcaiu et al. (1964) and Resmeriţă (1969), as well as in the White Carpathians by Škodová et al. (2008) (see Table 19).

Figure 50: *Iris sibirica* and *Filipendula vulgaris* in a *Molinietum caeruleae* stand in the Lord's Meadow (Dăbâca commune, 04.06.2011)

Figure 51: *Gentiana pneumonanthe* and *Serratula tinctoria* in a *Molinietum caeruleae* stand in the Lord's Meadow (Dăbâca commune, 13.08.2013)

Three diagnostic species are considered differential or character species for the alliance *Molinion caeruleae* (see Table 19). The first, *Molinia arundinacea*, is highly diagnostic for both this vegetation type and the *Brachypodio-Molinietum arundinaceae* (see Figure 52). It is important to emphasize that from the species aggregate of *Molinia caerulea,* only *Molinia arundinacea* occurs in the studied hay meadows, and not *Molinia caerulea*. *Molinia arundinacea* often occurs on rather alkaline substrate (Ellenberg 1996) and in drier grassland types (intermittently wet to intemittently dry up to semi-dry) than *Molinia caerulea* (Rothmaler 2005; Budzhak et al. 2016).

Figure 52: *Molinia arundinacea* and *Lythrum salicaria* in the Lord's Meadow (Dăbâca commune, 03.08.2009)

The second species is *Succisa pratensis* (see Table 19), which has a high diagnostic value for the *Molinietum caeruleae* according to Burkart et al. (2004), although it is only a differential species with distribution priorities in other alliances as well. The third species, *Plantago altissima,* which can reach a height of up to 80 cm (Ciocârlan 2000), occurs only in two *Molinietum caeruleae*-relevés. There are several studies (e.g. Zelnik and Čarni 2013 for Slovenia, Biondi et al. 2023 for Italy) which place *Plantago altissima* into the *Molinion caeruleae*. However, it can also be a character species of the river valley meadows of the *Deschampsion cespitosae* (see Table 19).

It is interesting that several species which often belong to the character species of the *Molinion caeruleae,* and indeed do occur in many vegetation types in the study area, are not diagnostic of the vegetation type described here (see also Chapter 3.3.4.3). *Serratula tinctoria,* for example, is diagnostic for the *Brachypodio-Molinietum* and the

Calamagrostis epigejos-community, but not for the *Molinietum caeruleae* (constancy class III). *Galium boreale* and *Carex filiformis* occur in most of the vegetation types and are diagnostic for some of them, but not for the *Molinietum caeruleae* (constancy class II). Finally, *Stachys officinalis* occurs (non-diagnostic) in most of the described vegetation types with a high constancy class (V or IV), including the *Molinietum caeruleae*.

The largest diagnostic species group of the local *Molinietum caeruleae*, comprising nine species, is the group of character species for wet meadows of the order *Molinietalia caeruleae* (see Table 20). Many of these species are tall forbs. *Sanguisorba officinalis*, the host species for *Phengaris nausithous* and *Phengaris teleius* (see Figure 53), belongs to this group. It occurs in all identified plant communities, except the *Caricetum vesicariae* and the *Danthonio-Stipetum,* and is diagnostic for the *Molinietum caeruleae* and the *Festuca pratensis*-community.

Table 20: Diagnostic species of the *Molinietum caeruleae* (total n = 19)

Association character species	*Iris sibirica, Gentiana pneumonanthe*
Molinion caeruleae	*Molinia arundinacea, Succisa pratensis, Plantago altissima*
Molinietalia caeruleae	*Sanguisorba officinalis, Cirsium canum, Lysimachia vulgaris, Lythrum salicaria, Thalictrum flavum, Equisetum telmateia, Juncus effusus, Deschampsia cespitosa, Colchicum autumnale, Trifolium hybridum*
Potentillion anserinae	*Potentilla reptans, Inula britannica, Agrostis stolonifera, Mentha pulegium*

Another *Molinietalia*-species is *Cirsium canum*, which is distributed in Europe and Western Siberia and has a Pannonic-Pontic center of geographic range (FloraWeb 2000-) (see Figure 53). The species occurs with consistency class V or IV in the four studied vegetation types with the highest soil moisture: The *Molinietum caeruleae*, the *Calamagrostis epigejos*-community, the *Mentho-Juncetum inflexi* and the *Caricetum vesicariae*.

Havlová (2006) classify *Cirsium canum* as a diagnostic species for the *Molinietum caeruleae* var. *Bromus erectus* in the Czech Republic, and in the White Carpathians it is also regarded as diagnostic (Škodová et al. 2008). An interesting aspect regarding *Cirsium canum* is raised by Wagner (1950), who found several examples of vicarious character species in the *Molinietum careuleae* throughout Europe. For example, *Cirsium canum* in the Pannonian variant of the *Molinietum caeruleae* replaces *Cirsium tuberosum* in the Central European variant of the association.

Within the *Molinietalia*, the diagnostic species *Lysimachia vulgaris, Lythrum salicaria,* and *Thalictrum flavum* have their main occurrence in the *Molinion caeruleae* and *Deschampsion cespitosae* (Dierschke 2012), and are also linked to tall-herb fringe communities. The diagnostic species *Equisetum telmateia* is a character species of the *Filipendulion ulmariae* as well (Rothmaler 2005). Furthermore, there are some references of its occurrence in *Molinia*-communities: For instance, *Equisetum telmateia* is a diagnostic species in a *Molinia arundinacea*-community in abandoned haymeadows in SW-Ukraine (Budzhak et al. 2016).

Buchwald (1996) mentions this species in his study of the *Molinietum caeruleae* in a region of SW-Germany as a tall-herb species of moist habitats, which can increase in abandoned *Molinietum caeruleae*-stands. In the analysed dataset, *Equisetum telmateia* occurs only in three *Molinietum*-relevés.

Further *Molinietalia*-species diagnostic for this vegetation type are *Juncus effusus, Deschampsia cespitosa, Colchicum autumnale,* and *Trifolium hybridum* (latter following Resmeriţă 1969 and Boşcaiu 1965). Finally, the following four diagnostic species are characteristic species of flooded grasslands (*Potentillion anserinae*), although they are diagnostic only for this vegetation type in the analysed dataset: *Potentilla reptans*, *Inula britannica, Agrostis stolonifera,* and *Mentha pulegium.*

Figure 53: *Sanguisorba officinalis, Cirsium canum* and *Lythrum salicaria* in a *Molinietum caeruleae* stand in the Great Meadow (Borșa commune, 23.08.2019)

3.3.4.2.2 *Molinietum caeruleae* and *Junco-Molinietum*

In most of the European literature about the alliance *Molinion caeruleae*, two major groups are indicated; those dominated by calcicole, and those dominated by calcifuge species (Hájková et al. 2007; Leuschner and Ellenberg 2017).

One of the most important associations on calcareous soils is the *Molinietum caeruleae* Koch 1926. It is the central association of the *Molinion caeruleae* (sensu Dierschke 1994 and Dengler 2003) because the association character species correspond to the alliance characters species. The *Molinietum caeruleae* is often species-rich and characterized by species like *Serratula tinctoria*, *Stachys officinalis*, *Carex filiformis*, *Gentiana pneumonanthe*, *Sanguisorba officinalis*, *Iris sibirica* and *Cirsium tuberosum* (Burkart et al. 2004; Hájková et al. 2007; Leuschner and Ellenberg 2017). In Germany, it occurs especially on base-rich fen soils in the montane and submontane level (Dierschke and Briemle 2008).

Opposite to this is the *Junco effusi-Molinietum caeruleae* Tüxen 1954: an acid, species-poor community with *Molinia caerulea* agg., which developed in place of birch swamp forests and damp birch-oak forests (Hájková et al. 2007; Leuschner and Ellenberg 2017). Even if the synsystematic position of the *Junco-Molinietum* is sometimes contested, as it lacks many or even all character species of the *Molinion* alliance (Leuschner and Ellenberg 2017), its existence has been confirmed by several recent vegetation classifications, for example in the Czech Republic (Havlová 2006; Hájková et al. 2007).

3.3.4.2.3 Mismatch with current Romanian *Molinion* syntaxonomy

The most recent phytosociological synopses of Romanian vegetation by Coldea et al. (2012) and Sanda et al. (2008) do not indicate the *Molinietum caeruleae* Koch 1926 for Romania, but include the vegetation stands described as such by other authors into the *Junco effusi-Molinietum caeruleae* Tüxen 1954, stating there would be no major differences in structure between the recorded relevés (Coldea et al. 2012). However, there are several descriptions of the *Molinietum caeruleae* in Romania, most of them dating from the 1950s to 1980s (see Chapter 3.3.4.5.4).

Coldea et al. (2012) describe the *Junco-Molinietum* for the north and central part of Romania as growing on acid substrate and brown gleyic, sometimes marsh soils. They do not name specific association character species. However, from their phytosociological table of the *Molinietalia caeruleae*, a higher frequency class of *Juncus conglomeratus* and *Nardus stricta* is apparent.

Sanda et al. (2008) indicate *Juncus conglomeratus* and *Juncus effusus* as characteristic species for the *Junco-Molinietum* alongside the dominant *Molinia caerulea*. Furthermore, many species of the *Arrhenatheretalia* and *Molinio-Arrhenatheretea* would occur in the association, like *Festuca rubra*, *Rhinanthus angustifolius*, *Plantago lanceolata*, *Stellaria graminea*, *Leucanthemum vulgare*, *Agrostis capillaris* and *Jacobaea vulgaris*.

Considering the characteristics of the *Junco effusi-Molinietum caeruleae* described for Romania, it can be safely stated that the *Molinion*-vegetation type described here does not belong to this association due to the following reasons:

- The occurrence on base-rich soils
- The missing indicator species for the *Junco-Molinietum* (like *Juncus conglomeratus*, *Nardus stricta*; *Juncus effusus* in only two relevés with cover values less than 5 % resp.1 %)
- The presence of calcicole species like *Galium boreale, Carex filiformis, Thalictrum flavum, Equisetum telmateia*

The above-mentioned points instead support an assignment to the *Molinietum caeruleae* or to another association characterised by calcicole species. The relatively low frequency values of some typical *Molinion* character species in the *Molinietum caeruleae* described here, like *Galium boreale*, *Carex filiformis,* and *Serratula tinctoria* (see Chapter 3.3.4.2.1), is presumably explained by the management of the stands (late or no mowing), which is also indicated by the high cover values of *Molinia arundinacea*, and does not speak per se against the assignment to the *Molinietum caeruleae*.

3.3.4.2.4 Associations with *Molinia arundinacea*

If one wants to find parallels between the analysed vegetation type and the already described associations or their subtypes in European literature, a similarity to communities with *Molinia arundinacea* is apparent.

One example is an association of the summerwarm lowlands of SW-Germany and the Upper Rhine Valley named *Cirsio tuberosi-Molinietum arundinaceae* Oberd. et Phil. ex Görs 1974 (Oberdorfer 1993; Burkart et al. 2004), with similarities and differences to the vegetation type described here:

- From the *Molinia caerulea* species aggregate, normally *Molinia arundinacea* is the dominant species (like in the study hay meadows).
- One of the other character species is *Cirsium tuberosum*, which, according to Wagner (1950), is the vicariant character species of *Cirsium canum* (diagnostic in the *Molinietum caeruleae* described here). However, *Cirsium tuberosum* is also a character species of the semi-dry *Bromion erecti* Koch 1926, while *Cirsium canum* is more restricted to wet *Molinietalia*-meadows (Rothmaler 2005). Another character species, *Lotus maritimus*, does occur in the study hay meadows, but was not diagnostic for any of the vegetation types.
- The *Cirsio-Molinietum arundinaceae* connects to the semi-dry grasslands of the *Bromion erecti* and contains character species of the class *Festuco-Brometea*, like *Bromus erectus* and *Brachypodium pinnatum* (Burkart et al. 2004). In the study area, the *Molinietum caeruleae* is embedded in a matrix of semi-dry *Cirsio-Brachypodio*-grassland, but does not contain *Festuco-Brometea*-species to a

significant extent (unlike the *Brachypodio-Molinietum arundinaceae* described in Chapter 3.3.6).

- Many of the German *Cirsio-Molinietum arundinaceae*-relevés are stands with dominating *Molinia caerulea* agg., which are no longer mowed or are used as litter meadows (Burkart et al. 2004; Dierschke and Briemle 2008); in the study meadows the stands are also dominated by *Molinia arundinacea* and at least semi-abandoned.
- The *Cirsio-Molinietum arundinaceae* has a Southwest-Central European distribution (Balátová-Tuláčková 1987), and has been described for summerwarm lowlands (Dierschke and Briemle 2008). The soils are clayey, intermittently wet (like the soils of the studied meadows) and only moderately humous (Dierschke and Briemle 2008) (unlike the soils of the studied meadows).

Interestingly, Balátová-Tuláčková (1987) describe a vicariant association of the *Cirsio-Molinietum arundinaceae*, namely the *Gentiano pneumonanthis-Molinietum litoralis* Ilijanić 1968, which has a subcontinental-submeditarranean distribution (Balátová-Tuláčková and Hájek 1998). This association shows a similar structure and can also be found on intermittently wet, summerwarm slopes or alluvial soils (Balátová-Tuláčková 1987). It has been identified in Croatia (Ilijanić 1968), Austria (Kuyper et al. 1978; Balátová-Tuláčková 1987; Ellmauer and Mucina 1993), the Czech Republic (Balátová-Tuláčková 1993; Balátová-Tuláčková and Hájek 1998) and Slovakia (Balátová-Tuláčková 1993).

According to Ilijanić (1968), who first described the association from Northeastern Croatia, the differences between the *Gentiano-Molinietum litoralis* and the Central European *Molinietum caeruleae* are the occurrence of *Molinia arundinacea* (= *M. litoralis*) instead of *Molinia caerulea* and of several other species like *Genista tinctoria*, *Rhinanthus rumelicus,* or *Clematis integrifolia*, which do not occur in the Central European *Molinietum caeruleae.* On the other hand, species of fen and bog hollow communities (*Scheuchzerio-Caricetea nigrae*), which do often occur in the Central European *Molinietum caeruleae*, would be missing in the *Gentiano-Molinietum litoralis.* Character species of this association would be, for example, *Selinum carvifolia*, *Laserpitium prutenicum* and *Peucedanum cervaria* (Ilijanić 1968).

For the southwest of Ukraine, a recent syntaxonomical analysis of communities with *Molinia caerulea* s. lat. by Budzhak et al. (2016), which considered the differences between *Molinia caerulea* and *Molinia arundinacea*, has resulted in nine clusters, such as the *Junco-Molinietum* Tüxen 1954 and the *Brachypodio pinnati-Molinietum arundinacea* Klika 1939. Fifteen relevés have been assigned to a rank-free community with *Molinia arundinacea* within the *Molinion*, for which no analogues to previously described associations have been found (Budzhak et al. 2016).

According to Budzhak et al. (2016), the stands were abandoned, species-rich hay meadows in the colline-submontane level, which developed under the influence of regular mowing and replaced communities of beech and oak forests. They bordered on meadow communities of the *Arrhenatherion elatioris* alliance. Diagnostic species were, for example, *Laserpitium latifolium*, *Dianthus membranaceus*, *Peucedanum oreoselinum*, *Adenophora liliifolia*, *Equisetum telmateia*, *Stachys officinalis*, *Sanguisorba officinalis* and *Lysimachia vulgaris* (Budzhak et al. 2016).

3.3.4.2.5 Narrow or broad definition of the *Molinietum caeruleae*

There are two main approaches with which different authors deal with the classification of the *Molinion caeruleae*. One option is that used by Burkart *et al.* (2004) in Germany, where a broadly defined association concept where all *Molinion* stands are summarized to a single association, the *Molinietum caeruleae*, is used (in this case excluding the relevés assigned to the *Junco effusi-Molinietum* by other authors). The *Molinietum caeruleae* is then subdivided into subtypes, like subassociations, geographical races, altitudinal forms, or land use-related subunits (Oberdorfer 1993; Burkart et al. 2004; Dierschke and Briemle 2008).

A similar approach is described for the Czech Republic, where the analysis of the Czech National Phytosociological Database identified only the two associations *Junco effusi-Molinietum caeruleae* Tüxen 1954 and *Molinietum caeruleae* Koch 1926 (Havlová 2006; Hájková et al. 2007), latter with *Molinia caerulea* and *M. arundinacea* (Hájková et al. 2007). The *Molinietum caeruleae* was subdivided into three variants, of which one is a variant with *Bromus erectus*. This variant includes species of the *Bromion erecti*, *Cirsio-Brachypodion pinnati,* and *Arrhenatherion elatioris* alliances and is found in the driest sites. Examples of diagnostic species for this variant are *Bromus erectus*, *Cirsium canum, Dactylis glomerata,* and *Inula salicina* (Hájková et al. 2007).

The second approach is to describe a larger number of associations, for example in the Czech Republic before the national vegetation classification (10 associations, see Havlová 2006) or in Austria, where nine associations of the *Molinion* alliance are listed (Ellmauer and Mucina 1993); the same was reported in Slovakia (Havlová 2006).

According to Havlová (2006), the large number of associations emerge because the associations are often distinguished by a high cover of some species, but the diagnostic species often overlap and the variability in species composition among the associations is very small. For example, the *Galio borealis-Cirsietum cani* Balátová-Tuláčková 2001 would only be characterized by a high cover of *Cirsium canum* (Havlová 2006).

Similarly, Havlová (2006) and Hájková et al. (2007) assign the *Gentiano pneumonanthis-Molinietum litoralis*-relevés in the Czech Republic to the *Molinietum caeruleae*, because the species composition would not differ between the associations. The same pattern can be found for the White Carpathians: Balátová-Tuláčková and Hájek (1998) speak of the *Gentiano-Molinietum litoralis* in their paper about the wet vegetation communities in the Southern White Carpathians, while in the book about the White Carpathian grasslands only the *Molinietum caeruleae* is named, although with *Molinia arundinacea* (Škodová et al. 2008).

The vicariant association from Southwestern Germany, the *Cirsio tuberosi-Molinietum arundinaceae*, is also not recognized by some authors, e.g. Burkart et al. (2004).

Instead, it is placed in the rank of a subassociation of the *Molinietum caeruleae (cirsietosum tuberosi*), since the character species *Cirsium tuberosum* and *Lotus maritimus* would occur with the same constancy in semi-dry grasslands (Burkart et al. 2004).

Based on these considerations, the broad association concept is applied in this thesis as well, and the vegetation type studied is assigned to the *Molinietum caeruleae* Koch 1926, with the note that only *Molinia arundinacea* is present from the *Molinia caerulea* species aggregate.

3.3.4.3 Environmental and ecological conditions

For half of the relevés, information about the exposition has been collected; most of these relevés are north-facing (six of eight). Other cardinal directions are north-northeast and northwest (see Table 9, page 64). The stands have only a slight inclination (median: 1.5°), which indicates that the vegetation type is found on flat parts within the hillslope (see Table 8, page 64).

The unweighted Ellenberg indicator value for nutrient availability N = 4.0 ± 0.3 for this vegetation type (see Table 3, page 57) reflects the occurrence of species that grow on moderately N-rich sites, but only rarely on N-poor sites (Schulze et al. 2002).

The occurrence on soils with low nitrogen availability is a general feature of *Molinion* meadows (Leuschner and Ellenberg 2017). The reasons are low-intensity management with or without low fertilizer supply, as well as waterlogging of the soil and drying-out of the topsoil in summer, which lead to temporarily inhibited or even interrupted decomposition of organic matter, and thus an irregular mineralization (Buchwald 1996). The annual net nitrogen mineralization for *Molinietum caeruleae* sites is indicated by Dierschke and Briemle (2008) with 0-40 kg N / ha. The dry matter productivity is very variable and ranges from approximately 25 to 60 dt / ha (Dierschke and Briemle 2008).

In general, not only the supply of nitrogen, but also of potassium can be insufficient on *Molinion* sites (Buchwald 1996), and *Molinion* character species generally have low leaf concentrations of nitrogen, phosphorus, and potassium (Leuschner & Ellenberg 2017).

The Ellenberg indicator value for soil moisture M = 5.5 ± 0.4 (unweighted) for the studied *Molinietum caeruleae* relevés reflects the occurrence of species that grow in damp locations (Dierschke and Briemle 2008). Dierschke and Briemle (2008) list an Ellenberg indicator value for soil moisture of 6 to 7 for *Molinion* meadows, which reflects moist conditions, while the value of 5.5 corresponds to the moderately moist *Arrhenatherion* meadows.

In the study meadows, the sites of the *Molinietum caeruleae* are characterized by periodic waterlogging or even standing water, the latter occurring especially during the period with the highest precipitations in late spring and early summer. During late summer, in turn, the sites can dry out completely. A high variability of water supply is generally found in *Molinia* grasslands on marl (Leuschner and Ellenberg 2017).

Accordingly, around half of the species (ten) from the 19 diagnostic species for this vegetation type are indicators for alternating soil moisture: *Molinia arundinacea*, *Sanguisorba officinalis, Cirsium canum, Lysimachia vulgaris, Lythrum salicaria, Thalictrum flavum, Deschampsia cespitosa, Colchicum autumnale, Agrostis stolonifera* and *Ranunculus repens* (Ellenberg et al. 2001).

There are several indications that suggest that the studied *Molinietum caeruleae* stands show several characteristics of sporadical, late and / or abandoned mowing. First, the cover values of *Molinia arundinacea* are high: in three-quarters of 16 relevés the cover values are 50 % or higher (Braun-Blanquet value 4 or 5), of which again seven relevés feature a *Molinia arundinacea* cover of 75 % or higher (Braun-Blanquet value 5). The longer the process of abandonment already lasts and the more summer-dry the locations are, the easier *Molinia* enriches in its typical tussock form (Buchwald 1996), which is the case in many of the studied stands.

Additionally, a mosaic of dominance stands of different species can be observed (e.g., *Iris sibirica*, *Galium boreale*) in some of the surveyed *Molinietum caeruleae* stands, as described for example by Zacharias et al. (1988) for fallow *Molinion* meadows. Furthermore, *Lysimachia vulgaris* occurs with high fidelity values, which is typical for abandoned or irregularly mown meadows (Burkart et al. 2004).

Finally, the relatively low fidelity of small-growing character species of the *Molinion caeruleae*, like *Galium boreale* or *Carex filiformis* (compare Chapter 3.3.4.2.1), which are diagnostic in the data set for adjacent vegetation types like the *Brachypodio pinnati-Molinietum arundinaceae*, may also be an indication of a less developed lower herb layer due to the dominance of *Molinia arundinacea* and the resulting dense litter layer.

3.3.4.4 Occurrence of the plant community in the study hay meadows

Of the approximately 300 ha of *utilised hay meadow* surface, it is estimated here that around 7 to 8.5 ha were covered by *Molinietum caeruleae* vegetation (with *Molinia arundinacea*), divided in numerous single stands, which thus represent around 2-3 % of the meadow area. Often, the *Molinietum caeruleae* stands were at least partly surrounded by *Brachypodio-Molinietum arundinacea* stands (see also Chapter 3.3.6.4).

3.3.4.4.1 Lord’s Meadow

In the Lord’s Meadow, the *Molinietum caeruleae* stands occur almost exclusively in the upper part of the middle slope, characterized by a small gradient and high clay contents. In 2010, the overall outlines of the *Molinia arundinacea* stands were mapped. Six stands could be identified, covering an area of 0.95 ha, with different tuft densities (see Figure 54). On 0.65 ha of the mapped area, *Molinia arundinacea* had a cover of at least 40 %, while a maximum of 5 % cover was found on around 0.3 ha (see Figure 54). The stands were bordered by smaller patches or single tufts, all separated from each other by drier vegetation types (see Figure 55).

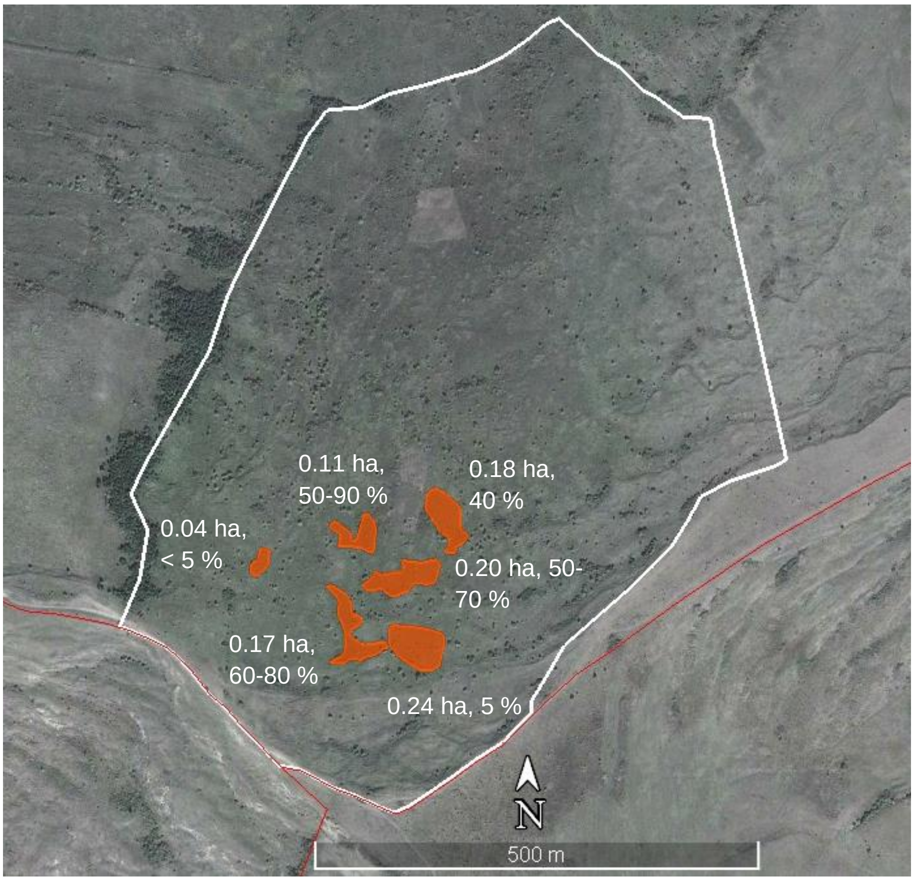

Figure 54: Stands of *Molinia arundinacea* (orange polygons) in the Lord's Meadow (white outline) in the year 2010 (Dăbâca commune) Red lines: communal borders; the percentages indicate the cover of *Molinia arundinacea* in the respective stand. The mapping was carried out by Inge Paulini & Gwyn Jones. The Google Earth image is from September 2011 (Google, © 2023 Maxar Technologies).

Figure 55: Autumn view on the *Molinia arundinacea* tufts in the Lord's Meadow (Dăbâca commune, 10.10.2010)

It is important to note that the mapped area did not correspond exactly to the extent of the *Molinietum caeruleae*, since *Molinia arundinacea* also occurs in the *Brachypodio-Molinietum arundinaceae* (see Chapter 3.3.6.2), and stands with low *Molinia* cover may belong to this community. Therefore, the area of the *Molinietum caeruleae* was estimated to be approximately 0.5 ha in size. The size of the area surrounding all *Molinia arundinacea* stands was about 2.5 ha.

3.3.4.4.2 Village Meadow

In the Village Meadow, there was one 1.5 ha continuous stand of *Molinia arundinacea* on the eastern margin, located below a reedbed and willow scrub (surveyed in 2010, data not shown). This area, according to personal observations, corresponded in large parts to the *Molinietum caeruleae* (see Figure 56).

Figure 56: Central part of a large, strip-shaped *Molinietum caeruleae* stand with *Molinia arundinacea* (fresh-green colour) in the eastern part of the Village Meadow (Dăbâca commune, 30.08.2011)

Additionally, there were a large number of various *Molinia arundinacea* stands distributed within the mostly semi-dry vegetation matrix of the Village Meadow, ranging from single tufts of several tens of square meters up to dense polygons of several hundreds of square meters; the larger stands belonged to the *Molinietum caeruleae* (see Figure 57). Taken together, these scattered *Molinietum caeruleae* stands covered 1 to 1.5 ha (estimated).

Figure 57: *Molinietum caeruleae* stands (orange areas marked by white arrows) in the western part of the Village Meadow (Dăbâca commune, 15.09.2010)

3.3.4.4.3 Great Meadow

In the Great Meadow, similar to the Village Meadow, *Molinia arundinacea* could be found in many small patches of single tufts to larger patches of several hundreds of square meters scattered over the meadow surface (estimated about 2 to 3 ha). The largest contiguous area with *Molinietum caeruleae* vegetation was located in the meadow centre, west of the path between the meadow sections *Sekelişte* and *Fânaia* (estimated around 2 ha, see Figure 58).

Figure 58: View on the central part of the largest *Molinietum caeruleae* stand (with *Molinia arundinacea*) in the Great Meadow (Borșa commune, 23.08.2019)
In the foreground: *Phragmites australis*, *Lythrum salicaria, Cirsium canum,* etc.

3.3.4.5 Occurrence of the plant community in Romania

3.3.4.5.1 *Molinia arundinacea* in publications about the *Molinion caeruleae* from Romania

In Romanian literature about *Molinion*-communities, *Molinia arundinacea* is not known to be mentioned; therefore, it is difficult to estimate how widespread the vegetation type described here is. *Molinia arundinacea* is listed as a subspecies of *Molinia caerulea* in the Romanian floras of Săvulescu (1952-1976) and Ciocârlan (2000).

Săvulescu (1952-1976) indicates only one occurrence of *Molinia caerulea* ssp. *arundinacea* in Cluj County; the communes Călățele (65 km W of Cluj) and Căpușu Mare (25 km W of Cluj) in the northern foothills of the Apuseni (Gilău) mountains. *Molinia caerulea* ssp. *caerulea* is described as frequent throughout the whole country.

3.3.4.5.2 Publications about *Molinion*-vegetation in Cluj County

Pop et al. (1999-2000) do not list the alliance *Molinion caeruleae* in their phytosociological and ecological study of Cluj County's vegetation at all. Furthermore, *Molinia* meadows are not mentioned in the PhD thesis and related article of Pop (1985, 1996) about the vegetation of the Cluj Hills, including part of Borșa commune with the Great Meadow.

However, Cristea (2014) includes in his enumeration of habitat types in Cluj-Napoca and surroundings the habitat type R3711: Dacian meadows with *Nardus stricta* and *Molinia caerulea* (Doniţă et al. 2005), but without further details of location or type. The reference could be related to the *Molinion*-occurrence in Făget forest and Morii Valley (see below).

There are two publications by Soó (1927, 1947) which mention the *Molinietum caeruleae* for the surroundings of Cluj, mainly for Făget forest (*Făgetul Clujului*) and Morii Valley (*Valea Morii*), an area in the south of the municipal center of Cluj-Napoca (see information about the Natura 2000-site '*Făgetul Clujului – Valea Morii'* below).

In the 1927 publication by Soó there is a constancy table for the *Molinietum caeruleae*; the 1947 publication shows only a list of local character species without a phytosociological table. However, the species composition is comparable in both publications, and suggests that the described vegetation belongs to other communities of wet meadows and communities of mesotrophic fens of the class *Scheuchzerio-Caricetea* with occurence of *Molinia caerulea*: *Molinia caerulea, Nardus stricta, Carex flava, Carex cespitosa, Carex panicea, Juncus atratus, Juncus thomasii, Gladiolus imbricatus, Herminium monorchis, Epipactis palustris, Parnassia palustris, Pedicularis palustris, Succisa pratensis, Cirsium rivulare, Ligularia sibirica and Agrostis stolonifera*.

3.3.4.5.3 SCIs with *Molinion*-habitat in Romania and Cluj County

Another source of information about the occurrence of *Molinion*-vegetation in Romania is data on the Natura 2000 network, which includes the protection of the habitat type 6410 '*Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion* *caeruleae*)', on both neutro-alkaline and more acid soils (European Commission DG Environment 2013).

From the 435 Sites of Community Importance (SCIs) in Romania (European Environment Agency 2018), there are 29 SCIs (European Environment Agency 2021) listing the habitat type 6410 in the Standard Data Form (6,7 %). Most of the sites are located in the Carpathian Mountains and the Maramureș region, and there are only two sites with the habitat type 6410 in the whole Translyvanian Basin. In Cluj County, there are four Natura 2000-Sites of Community Importance (SCIs), which include the habitat type 6410 (European Environment Agency 2021); two of them in the surroundings of Cluj are treated in the following.

SCI 'Eastern Hills of Cluj' (ROSCI2095): In the management plan of the SCI 'Eastern Hills of Cluj', in which the study hay meadows are included, the vegetation of the Lord's and Village Meadow is indicated as a complex of three habitat types (6430, 6510 and 6410) (Societatea Lepidopterologică din România 2016). The *Molinion* stands in the Great Meadow are not shown on the map of habitat types (the area is mapped as habitat complex 6510-6430), like several other locations in the area of the SCI, in which the author of this thesis has found stands with *Molinia caerulea* agg. and species like *Serratula tinctoria* and *Sanguisorba officinalis*. Common features of these stands are that they are all located in old (former) hay meadows (Paulini et al. 2012) and are of small size, i.e. several tens to hundreds of square meters. The total area covered by the habitat type 6410 in the SCI is not specified in the management plan (Societatea Lepidopterologică din România 2016).

It is somewhat surprising that the *Molinion* vegetation in the Cluj Hills has received so little attention up to now, despite its close proximity to the nature reserve 'Hay Meadows of Cluj' which has been visited by numerous botanists since the 19th century. Only the discovery of the *Phengaris* spp. occurrence in the studied hay meadows finally drew attention to the *Molinia* meadows.

SCI 'Făgetul Clujului – Valea Morii' (ROSCI0074): Today, a large part of the Făget forest and the Morii Valley mentioned in the publication of Soó (1947) is covered by the Site of Community Importance 'Făgetul Clujului – Valea Morii'. The SCI measures 1686 ha and, according to the management plan, is covered mainly by forests (1423 ha), grasslands (217 ha), alkaline fens (5 ha), and *Molinia* meadows (11 ha; habitat type 6410) (Erős and Platon 2015). In the SCI, there are three plant and two butterfly species protected by the Habitats Directive which are linked to the alkaline fens and *Molinia*-meadows: *Adenophora lillifolia*, *Ligularia sibirica* and *Liparis loeselii*, as well as *Phengaris nausithous* and *Phengaris teleius*.

However, the management plan does not identify the *Molinion* associations occuring in the area. The height above mean sea level of the designated *Molinia* habitat is around 200-300 m higher than that of the study hay meadows (620-680 versus 370-470 m a.s.l.). According to Soó (1927), the area belongs to the montaneous forest zone, while the Hills of Cluj are located in the transition area towards the steppe zone of the Translyvanian Basin.

3.3.4.5.4 Locations of *Molinietum caeruleae* in Romania

From the botanical literature it can be observed that a significant part of the publications describing the *Molinietum caeruleae* Koch 1926 in Romania have been published in the 1960s to 1980s, either as papers about *Molinia*-vegetation, for example by Boşcaiu et al. (1964), Boşcaiu (1965), Resmeriţă (1969), and Borza and Raţiu (1970), or as part of the vegetation description of a certain region, for example by Pop et al. (1964) and Gergely et al. (1988). More authors can be found in the vegetation synopsis of Coldea et al. (2012), who list the source of the relevés used for the classification.

Many of the publications mentioned above classify their analysed vegetation as *Molinietum caerulaea* (Boşcaiu et al. 1964; Resmeriţă 1969; Borza and Raţiu 1970; Gergely et al. 1988). Boşcaiu (1965) describes the new association *Peucedano rocheliani-Molinietum coeruleae*, which is generally accepted in Romanian syntaxonomy (Sanda et al. 2008; Coldea et al. 2012).

Despite the assignment of the mentioned authors, Coldea et al. (2012) and Sanda et al. (2008) allow only the *Junco effusi-Molinietum caeruleae* Tüxen 1954 and the *Junco effusi-Molinietum caeruleae galietosum boreale* Gergely et al. (1988) for Romania (see also Chapter 3.3.4.2.3). Clarity in this contradictory classification of the *Molinion* stands can only be achieved by a classification of a large number of *Molinion*-relevés from Romania and comparison with other European classifications.

From the analysed literature, the *Molinia*-vegetation described by Boşcaiu et al. (1964), Boşcaiu (1965), and Resmeriţă (1969) is floristically the most similar to the *Molinietum caeruleae* described here. Boşcaiu et al. (1964) mention stands of *Molinia* meadows with sizes of 2 and 5 ha, but also 40 and 60 ha in the Oaș region (Satu Mare County) and Sighet region (Maramureș County), both NW Romania. These *Molinietum caeruleae* stands were used partly as hay meadows, but some of them were already abandoned and experiencing succession towards forest communities (Boşcaiu et al. 1964). The *Molinia* stands in the Maramureș County are located in what is now the Site of Community Importance '*Igniș*' (ROSCI0092).

One year later, Boşcaiu (1965) describes the new association *Peucedano rocheliani-Molinietum coeruleae* from two locations in W-Romania (SE-Banat near Caransebeș and Lugoj, and from the Haţeg depression). He speaks of relic stands and suspects a larger extension of the *Molinia* meadows in the past. The association is defined based on 7 relevés of 100 m^2 size.

Boşcaiu (1965) names 10 character species for the association, which correspond to the *Molinietum caeruleae* Koch 1926: *Molinia caerulea, Sanguisorba officinalis, Cirsium canum, Inula salicina, Gentiana pneumonanthe, Euphorbia illirica, Iris sibirica, Gladiolus imbricatus, Selinum carvifolia,* and *Thalictrum simplex* subsp. *galioides*. Additionally, he lists four regional characteristic species: *Narcissus poeticus* subsp. *radiiflorus* (= *Narcissus stellaris*), *Peucedanum rochelianum*, *Polygala vulgaris* f. *albida* and *Ranunculus polyanthemos*.

Boşcaiu (1965) calls his new community a regional association with daco-illyric character; in the system of Wagner (1950) about the geographic variants of the

Molinietum caeruleae it would be a new, sub-illyric unit from Romania (Banat, South-Transylvania) with similarities to the illyric variant. In this sense, the *Peucedano rocheliani-Molinietum coeruleae* could also be considered a geographic vicariant/race of the *Molinietum caeruleae*, which is distinguished by several differential species (sensu Dierschke 1994).

Resmeriţă (1969) describes *Molinietum caeruleae* stands near Bistriţa (Bistriţa-Năsăud county; 70 km straight-line distance from the studied hay meadows towards NE), which were located in around 3000 ha of hay meadows and pastures, with scattered *Salix cinerea* shrubs and individuals of *Rhamnus frangula*, *Quercus robur* and *Quercus petraea*.

Resmeriţă (1969) considers these *Molinietum caeruleae* stands to be among the most representative and best developed in Romania. However, similar to Boşcaiu (1965), he suspects a larger extension in the past and considers them relic stands. As reasons for their reduction Resmeriţă (1969) names natural processes of drying out of the sites, as well as anthropogenic influence (drainage, transformation into arable), and predicts a further reduction of their area.

3.3.4.6 Agricultural use, conservation value and protection status

According to the statement of a farmer from Luna de Jos, the *Molinia arundinacea* plants were traditionally harvested separately from the other hay species and either fed to horses or water buffaloes, or used as bedding in the stables (Vasile Rus Sr., personal communication, March 2023).

Although the *Molinietum caeruleae* (with *Molinia arundinacea*) occurs only on around 2-3 % of the *utilised hay meadows* surface (see Chapter 3.3.4.4), these areas can be regarded as a focus for conservation due to the following reasons.

Two host plants of three different *Phengaris* taxa have their main occurrence in this plant community, at least according to the analysed vegetation table: *Sanguisorba officinalis* (in 88 % of the *Molinietum*-relevés) and *Gentiana pneumonanthe* (in 57 % of the *Molinietum*-relevés). Additionally, *Gentiana pneumonanthe* is of national conservation concern, being classified as vulnerable by Boşcaiu et al. (1994).

Two more vascular plant species of national conservation concern occur in the 16 relevés made in this vegetation type: *Iris sibirica*, a rare (Dihoru and Dihoru 1994) and vulnerable (Boşcaiu et al. 1994) species was found in 44 % of the relevés, and *Klasea radiata* (synonym: *Serratula radiata*), a rare species according to Oltean et al. (1994) was found in one *Molinietum*-relevé.

Also worth mentioning is the high nature conservation value of the *Molinietum caeruleae* with *Molinia arundinacea* in the hay meadows, which results from the first description of the community with this *Molinia* species for Romania so far, as well as the frequent co-occurrence with the *Brachypodio-Molinietum arundinaceae*, which is also rarely indicated for Romania up to now (see Chapter 3.3.6.5).

In general, *Molinion* meadows, together with the dry and semi-dry grasslands of the *Festuco-Brometea* class, are ranked among the most species-rich and flower-rich ecosystems of Central Europe (Leuschner and Ellenberg 2017).

While *Molinion* meadows used to be widespread in some areas of Europe (e.g. in Germany in the northern Upper Rhine Plain and the Bavarian Alpine Foreland), occurrences have declined significantly since the second half of the 20th century, and the meadows survive only in areas with exceptionally extensive land use and in protected areas (Burkart et al. 2004; Leuschner and Ellenberg 2017).

On the European red list of habitats by Janssen et al. (2016), the entire group of moist or wet oligotrophic grasslands (code E3.5) is classified as endangered. Furthermore, the *Molinietum caeruleae* is included in Annex I of the EU Habitats Directive as part of the habitat type 6410 - *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*).

The study hay meadows are located, as previously mentioned, in a Site of Community Importance (ROSCI2095), hence the status and management recommendations for Annex I habitat types are specified in the management plan of the site (Societatea Lepidopterologică din România 2016).

The habitat type 6410 is included in the SCI management plan but was not mapped as a separate habitat type due to its small extent, or in some cases not mapped at all. Moreover, the management plan does not mention the *Molinietum caeruleae*, only the '*Junco-Molinietum* Preising 1951', hence the plant community is not properly adressed by the management plan.

3.3.5 *Calamagrostis epigejos*-[Molinietalia caeruleae]-community

Vegetation type: *Calamagrostis epigejos*-dominance community

Names:

English: Wood small-reed community within the order of wet meadows
Romanian: Comunitate de trestie de câmp în cadrul ordinului de pajiști umede
German: Land-Reitgras-Gesellschaft innerhalb der Ordnung der Feucht- und Nasswiesen

Information relevés:

Number: 10
Type, size, year: phytosociological relevés, 25 m^2, 2009
Surveyors: 2 different persons / teams

Locations:

Dăbâca: Lord's Meadow (1)
Borșa: Great Meadow (9)

3.3.5.1 Structure and species composition

The following descriptions are based on 10 phytosociological relevés carried out in the year 2009 in the Great Meadow (n = 9) and the Lord's Meadow (n = 1). When selecting the plots in the meadows, preference was given to stands with *Serratula coronata* by one surveyor (S. Bădărău, personal communication, July 2009), since the meadows have been an unknown location of this rare species in Romania at this time. The surveyed parameters of vegetation structure are shown in Table 21.

Table 21: Data on vegetation structure for the *Calamagrostis epigejos*-community

Total cover (n = 10)	mean +/- SD	94.3 % +/- 4.5 %
	min. - max.	90.0 % - 100.0 %
Share of relevés with *Crataegus monogyna*		30 %
Share of relevés with *Rosa canina*		10 %
Average hight of herb layers (n = 5)	mean +/- SD	58 cm +/- 21 cm
	min. - max.	30 cm - 90 cm
Max. hight of herb layers (n = 5)	mean +/- SD	140 cm +/- 24 cm
	min. - max.	100 cm - 170 cm

Data on the shrub layer have not been recorded.

The stands of this vegetation type are characterized in general by a high cover of the wood small-reed *(Calamagrostis epigejos)*: it was recorded in seven of 10 relevés with cover values between 50 and 100 % (Braun-Blanquet value 4 or 5). However, the plots have a variable degree of co-dominant species: in four of seven plots dominated by the wood small-reed, there is just one or no co-dominant species at all, with the other species reaching cover values of, at most, a few percent. In the remaining three plots, four or five species reach the Braun-Blanquet value 2 (5-25 % cover) or higher.

Additionally, three relevés have been assigned to this vegetation type, which contain no or less than 1 % *Calamagrostis epigejos*; in these relevés, *Festuca pratensis* and *Carex filiformis* as well as several forb species like *Galium boreale*, *Serratula tinctoria,* or *Cirsium canum* reach high cover values (25 % to 75 %).

Besides the species already mentioned, other frequent species in this vegetation type are *Stachys officinalis, Thalictrum lucidum, Centaurea phrygia, Inula salicina, Serratula coronata, Filipendula vulgaris, Ononis spinosa* subsp. *hircina, Euphorbia esula, Sanguisorba officinalis, Rhinanthus minor, Symphytum officinale, Lysimachia vulgaris, Lythrum salicaria, Carex filiformis, Galium verum, Daucus carota, Lotus corniculatus,* and *Leontodon hispidus*. Several of the frequent and diagnostic species are tall forb species, for example *Thalictrum lucidum, Cirsium canum, Serratula coronata, Symphytum officinale, Lysimachia vulgaris, Lythrum salicaria,* and *Valeriana officinalis*.

Due to the dominant *Calamagrostis epigejos* and the tall forb species, the stands of this vegetation type reach, after the *Molinietum caeruleae*, the second highest values of the maximum height of the herb layers, averaging 140 cm +/- 24 cm and ranging between 100 cm and 170 cm. The lower herb layer is clearly smaller, as the average height of the vegetation layer of 58 cm +/- 21 cm and the range between 30 cm and 90 cm suggest (see Figure 59). The total cover of vegetation averages 94.3 % +/- 4.5 % and ranges between 90 % and 100 %. Phanerophytes occur in four of 10 relevés (*Crataegus monogyna* and *Rosa canina*); it has not been recorded if the specimens are taller than 0.5 m and thus may be attributed to the shrub layer.

Figure 59: *Calamagrostis epigejos*-community stand in the Great Meadow (Borșa commune, 18.09.2011)
The light-brown *Asteraceae* infructescences belong to *Serratula tinctoria*.

3.3.5.2 Syntaxonomy and diagnostic species

Class:	*Molinio-Arrhenatheretea* Tx. 1937
Order:	*Molinietalia caeruleae* Koch 1926[a]
Community:	*Calamagrostis epigejos*-[Molinietalia caeruleae]-community

Selected synonyms:

[a] *Molinietalia* Rübel 1933, *Deschampsietalia cespitosae* Horvatić 1958

The nomenclature and selected synonyms regarding the class and order come from Mucina et al. (2016).

For the vegetation type described here, 17 diagnostic species have been found, of which the following five species are mainly diagnostic for this vegetation type.

Calamagrostis epigejos (wood small-reed, see Figure 60) has high fidelity values as a diagnostic species in this vegetation type and is diagnostic also for the *Brachypodio-Molinietum* (see Table 22). The wood small-reed is a tall growing perennial grass species which spreads predominantly vegetatively through creeping rhizomes (Rebele and Lehmann 2001; Rebele 2014). The species is characterized by extraordinarily broad ecological amplitudes with regard to the factors moisture, soil reaction and nutrients (Rebele 2014). Hence, the tall growing species occurs in a wide range of different habitat types.

Figure 60: *Calamagrostis epigejos* stand in the Great Meadow (Borșa commune, 30.08.2011)

Table 22: Fidelity values and preferential occurrence in plant communities of selected diagnostic species of the *Calamagrostis epigejos*-community

	Calamagrostis epigejos	***Serratula coronata***	***Thalictrum lucidum***	***Symphytum officinale***	***Valeriana officinalis***
	Fidelity values: perc (class) *fid*				
***Calamagr. epigejos*-comm.**	90 (V) *fid 62***	70 (IV) *fid 75***	90 (V) *fid 66***	50 (III) *fid 42**	30 (II) *fid 40**
Mentho-Juncetum			33 (II)		
Molinietum caeruleae	19 (I)		13 (I)	31 (II) *fid 21**	
Brachypodio-Molinietum	50 (III) *fid 26**				
Festuca pratensis- comm.		13 (I)	25 (II)	13 (I)	
Polygalo-Brachypodietum	3 (I)		3 (I)		3 (I)
Cirsium furiens- comm.	19 (I)			13 (I)	13 (I)
Braun-Blanquet-values	5, 4, +	1, +	+	+	+
Coldea et al. (2012), p. 194*ff.* : table *Filipendulion, Calthion & Molinion*	-	-	C **alliance** *Molinion caeruleae*	C **order** *Molinietalia caeruleae*	C **alliance** *Filipendulion*

Perc = percentage frequency; class = frequency class; fid = statistical fidelity; C = character species; empty cells = zero. The Braun-Blanquet-values are indicated for the *Calamagrostis epigejos*-community. The statistic fidelity measure is the phi-(Φ)-coefficient of association. Species with phi-coefficient values of at least 20 are considered diagnostic (indicated by fid* and yellow colour); species with phi-coefficient values of at least 45 are considered highly diagnostic (indicated by fid** and green colour).

Serratula coronata is highly diagnostic for this vegetation type and occurs only in one relevé belonging to another vegetation type (*Festuca pratensis*-community, see Table 22). According to S. Bădărău (personal communication, August 2009), the study hay meadows are a new location of the rare species in Romania and one of the westernmost populations regarding the entire distribution area. It is a hemicryptophyte which can reach a height of 80-150 cm and flowers in August and September (Săvulescu 1952-1976; Ciocârlan 2000) (Figure 61 and Figure 62). In Europe, the species is native only to Romania, Moldova, Ukraine, Belarus, and Russia, as well as to Transcaucasia (Greuter 2006+). It extends over large parts of Asia up to Japan (Royal Botanic Gardens). The nearest locations mentioned by Săvulescu (1952-1976) are the 'Hay Meadows of Cluj' nature reserve and Jucu commune, which borders on Borşa commune.

Greuter (2006+) indicates *Serratula wolffii* Andrae as a heterotypic synonym of *Serratula coronata* L. Săvulescu (1952-1976) on the other hand rejects the name *Serratula coronata* for the Romanian specimens and opts for the name *Serratula wolffii*, since *Serratula coronata* L. would have been described as very similar to *Serratula tinctoria* L. (see Săvulescu 1952-1976). In this thesis, the name *Serratula coronata* L. is used, referring to that *Serratula* species which differs clearly from *Serratula tinctoria*, especially with regard to size.

Figure 61: Floral head of *Serratula coronata* (Cojocna commune, 27.07.2009)

Figure 62: Flower buds of *Serratula coronata* in the Great Meadow with *Molinia arundinacea* in the background (Borșa commune, 23.07.2011)

According to Săvulescu (1952-1976), *Serratula coronata* (=*S. wolffii*) occurs in hay meadows and scrubs in the lowland layer, while in the flora of China the following habitats are mentioned: forests, forest margins on mountain slopes, steppes, meadows, and riverbanks (Missouri Botanical Garden and Harvard University Herbaria 2023). Sanda et al. (2008) considers *Serratula coronata* (=*S. wolffii*) a character species of the *Molinietalia caeruleae*. According to Roleček et al. (2014), *Serratula coronata* is a mesophilous species typical of hemiboreal forests and continental forest meadows.

Thalictrum lucidum is a good diagnostic species for this vegetation type, with high frequency and fidelity values (see Table 22). It is a typical species of tall forb communities and wet to intermittently wet meadows (Rothmaler 2005). Coldea et al. (2012) assign it to the *Molinion caeruleae*. For Southeast Lower Saxony (Germany), Zacharias et al. (1988) describe fallow litter meadows of the *Molinietum caeruleae* with a high frequency of *Thalictrum lucidum* (as well as *Calamagrostis epigejos*).

Symphytum officinale is diagnostic for this group, and, with lower diagnostic values, also for the *Molinietum caeruleae* (see Table 22). The species indicates a good supply of nutrients (Buchwald 1996) and often occurs in wet meadows (*Molinietalia caeruleae*) (Rothmaler 2005; Coldea et al. 2012) and tall-herb fringe communities (Dierschke 1996).

Valeriana officinalis is diagnostic only for this group (see Table 22). The species occurs in similar habitats like *Thalictrum lucidum* and *Symphytum officinale*: tall forb communities, wet meadows, alder and hardwood floodplain forests, and also on nutrient-rich sites like nitrophytic fringe communities (Rothmaler 2005); Coldea et al. (2012) assign the species to the *Filipendulion*.

Furthermore, there are four diagnostic species for this vegetation type which are character species of the *Molinion caeruleae* (*Serratula tinctoria*) and *Molinietalia caeruleae* (*Clematis integrifolia, Cirsium canum* and *Lysimachia vulgaris*; see also Table 23).

Table 23: Selected diagnostic species of the *Calamagrostis epigejos*-community (15 from a total of 17)

Diagnostic mainly for this community	*Calamagrostis epigejos, Serratula coronata, Thalictrum lucidum, Symphytum officinale, Valeriana officinalis*
Molinion caeruleae and *Molinietalia caeruleae*	*Serratula tinctoria, Clematis integrifolia, Cirsium canum, Lysimachia vulgaris*
Molinio-Arrhenatheretea	*Alopecurus pratensis, Avenula pubescens*
Fringe communities	*Poa trivialis, Calystegia sepium, Solidago virgaurea, Erigeron canadensis*

The following diagnostic species occur only with low frequency, that is, in two or three relevés out of 10, and are species of *Molinio-Arrhenatheretea* grasslands and fringe communities. *Alopecurus pratensis, Poa trivialis,* and *Calystegia sepium* are nutrient-demanding species from rather moist sites, while *Solidago virgaurea, Erigeron* *canadensis,* and *Avenula pubescens* are growing on damp to dry sites with moderate nitrogen supply (see also Table 23).

There is one association mentioned in Romanian literature which has some similarities to the vegetation type described here, namely the *Lythro-Calamagrostietum epigei* I. Pop 1968 with *Lythrum salicaria*, *Symphytum officinale* and *Cirsium canum* indicated for NE-Romania (Chifu 1995; Sanda et al. 2008). However, this association is assigned to the order of flooded grasslands and creeping plants (*Potentillo-Polygonetalia)*, while the vegetation type found in the meadows belongs to the order of wet grasslands (*Molinietalia careuleae*). This is indicated by the diagnostic species named above and high frequency values of *Sanguisorba officinalis*, *Cirsium canum*, *Lysimachia vulgaris* and *Lythrum salicaria*.

Since no good match was found with associations described in the literature, it was decided to describe the vegetation type as a dominance community (German: *Dominanzgesellschaft*) of *Calamagrostis epigejos*. Dominance communities are frequently recurring stands dominated by a certain species, and do not possess association character species (Dierschke 2012). The dominants often are species with a pronounced vegetative growth like *Calamagrostis epigejos*, *Elytrigia repens,* or *Agrostis stolonifera*. If association character species can be identified, the stands are assigned to the respective associations, for example as a facies (Dierschke 2012).

Due to the assignment of several diagnostic species to the *Molinietalia caeruleae*, the community is placed here into this order of wet grasslands, leading to the name *Calamagrostis epigejos*-[Molinietalia caeruleae]-community. Whether the dominance community can be assigned to the *Molinion*-alliance remains to be clarified. The greatest similarities in diagnostic species are with the *Molinietum caeruleae* and the *Brachypodio-Molinietum arundinaceae*.

3.3.5.3 Environmental and ecological conditions

For five of 10 relevés the exposition has been recorded: one is N-facing, one NW-facing and three are NNW-facing (see Table 9, page 64). The stands have only a slight or no inclination (median: 0°), which indicates that the *Calamagrostis epigejos*-community is generally found in flat areas of the meadow hill slope (see Table 8, page 64).

It can be assumed that these depressions are exposed to irregular waterlogging as well as drought; according to Rebele and Lehmann (2001), established clones of *Calamagrostis epigejos* are tolerant to both conditions and survive fluctuations between those extremes. The tolerance towards flooding of *Calamagrostis epigejos* is mentioned by Thomas (1990) as well.

The high number of species in the *Calamagrostis epigejos*-community which are characteristic of sites with alternating soil moisture or regularly flooded sites supports this assumption: *Thalictrum lucidum*, *Valeriana officinalis*, *Clematis integrifolia*, *Serratula tinctoria*, *Cirsium canum*, *Lysimachia vulgaris* and *Lythrum salicaria* as diagnostic species, as well as *Sanguisorba officinalis, Inula salicina*, *Filipendula* *vulgaris, Galium boreale*, *Stachys officinalis, Galium verum* and *Carex filiformis* as non-diagnostic species with high frequency values.

The unweighted Ellenberg indicator value for soil moisture M = 5.4 ± 0.4 (see Table 3, page 57) for the studied *Calamagrostis epigejos*-community reflects the favoured occurrence of species that grow in damp to slightly moist locations (Ellenberg et al. 2001; Dierschke and Briemle 2008). The Ellenberg indicator value for moisture is almost identical to that of the studied *Molinietum caeruleae* (M = 5.5 ± 0.4, unweighted).

The unweighted Ellenberg indicator value for nitrogen supply N = 4.2 ± 0.3 for this vegetation type reflects the favoured occurrence of species that grow on moderately N-rich sites (Dierschke and Briemle 2008); the *Molinietum caeruleae* (N = 4.0 ± 0.3) and *Mentho-Juncetum* (N = 4.3 ± 0.4) have comparable unweighted values.

The similar values for moisture and nitrogen supply raise the question of which environmental conditions distinguish the sites of the *Molinietum caeruleae* from those of the *Calamagrostis epigejos*-[Molinietalia caeruleae]-community, since both vegetation types occur in depressions within the meadow hillslope. The results of the DCA (see Figure 41, page 59) indicate that there are factors that separate the vegetation types on the y-axis. If this difference is the reason for the different manifestation or whether the vegetation itself has changed site conditions requires further investigation.

An aspect that may play a role in the formation of the *Calamagrostis epigejos*-[Molinietalia caeruleae]-community is the gradual abandonment of regular mowing since the 1990ies (see Chapter 4.3.3). The absence of regular cuts changes the competition conditions in the meadow vegetation, and can lead to increasing dominance of expanding species like *Calamagrostis epigejos* (e.g. Dierschke and Briemle 2008). A spread of the *Calamagrostis*-dominance stands starting from small depressions is plausible. Furthermore, the frequent occurrence of *Serratula coronata* in this vegetation type, which is disadvantaged on regularly or early mowed sites due to its late phenology, may also indicate the absence of mowing.

Quinger et al. (1995) observed that *Calamagrostis epigejos* shows an increased development in shaded places and often colonizes the areas of fallow litter meadows bordering on forest edges. It is possible that the expansion of *Calamagrostis epigejos* in the study meadows is enhanced by the increasing scrub encroachment (see Chapter 4.3.3).

3.3.5.4 Occurrence of the plant community in the study hay meadows

The location and extent of *Calamagrostis epigejos*-dominance stands in the hay meadows has not been surveyed in these studies. However, it can be stated with confidence that they occur in all three meadow sites. The abundance of the *Calamagrostis epigejos*-[Molinietalia caeruleae]-community and the *Calamagrostis epigejos*-dominance stands in general was higher in the Great Meadow than in the Lord's and Village Meadow at the time of data collection (2009-2013) (see Figure 63).

In the Great Meadow, *Calamagrostis epigejos*-dominance stands were found especially in the depressions, in some cases with large area extent (see Figure 60, page 106). It is assumed that the area covered in the Great Meadow by *Calamagrostis epigejos*-dominance stands was larger than the area covered by *Molinietum caeruleae*-vegetation. Furthermore, the continuing abandonment of mowing has probably led to an increase of *Calamagrostis epigejos*-dominance stands since the time of data collection.

Figure 63: Occurrence of *Calamagrostis epigejos*-dominance stands in the Great Meadow: large stand in the foreground and bright patches in the background (Borșa commune, 30.08.2011)

In the area SE of the Village Meadow, which formerly was part of the meadow and has been an abandoned arable field since 1990 (see Chapter 4.2.1.3), *Calamagrostis epigejos*-dominance stands covered large areas at the beginning of the 2010s, while in the actual Village Meadow there were only sporadic stands (see Figure 64).

Concerning the occurrence of *Serratula coronata* in the study hay meadows, the species was not found in the Lord's Meadow at all, and only in one single location in the Village Meadow in the year 2009. The main occurrence of *Serratula coronata* lies in the Great Meadow, where 17 locations were recorded in the years 2009 and 2011.

Figure 64: Sporadic *Calamagrostis epigejos*-stands in the Village Meadow: bright patches indicated by arrows (Dăbâca commune, 24.08.2011)
In the left background, the abandoned arable field mentioned in the text with numerous *Calamagrostis epigejos*-stands.

3.3.5.5 Occurrence of the plant community in Romania

No exact correspondences to the *Calamagrostis epigejos*-[Molinietalia caeruleae]-dominance community have been found in the relevant literatur for Romania. The association *Lythro-Calamagrostietum epigei* I. Pop 1968 (see Chapter 3.3.5.2), which has some similarities to the vegetation presented here, has been described for the Moldavia region in the East of Romania (Chifu 1995; Sanda et al. 2008).

3.3.5.6 Conservation value and problems

Calamagrostis epigejos is a native expansive species which often acts as a dominant. It spreads by clonal dispersal using the guerilla strategy (Rebele and Lehmann 2001). The competitive success of the *C. epigejos* lies among others in its ability to store and translocate resources below ground (Holub et al. 2012; Těšitel et al. 2017), similar to *Molinia caerulea* agg.

In many European countries, the wood small-reed has become a problem in various habitat types, reaching from alluvial meadows (Holub 2002), mesic (Pruchniewicz and Żołnierz 2017), semi-dry (Somodi et al. 2008) and dry grasslands (Schuhmacher and Dengler 2013; Vrahnakis et al. 2013; Těšitel et al. 2017), as well as in grassland succession on old-fields (Bartha et al. 2013).

Unlike most other competitive meadow grasses, such as *Arrhenatherum elatius*, the wood small-reed does not require high soil nutrient (N) availability to spread and attain dominance. Instead, it occurs also in HNV grasslands with low nutrient availability, and often benefits from their low-intensity conservation management and/or their abandonment (Těšitel et al. 2017). All these conditions are also present in the investigated meadows.

There are several examples in which the spreading of *Calamagrostis epigejos* has been observed in *Molinion* meadows: in the Wieliczka Foothills (S Poland), Bator 2005 (in Wójcik and Janicka 2016) report abandoned *Molinietum caeruleae* stands dominated by *Calamagrostis epigejos* in dry and insolated sites (while areas with a variable groundwater level are invaded by *Phragmites australis).* An example from Germany is *Calamagrostis epigejos* spreading into *Molinia* litter meadows in Bavaria (Quinger et al. 1995). Apparently, the colonies of the wood small-reed appear in rather dry and somewhat eutrophic abandoned litter meadows, especially in the *Cirsio tuberosi-Molinietum arundinaceae* (see Chapter 3.3.4.2.4) (Quinger et al. 1995).

Hence, the *Calamagrostis epigejos*-dominance stands can become a threat for the hay meadow vegetation if they expand and replace the formerly established semi-natural vegetation types. This can be relevant for the vegetation types *Molinietum caeruleae* and *Brachypodio-Molinietum arundinaceae* and the *Phengaris* spp. host species, like *Gentiana pneumonanthe* (see Figure 65). Furthermore, the spreading of the dominance stands is likely to reduce the agronomic value of the meadows by suppressing more valuable forage species.

Figure 65: *Calamagrostis epigejos* (left and foreground) next to a *Molinietum caeruleae*-stand with *Molinia arundinacea* (right side and foreground) in the Great Meadow (Borșa commune, 15.08.2010)
Other visible species: *Sanguisorba officinalis, Cirsium canum, Lythrum salicaria*

While the *Calamagrostis epigejos*-[Molinietalia caeruleae]-dominance community grows in moist to wet sites, it cannot be excluded that the semi-dry grassland is or will be affected by the *Calamagrostis epigejos*-expansion, as the moist and semi-dry sites interlock in a small-scale mosaic. Disturbances in the vegetation cover, for example through excessive and unregulated grazing, could facilitate the expansive tendencies.

The increasing dominance of *Calamagrostis epigejos* usually reduces the plant diversity of the vegetation stands by competitive exclusion of subordinate species (Somodi et al. 2008; Těšitel et al. 2017) due to, among other factors, strong shading (Somodi et al. 2008; Rebele 2014), which can hinder the reappearance of species of the original grassland (Somodi et al. 2008).

On the other hand, *Serratula coronata*, which is is designated as a rare species for Romania on the red lists of Dihoru and Dihoru (1994) and Oltean et al. (1994), seems to have a certain preference or co-occurrence with this plant community, at least in the Great Meadow. Management recommendations aimed at limiting the *Calamagrostis epigejos*-dominance stands must take this into account. However, the high frequency of the species (75 %) in the *Calamagrostis epigejos*-community is likely to be over-determined, since the relevé plots have been selected subjectively towards this species.

That means only a small part of *Calamagrostis-epigejos*-dominated stands in the studied hay meadows include specimens of *Serratula coronata*. Furthermore, *Serratula coronata* has been observed in stands not dominated by *Calamagrostis epigejos* as well, for example in meadow steppe communities.

Furthermore, three other vascular plant species of conservation concern have been found in the 10 relevés made in this vegetation type (see also Table 12, page 67): *Iris aphylla*, a rare species in Romania according to Dihoru and Dihoru (1994) was recorded in one relevé. *Iris aphylla* was also found in the Lord's Meadow in semi-dry *Cirsio-Brachypodion* vegetation. *Iris sibirica*, a rare (Dihoru and Dihoru 1994) and vulnerable (Oltean et al. 1994) species in Romania, was also found in one relevé of this vegetation type; however, it occurs mainly in the *Molinietum caeruleae*. The third species, *Seseli peucedanoides,* is considered a rare species in Romania according to Oltean et al. (1994), and was found in one relevé of this vegetation type. It also occurs in three *Cirsio-Brachypodion*-communities.

3.3.6 *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939

Vegetation type: Semi-dry basiphilous grassland

Names:

English:	Semi-dry meadow of tall purple moor grass and tor-grass
Romanian:	Pajiște semi-uscată de *Molinia arundinacea* și *Brachypodium pinnatum*
German:	Halbtrockenrasen mit *Brachypodium pinnatum* und *Molinia arundinacea*, Fiederzwenken-Pfeifengraswiese

Information relevés:

Number:	10
Type, size, year:	3 phytosociological relevés, 25 m^2, 2009 7 diversity-relevés, 10 m^2, 2012 & 2013
Surveyors:	3 different persons / teams

Locations:

Dăbâca:	Lord's Meadow (4), Village Meadow (2), Meadow Hill (3)
Borșa:	Great Meadow (1)

3.3.6.1 Structure and species composition

The following descriptions are based on 10 relevés carried out in the years 2009, 2012, and 2013 in three *utilised hay meadows* and one *former hay meadow*. The surveyed parameters of vegetation structure are shown in Table 24.

This vegetation type is often found in the transition zone between the *Molinietum caeruleae* and drier vegetation types such as the *Polygalo-Brachypodietum*. The plant community stands out for its colorful, flower-rich appearance (see Figure 66). It is characterized by a loose tall layer rich in herb species like *Serratula tinctoria*, *Gentiana pneumonanthe*, the *Apiaceae* species *Seseli annuum*, *Peucedanum cervaria* and *Dichoropetalum carvifolia*, *Genista tinctoria*, *Centaurea phrygia*, *Galium verum,* and flower stems of *Sanguisorba officinalis* and *Stachys officinalis* (see Figure 67).

Frequent grass species in this layer are *Molinia arundinacea*, which occured in eight of 10 relevés, mostly with cover values between 5 and 50 %, *Festuca arundinacea*, *Festuca pratensis,* and *Calamagrostis epigejos*, with the latter three usually with a cover of up to 5%.

Furthermore, the plant community is characterized by a dense lower herb layer with *Festuca stricta* subsp. *sulcata* (in nine of 10 relevés, cover values between 5 and 50 %), *Brachypodium pinnatum* (in six of 10 relevés, cover values up to 5 %), *Galium boreale, Inula salicina, Potentilla alba, Clematis integrifolia, Carex filiformis, Ononis spinosa* subsp. *hircina, Linum catharticum*, the rosettes of *Sanguisorba officinalis* and *Stachys officinalis,* and many other species.

The mean height values of the herb layers (upper layer 63 cm, lower layer 28 cm) indicate a relatively low growing vegetation. However, these are average values; where tall growing grasses occur, the maximum height can also reach almost 2 m.

Table 24: Data on vegetation structure for the *Brachypodio-Molinietum arundinaceae*

Total cover (n = 10)	mean +/- SD	95.3 % +/- 4.4 %
	min. - max.	85.0 % - 100.0 %
Cover bare ground (n = 7)	median	1.0 %
	mean +/- SD	2.6 % +/- 3.1 %
	min. - max.	0.3 % - 10.0 %
Cover moss layer (n = 7)	median	0.0 %
	mean +/- SD	0.3 % +/- 0.5 %
	min. - max.	0.0 % - 1.0 %
Cover litter layer (n = 7)	median	97.0 %
	mean +/- SD	95.6 % +/- 4.3 %
	min. - max.	88.0 % - 99.0 %
Depth litter layer (n = 7)	median	1.0 cm
	mean +/- SD	1.8 cm +/- 2.0 cm
	min. - max.	0.5 cm - 6.5 cm
Shrub cover (n = 3)	median	2.0 %
	mean +/- SD	5.8 % +/- 6.1 %
	min. - max.	1.0 % +/- 14.5 %
Shrub hight (n = 3)	mean +/- SD	0.3 m +/- 0.0 m
	max. +/- SD	0.6 m +/- 0.1 m
Share of relevés with phanerophytes		70%
Share of relevés with *Crataegus monogyna*		60 %
Share of relevés with *Prunus spinosa*		30 %
Share of relevés with *Rosa canina*		10 %
Mean hight of low herb layer (n = 6)	median	28 cm
	mean +/- SD	28 cm +/- 7 cm
	min. - max.	15 cm - 35 cm
Mean hight of tall herb layer (n = 6)	median	65 cm
	mean +/- SD	63 cm +/- 12 cm
	min. - max.	50 cm - 80 cm

Regarding the proportion of relevés with phanerophytes, 70 % of the relevés contain at least one of the six considered woody species, with the most common being *Crataegus monogyna* (see Table 24); this is the second highest value after the *Cirsium furiens*-community. More studies are needed to reveal if this vegetation type is particularly endangered by shrub encroachment as the data suggest. The three relevés with species in the shrub layer are all located in the grazed *former hay meadow* 'Meadow Hill' and therefore exposed to a higher abandonment extent than the other relevés.

The vegetation type is furthermore characterized by a higher average cover of litter (median of 97 %) and litter depth (median of 1 cm) and lower average cover of the bryophyte layer (median of 0.0 %) than the *Polygalo-Brachypodietum* and *Cirsium furiens*-community.

Figure 66: Flower-rich aspect of the *Brachypodio-Molinietum arundinaceae* in the Lord's Meadow with *Gentiana pneumonanthe, Sanguisorba officinalis, Centaurea jacea, Serratula tinctoria, Genista tinctoria, Ononis spinosa* subsp. *hircina,* etc. (Dăbâca commune, 23.07.2009)

Figure 67: *Brachypodio-Molinietum arundinaceae* stand in the Lord's Meadow with *Inula hirta, Genista tinctoria, Gentiana pneumonanthe, Prunella grandiflora, Stachys officinalis, Anthericum ramosum, Clematis recta, Peucedanum cervaria,* etc. (Dăbâca commune, 23.07.2009)
In the background, a *Molinietum caeruleae* stand with *Molinia arundinacea*.

3.3.6.2 Syntaxonomy and diagnostic species

Class:	*Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947
Order:	*Brachypodietalia pinnati* Korneck 1974 *nom. conserv. propos.*[a]
Alliance:	*Cirsio-Brachypodion pinnati* Hadač et Klika in Klika et Hadač 1944[b]
Association:	*Brachypodio pinnati-Molinietum arundinaceae* Klika 1939

Selected synonyms:

[a] *Brometalia erecti* Koch 1926 nom. ambig. rejic. propos., *Brometalia erecti* Br.-Bl. 1936 nom. ambig. rejic. propos.

[b] *Festucion sulcatae* Soó 1938, *Danthonio-Brachypodion* Boşcaiu 1970

The nomenclature and selected synonyms regarding the class, order, and alliance come from Mucina et al. (2016); the nomenclature of the association follows Chytrý et al. (2007).

3.3.6.2.1 Diagnostic species

The vegetation type described here was assigned to the association *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939. Of the species mentioned by Klika (1939) in the first description of the association for the Moravian White Carpathians as character species, only *Peucedanum cervaria* was identified as diagnostic in the relevé table (see Table 25).

Peucedanum cervaria grows in thermophilic mixed oak forests (Rothmaler 2005; Chytrý et al. 2021) and their fringes (Rothmaler 2005; Coldea et al. 2012; Chytrý et al. 2021), as well as in semi-dry grasslands (Rothmaler 2005). According to Chytrý et al. (2007) and Chytrý et al. (2021), the species is highly diagnostic and constant in the *Brachypodio-Molinietum arundinaceae,* and diagnostic and constant in the *Polygalo-Brachypodietum*.

Table 25: Selected diagnostic species of the *Brachypodio pinnati-Molinietum arundinaceae* (24 from a total of 31)

Character species association (Klika 1939)	*Peucedanum cervaria*
Diagnostic / constant for association (Chytrý et al. 2007)	*Molinia arundinacea, Serratula tinctoria, Inula salicina, Genista tinctoria, Linum catharticum, Ranunculus polyanthemos, Trifolium montanum, Festuca stricta* subsp. *sulcata, Potentilla alba, Inula hirta, Peucedanum cervaria*
Wet meadows with alternating soil moisture	*Gentiana pneumonanthe, Galium boreale, Carex filiformis, Clematis integrifolia*
Basiphilous (semi-)dry grassland communities	*Leucanthemum vulgare, Seseli annuum, Danthonia alpina, Fragaria viridis, Koeleria macrantha*
Thermophilic forests, scrubs and their fringes	*Dichoropetalum carvifolia, Rosa gallica, Euphorbia epithymoides*

*Veronica orchidea (*synonym: *V. spicata* subsp. *orchidea)* is also an association character species according to Klika (1939). In the analysed dataset it is only diagnostic for the *Festuca pratensis*-community and occurs in three of 10 relevés of the *Brachypodio-Molinietum arundinaceae* (constancy class II). However, the *Festuca pratensis*-community has the closest similarities in species composition to this vegetation type or may even be a subunit of it (see Chapter 3.3.7.2).

The other species indicated by Klika (1939) as character species of the *Brachypodio-Molinietum arundinaceae* either do not occur in the analysed relevés, like *Cytisus hirsutus, Koeleria pyramidata, Astragalus danicus, Iris variegata,* and *Lathyrus pannonicus*, or are diagnostic for the vegetation type identified here as *Polygalo-Brachypodietum pinnati* (*Polygala major, Cirsium pannonicum, Thesium linophyllon,* and *Scabiosa ochroleuca*; see Chapter 3.3.8.2).

The vegetation type was nevertheless assigned to the *Brachypodio-Molinietum arundinaceae*, mainly because of the high concordance of diagnostic and constant species specified by Chytrý et al. (2007) for the association in the Czech Rebublic and the diagnostic species for the vegetation type in the studied meadows (see also Table 25). These are *Molinia arundinacea, Serratula tinctoria, Inula salicina, Genista tinctoria,* and *Linum catharticum* as species indicating intermittent soil moisture. Some of these species are also diagnostic species of the order *Brachypodietali pinnati* (see Table 26).

Table 26: Fidelity values and preferential occurrence in plant communities of selected diagnostic species of the *Brachypodio-Molinietum arundinaceae* (species of intermittently wet meadows)

	Serratula tinctoria	***Inula salicina***	***Genista tinctoria***	***Linum catharticum***	***Galium boreale***	***Carex filiformis***	***Clematis integrifolia***
	Fidelity values: perc (class) *fid*						
Brachypodio-Molinietum	90 (V) *fid 44*	100 (V) *fid 38*	60 (III) *fid 44*	60 (III) *fid 39*	80 (IV) *fid 43*	90 (V) *fid 30*	70 (IV) *fid 42*
Caricetum vesicariae		100 (V)					
Mentho-Juncetum				33 (II)		67 (IV)	
Molinietum caeruleae	50 (III)	31 (II)	31 (II)	6 (I)	31 (II)	38 (II)	6 (I)
Calamagr. epigejos -comm.	90 (V) *fid 43*	70 (IV)			50 (III)	60 (III)	60 (III) *fid 33*
Festuca pratensis-comm.	50 (III)	38 (II)	25 (II)		13 (I)	25 (II)	50 (III) *fid 25*
Polygalo-Brachypodietum	6 (I)	36 (II)	17 (I)	17 (I)	25 (II)	58 (III)	6 (I)
Cirsium furiens-comm.	6 (I)	44 (III)	6 (I)	44 (III) *fid 24*	38 (II)	81 (V) *fid 25*	
Braun-Blanquet-values	2, 1, +	3, 2, 1, +	+	+, r	3, 2, 1, +	1, +	2, 1, +, r
Chytrý et al. (2007) p. 447: *Brachypodio-Molinietum*	highly diagnostic, constant	diagnostic, constant	diagnostic, constant	diagnostic, constant	-	-	-
Coldea et al. (2012), p. 194 ff.: table *Filipendulion*, *Calthion* & *Molinion*	**alliance** *Molinion caeruleae*	**alliance** *Molinion caeruleae*	**order** *Molinietalia caeruleae*	**order** *Molinietalia caeruleae*	D **subass.** *Junco-Molinietum galietosum boreale*	-	-
Willner et al. (2019), electronic appendix 3, p. 3: order *Brachypodietalia pinnati*	-	**order** *Brachypodie-talia pinnati*	-	**order** *Brachypodie-talia pinnati*	**order** *Brachypodie-talia pinnati*	**order** *Brachypodie-talia pinnati*	-

Perc = percentage frequency; class = frequency class; fid = statistical fidelity; D = differential species; empty cells = zero. The Braun-Blanquet-values are indicated for the *Brachypodio-Molinietum arundinacea*e. The statistic fidelity measure is the phi-(Φ)-coefficient of association. Species with phi-coefficient values of at least 20 are considered diagnostic (indicated by fid* and yellow colour).

Other species of wet meadows with alternating soil moisture which are diagnostic for the local *Brachypodio-Molinietum* are *Gentiana pneumonanthe, Galium boreale, Carex filiformis,* and *Clematis integrifolia* (see Table 26).

According to Wagner (1950), *Clematis integrifolia* is a character species of the pannonian variant of the *Molinietum caeruleae* (see Figure 68). Interestingly, Budzhak et al. (2016) found *Clematis integrifolia* in *Brachypodio-Molinietum arundinaceae* relevés in Southwestern Ukraine. Ciocârlan (2000) and Săvulescu (1952-1976) indicate grasslands, but also shrub vegetation, forest edges, and clearings as habitats of *Clematis integrifolia* in Romania. Coldea et al. (2012) mentions the species for the association *Geranio-Dictamnetum* Wendelbg. 1954 (alliance *Geranion sanguinei*).

Species occuring in semi-dry grasslands named by Chytrý et al. (2007) as diagnostic and constant for the *Brachypodio-Molinietum arundinaceae* are *Ranunculus polyanthemos, Trifolium montanum,* and *Festuca stricta* subsp. *sulcata*. Other species of basiphilous dry and semi-dry grasslands which are diagnostic for the local

Brachypodio-Molinietum are, for example, *Leucanthemum vulgare, Seseli annuum, Danthonia alpina, Fragaria viridis,* or *Koeleria macrantha* (see Table 25).

Figure 68: *Clematis integrifolia* in the Great Meadow (Borșa commune, 09.06.2009)

Finally, *Potentilla alba, Inula hirta* and *Peucedanum cervaria* are species of thermophilic forests and their fringes named by Chytrý et al. (2007) as diagnostic and constant for the *Brachypodio-Molinietum arundinaceae.* Other species of thermophilic forests and scrubs and their fringes which are diagnostic for the local *Brachypodio-Molinietum* are *Dichoropetalum carvifolia* (synonym: *Peucedanum carvifolia*), *Rosa gallica*, and *Euphorbia epithymoides* (synonym: *E. polychroma*) (see Table 25).

The occurrence of character species of subcontinental mixed *Potentilla*-oak forests (*Potentillo albae-Quercion petraeae*), namely *Potentilla alba* and *Inula hirta,* and of thermophilic mixed oak forests (*Quercion / Quercetalia pubescenti-petraeae*), namely *Peucedanum cervaria*, *Rosa gallica,* and *Euphorbia epithymoides*, may be explained by the replacement of the corresponding forest communities through this association. For example, Chytrý et al. (2007) state that the *Brachypodio-Molinietum arundinaceae* grasslands are replacing beech and hornbeam forests, and Illyés et al. (2007) write that they developed after clearing of *Fagus, Quercus-Carpinus,* and *Quercus* forests, which included islands of the association *Potentillo albae-Quercetum petraeae.*

Seventeen of the 31 diagnostic species identified are characteristic species of semi-dry grasslands, and thus warrant assignment to a corresponding alliance. Chytrý et al. (2007) place the association into the alliance of subatlantic basiphilous semi-dry grasslands *Mesobromion erecti* (Br.-Bl. et Moor 1938) Oberd. 1957 (synonym: *Bromion erecti* Koch 1926), while Willner et al. (2019) assign it to the alliance of subcontinental semi-dry grasslands *Cirsio-Brachypodion pinnati*.

According to Willner et al. (2019), the best diagnostic taxa to distinguish these two alliances are *Festuca* Ser. *Ovinae* (mostly *F. guestfalica*) for the *Mesobromion* and *Festuca* Ser. *Valesiacae* (mostly *F. stricta* subsp. *sulcata*) for the *Cirsio-Brachypodion*. Thus, the occurrence of *Festuca stricta* subsp. *sulcata* in the studied vegetation type speaks for the assignment to the *Cirsio-Brachypodion pinnati*. However, Willner et al. (2019) also state that there are several associations which have a transitional position between the two alliances, for example the *Brachypodio-Molinietum arundinaceae.*

3.3.6.2.2 Correspondences with *Brachypodio-Molinietum arundinaceae* in the White Carpathians

The assignment of the vegetation type to the *Brachypodio-Molinietum arundinaceae* is supported, in addition to the diagnostic species listed in the previous chapter, by the correspondences of the following characteristics of the studied sites with sites of the association in the White Carpathians described by Klika (1939), Chytrý et al. (2007), Illyés et al. (2007), Hájková et al. (2011), Roleček et al. (2014), and Fajmonová et al. (2020):

- The climatic conditions of the area in the south-western part of the White Carpathians (WC), where the *Brachypodio-Molinietum* is mainly found, are comparable to the conditions of the study area: mean annual temperature WC: 7.0 – 8.5°C (Roleček et al. 2014), study area: 8.2°C; mean annual precipitation WC: 630 – 840 mm, study area: 550 – 700 mm.
- The bedrock at the sites with *Brachypodio-Molinietum* consists mainly of calcareous sediments of Tertiary age, on which base-rich to moderately base-rich soils have developed (Roleček et al. 2014), as in the case of the study area. Accordingly, Klika (1939) indicates the *Brachypodio-Molinietum* on Tertiary clay marls and sandstones of the White Carpathians.
- Another shared feature of the sites with *Brachypodio-Molinietum* are an unstable bedrock with slope movements like sliding or slumping, which could create a characteristic complex topography supporting a mosaic of wet, mesic and dry sites (Roleček et al. 2014), like in the studied meadows.
- In their comparison of *Brachypodio-Molinietum* grassland sites in the White Carpathians, the Ukraine, and Transylvania, Roleček et al. (2014) found that the grasslands occurred in similar landscapes, mostly hilly regions suitable for mesophilous species, but with links to sources of forest-steppe species. This is also

the case in the study area, with mesophilous oak-hornbeam forests as potential natural vegetation (see Chapter 2.5), but bordering to the Transylvanian Plain, which has more of a forest-steppe character (Kun et al. 2004).

- According to Chytrý et al. (2007), the stands of this association are composed of species of meadows, dry grasslands, open forests, and forest fringes, including species of intermittently moist soils, which corresponds to what was found in the studied meadows. The presence of meadow species indicating intermittently moist/dry conditions is also mentioned by Hájková et al. (2011) and Illyés et al. (2007) for this association, caused by a high clay content of the soil (Hájková et al. 2011); this is the case in the study meadows as well.
- One of the most striking characteristics of the *Brachypodio pinnati-Molinietum arundinaceae* is its extremely high vascular plant species richness, mentioned by numerous authors, e.g. Chytrý et al. (2007), Illyés et al. (2007), Hájková et al. (2011), Roleček et al. (2014), Chytrý et al. (2015), and Willner et al. (2019). Roleček et al. (2014) indicate mean species richness values for the *Brachypodio-Molinietum* from sites in the Ukraine and the Czech White Carpathians of 54-57 respectively 62 species on 10 m^2. With a mean vascular plant species richness of 56 +/- 8 species on 10 $m^{2,}$ the studied relevés also show this feature.
- In the White Carpathians, the grasslands belonging to this association have been traditionally mown for hay once a year, usually in summer, with occasional aftermath grazing in the late summer and autumn (Chytrý et al. 2007; Bonari et al. 2017). Intensive management, such as application of mineral fertilizers, intensive grazing, or ploughing was rare or absent (Roleček et al. 2014). This corresponds to the traditional meadow management in the study area (see Chapter 4.3.2).
- There seems to be a long continuity of human activities since prehistoric times in the areas with extremely species-rich semi-dry grassland in the White Carpathians, the south-western Ukraine, and Transylvania (Hájková et al. 2011; Roleček et al. 2014). These activities probably helped maintain an ancient pool of Eurasian forest-steppe and hemiboreal forest species (Roleček et al. 2014; Fajmonová et al. 2020), like *Veratrum nigrum* (see Figure 69), *Serratula coronata* (see Chapter 3.3.5.2), or *Adenophora liliifolia* (Roleček et al. 2014). Many of these species are heliophilous species with disjunct distributions, like *Danthonia alpina* and *Dichoropetalum carvifolia* (Hájková et al. 2011), both of which are diagnostic for the *Brachypodio-Molinietum arundinaceae* in the studied meadows.

Figure 69: *Veratrum nigrum* below the slope edge in the Lord's Meadow (Dăbâca commune, 28.07.2010)
Other species on the picture: *Geranium pratense, Adonis vernalis, Anthericum ramosum,* and *Brachypodium pinnatum*

3.3.6.2.3 Relation to other associations

The assignment of the vegetation type to the *Brachypodio-Molinietum arundinaceae* is highly supported by the correspondences listed in the previous chapter, even though this association is not included in the current synopses of the vegetation of Romania (Sanda et al. 2008; Coldea et al. 2012) nor the monography about the vegetation of Cluj County by Pop et al. (1999-2000). However, there have been recent publications mentioning the occurrence of the *Brachypodio-Molinietum arundinaceae* directly or indirectly in Transylvania (see Chapter 3.3.6.5).

In some of these publications, the association is synonymized with the *Festuco sulcatae-Brachypodietum pinnati* Soó 1927, more precisely by Willner et al. (2019), who denote this name as the oldest valid name used for the *Brachypodio-Molinietum arundinaceae* (see also Chapter 3.3.8.2). Similarly, Roleček et al. (2019) assign the world record relevé of vascular plant diversity on $10m^2$ reported by Dengler et al. (2012) in the nearby nature reserve 'Hay Meadows of Cluj', classified at the time as *Festuco sulcatae-Brachypodietum pinnati*, to the *Brachypodio-Molinietum arundinaceae* 'in a broadly conceived sense'.

Interestingly, in the species list of the mentioned 'world-record-relevé' provided by Roleček et al. (2019), as well as in the repetition of the sampling by Roleček et al. (2021), numerous species indicating intermittently moist conditions are either missing, like *Genista tinctoria* and *Sanguisorba officinalis,* or present with low cover values, like *Molinia arundinacea*, *Serratula tinctoria, Inula salicina, Galium boreale,* or *Clematis integrifolia.* On the other hand, in the first description of the *Brachypodio-Molinietum* by Klika (1939), *Inula salicina, Galium boreale* and *Clematis integrifolia* are also not mentioned, and *Molinia arundinacea, Serratula tinctoria,* and *Sanguisorba officinalis* are indicated only as accompanying species.

Based on the above, it becomes clear that analysis of more relevés from Transylvania is needed to conclusively clarify the relationship between the *Brachypodio-Molinietum* and the *Festuco sulcatae-Brachypodietum pinnati*, especially in comparison to the *Polygalo majoris-Brachypodietum pinnati* (see Chapter 3.3.8.2).

For instance, one could postulate a broad conception of the *Brachypodio-Molinietum arundinaceae*, as Roleček et al. (2019) also suggest, and include stands into the association with more drought-tolerant species and fewer species indicating intermittently moist conditions. An example of this would be the *Festuco sulcatae-Brachypodietum pinnati*-relevés listed by Dengler et al. (2012). Stands with many indicators for alternating soil moisture, mentioned for example by Chytrý et al. (2007), Illyés et al. (2007), and Hájková et al. (2011) would be included in this broad conception as well.

The vegetation type described in this chapter belongs to the latter type, that is, the *Brachypodio-Molinietum arundinaceae* with indicator species of alternating moisture. It seems to be part of a vegetation complex along a humidity gradient which is found throughout the studied meadows several times. The sequence of elements from moister to drier conditions are:

- Moderately moist: *Molinietum caeruleae* (with *Molinia arundinacea*)
- More mesic with alternating soil moisture: *Brachypodio-Molinietum arundinaceae*
- Semi-dry: *Polygalo-Brachypodietum* (or *Brachypodio-Molinietum arundinaceae* 'sensu lato')

The *Brachypodio-Molinietum arundinaceae* 'with alternating moisture indicators' discussed here thus occurs in the transitional area between the moist and semi-dry sites.

An alternative view to the designation of an independent association *(Brachypodio-Molinietum arundinaceae)* would be the use of an ecologically defined subassociation. For example, the vegetation type described here could be a subassociation of the semi-dry association, e.g. *Polygalo-Brachypodietum pinnati molinietosum arundinaceae*', or, vice-versa, the *Polygalo-Brachypodietum pinnati* discussed in Chapter 3.3.8 could be a subassociation of the *Brachypodio-Molinietum arundinaceae* on drier sites, e.g. *'Brachypodio pinnati-Molinietum arundinaceae salvietosum*'. Interestingly, Klika (1939) describes the subassociation *Brachypodio-Molinietum stipetosum stenophyllae,* which has similarities to the *Danthonio-Stipetum stenophyllae* described in Chapter 3.3.10.

The decision of whether the vegetation type discussed here has the rank of an independent association or only a subassociation is, ultimately, based on whether the diagnostic species are valid association character species, or only differential species of a subassociation. Here, the vegetation type is described as a distinct association, because the species composition and other characteristics largely correspond to the *Brachypodio-Molinietum arundinaceae* mentioned in the literature; however, further research should be carried out to delineate and classify the plant communities along the aforementioned moisture gradient.

There are several descriptions of contact communities between *Molinia* meadows and semi-dry grasslands, which are counted as belonging to either the *Molinion* or the *Mesobromion erecti*; an overview is given by Buchwald (1996). The relatively frequent transitional communities between *Molinia* meadows and semi-dry grasslands show that there are many species that can occur both in (intermittently) dry *Molinia* meadows and (intermittently) moist semi-dry grasslands, such as *Carex filiformis, Galium boreale, Serratula tinctoria,* or *Brachypodium pinnatum* (Buchwald 1996).

3.3.6.3 Environmental and ecological conditions

Most of the relevés are north-facing (six of 10); other cardinal directions are north-northeast, northwest, and east (see Table 9, page 64). The stands have a slight inclination (median: 2°), which indicates that the vegetation type is found on relatively flat parts within the hillslope (see Table 8, page 64).

The unweighted Ellenberg indicator value for nutrient availability N = 3.4 ± 0.1 for this vegetation type (see Table 3, page 57) reflects the occurrence of species that grow more frequently on nitrogen-poor sites than on sites moderately rich in nitrogen (Ellenberg et al. 2001).

The main reasons for the nutrient deficiency as compared to the conditions in the *Molinia* meadows may be low-intensity management without fertilizer supply and drying-out of the topsoil in summer, which can lead to temporarily inhibited or even interrupted decomposition of organic matter and thus an irregular mineralization (Buchwald 1996).

The unweighted Ellenberg indicator value for soil moisture M = 4.3 ± 0.2 for the studied *Brachypodio-Molinietum* relevés reflects their intermediate position between the moderately moist sites of the local *Molinietum caeruleae* and *Calamagrostis*-community (moisture indicator value around 5.4) and the slightly drier, but still semi-dry sites of the *Polygalo-Bachypodietum* and the *Cirsium furiens*-community (moisture indicator value around 3.8, see also Table 3, page 57). This is consistent with the assumption that the *Brachypodio-Molinietum* takes the central position in a vegetation zonation along a gradient of humidity described in the previous chapter.

Another feature of the relevé sites are changing moisture levels in the upper soil layers, indicated by many species adapted to intermittently moist or dry conditions, which, according to Buchwald (1996), are often also indicators of nutrient shortage. From the 31 diagnostic species of this vegetation type, 14 species, i.e. 45 % of the diagnostic species, indicate alternating soil moisture conditions.

3.3.6.4 Occurrence of the plant community in the study hay meadows

The 10 relevés classified as *Brachypodio-Molinietum arundinaceae* have been recorded in different meadows: four in the Lord's Meadow, two in the Village Meadow, three in the *former hay meadow* Meadow Hill, and one in the Great Meadow (see Figure 70). Our observations in the field also confirm that the vegetation type occured in all three *utilised hay meadows* and in the Meadow Hill at the time of the data collection.

Figure 70: Stand of the *Brachypodio-Molinietum arundinaceae* (in the foreground) in front of a *Molinietum caeruleae* stand with *Molinia arundinacea* (in the middle part of the image) in the Great Meadow (Borșa commune, 23.08.2019)
Noticeable are the numerous inflorescences of *Daucus carota*, a disturbance indicator. Other visible species are for example *Sanguisorba officinalis, Phragmites australis, Galium boreale,* and *Clematis recta.*

An observed pattern was that stands of this vegetation type often occurred adjacent to *Molinietum caeruleae* stands, such as in the Lord's Meadow and the Great Meadow (see Figure 70Figure 70), but not exclusively; in the Great Meadow (*Fânaia* part), the vegetation type also occured independently. In general, there could be differences between the *Brachypodio-Molinietum* stands of the different hay meadows; for example, during a 2019 site visit, more *Brachypodium pinnatum* was observed in the *Fânaia* part than in the *Sekelişte part* of the Great Meadow, where, on the other hand, more *Equisetum arvense* was present.

The number of relevés in the studied dataset is not indicative of the actual area occupied by the vegetation type; the *Brachypodio-Molinietum* was also widespread in the Great Meadow, which was most recently confirmed during a 2019 site visit. However, the current extent and condition of the vegetation type, especially in light of increased sheep grazing in recent years, would need to be investigated.

3.3.6.5 Occurrence of the plant community in Romania

In the classification of semi-dry grasslands in Central and Eastern Europe by Willner et al. (2019), relevés in several European countries have been assigned to the *Brachypodio-Molinietum*. This includes relevés from the Romanian Grassland Database (EU-RO-008) (Vassilev et al. 2018), mainly in Transylvania (see Figure 71). According to Willner et al. (2019), the association is restricted to the Carpathian fringes, and plots assigned to the *Brachypodio-Molinietum* outside the Carpathians might be considered as misclassified.

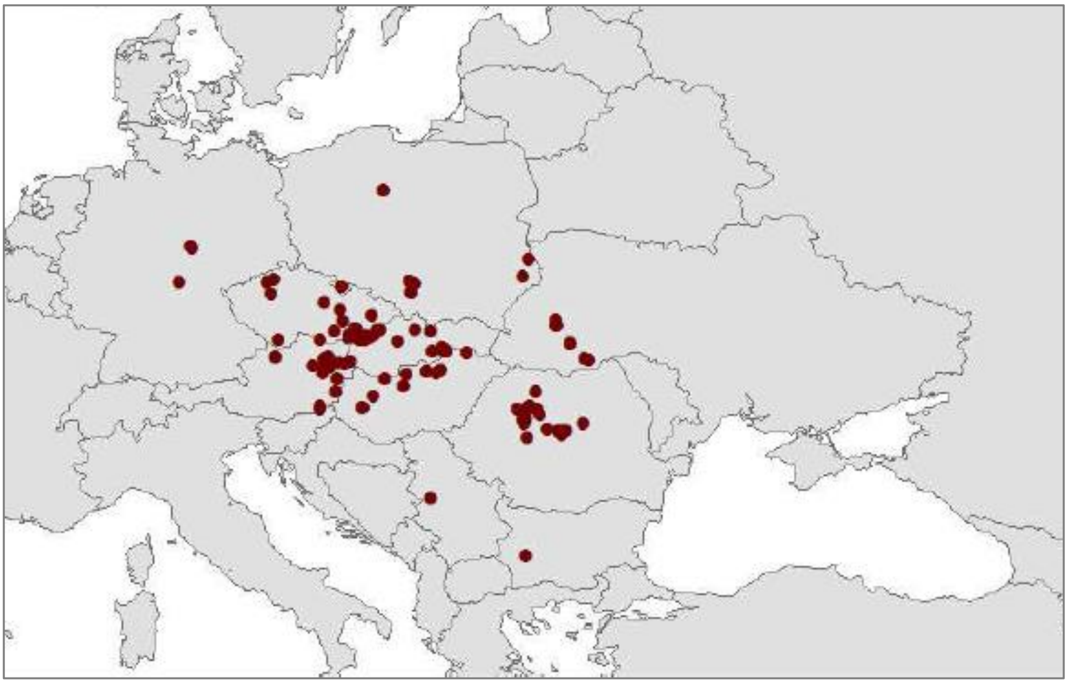

Figure 71: Location of relevés in Central and Eastern Europe classified as *Brachypodio pinnati-Molinietum arundinaceae*; from: Willner et al. (2019), electronic appendix 7, page 11

The association has been mentioned indirectly by Dengler et al. (2012) and Roleček et al. (2014) as similar to the *Festuco sulcatae-Brachypodietum pinnati* Soó 1927, both referring to data from the nature reserve 'Hay Meadows of Cluj' and the 'Nature Reserve of the Steppe Peonys'. Furthermore, one relevé in the nature reserve 'Hay Meadows of Cluj' has been directly assigned by Roleček et al. (2019) to the *Brachypodio-Molinietum* (variant without indicator species for alternating soil moisture, see Chapter 3.3.6.2).

3.3.6.6 Conservation value and protection status

Two vascular plant species of conservation concern occur in the 10 relevés made in this vegetation type: *Gentiana pneumonanthe* in half of the relevés, and *Iris sibirica* in one relevé (see Table 12, page 67). Furthermore, two host plants of three different *Phengaris* taxa have an important occurrence in this plant community, at least according to the analysed vegetation table: *Sanguisorba officinalis* (in 40 % of the relevés) and *Gentiana pneumonanthe* (in 50 % of the relevés).

On the European red list of habitats by Janssen et al. (2016), the group of semi-dry perennial calcareous grasslands (EUNIS 2007 code E1.2a) is classified as vulnerable. Additionally, the *Brachypodio-Molinietum arundinaceae* as part of the alliance *Cirsio-Brachypodion pinnati* is included in Annex I of the EU Habitats as part of the habitat type 6210 (Olmeda et al. 2019).

Furthermore, the high ecological value of the *Brachypodio-Molinietum arundinaceae* is also based on its high richness of vascular plant species and its assumed rarity due to the sparse mentions in the relevant literature.

3.3.7 *Festuca pratensis*-[Cirsio-Brachypodion pinnati]-community

Vegetation type: Informal community of semi-dry basiphilous grassland

Names:

English: Meadow fescue-community
Romanian: Comunitate de păiuș de livadă
German: Wiesen-Schwingel-Gesellschaft

Information relevés:

Number: 8
Type, size, year: phytosociological relevés, 25 m^2, 2009
Surveyors: 2 different persons / teams

Locations:

Dăbâca: Lord's Meadow (7)
Borșa: Great Meadow (1)

3.3.7.1 Structure and species composition

The following descriptions are based on eight phytosociological relevés carried out in the year 2009 in the Lord's Meadow (n= 7) and the Great Meadow (n = 1). The surveyed parameters of vegetation structure are shown in Table 27.

Table 27: Data on vegetation structure for the *Festuca pratensis*-community

Total cover (n = 8)	mean +/- SD	97.6 % +/- 3.9 %
	min. - max.	90.0 % - 100.0 %
Average hight of herb layers (n = 7)	mean +/- SD	29 cm +/- 11 cm
	min. - max.	15 cm - 50 cm
Max. hight of herb layers (n = 7)	mean +/- SD	107 cm +/- 19 cm
	min. - max.	80 cm - 130 cm
Shrub hight (n = 1)	mean	0.4 m
	max.	0.7 m
Shrub cover (n = 1)		8 %
Share of relevés with *Crataegus monogyna*		25 %
Share of relevés with *Rosa micrantha*		13 %

When selecting the plots, preference was given to the stands with high cover of *Festuca pratensis* (synonym: *Schedonorus pratensis*) by one of the authors (S. Bădărău, personal communication, July 2009). As a consequence, the most prominent feature of this vegetation type is the high cover of *Festuca pratensis*: in half of the relevés it was recorded with the Braun-Blanquet value 3 (25-50 % cover), and in three of eight relevés with the Braun-Blanquet value 4 (50-75 % cover).

The pattern of co-dominant grass and sedge species is quite heterogenous: The second most common *Poaceae* species is *Danthonia alpina* (over 25 % cover in three relevés), while the following species reach high cover values only in single relevés:

Festuca stricta subsp. *sulcata*, *Elytrigia intermedia*, *Brachypodium pinnatum*, *Arrhenatherum elatius,* and *Carex caryophyllea*.

Apart from *Festuca pratensis*, forb species are, in most of the relevés at least as dominant as the mentioned graminoid species. Examples include *Stachys officinalis*, *Centaurea phrygia*, *Galium verum*, *Filipendula vulgaris*, *Serratula tinctoria*, *Sanguisorba officinalis*, *Securigera varia*, *Dichoropetalum carvifolia*, *Clematis recta*, *Rhinanthus minor*, *Campanula glomerata,* or *Cruciata laevipes*.

The total cover of the vegetation averages 97.6 % +/- 3.9 %, which is the third highest value after the *Mentho-Juncetum* and *Molinietum caeruleae*. The mean height of the herb layers averages 29 cm and ranges between 15 and 50 cm, while the maximum height of the herb layers averages 107 cm and ranges between 80 and 130 cm.

Phanerophytes occur in two of eight relevés (*Crataegus monogyna* and *Rosa micrantha*), but only in one relevé were the *Crataegus monogyna* specimens taller than 0.5 m and thus attributed to the shrub layer.

3.3.7.2 Syntaxonomy and diagnostic species

Class:	*Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947
Order:	*Brachypodietalia pinnati* Korneck 1974 *nom. conserv. propos.*[a]
Alliance:	*Cirsio-Brachypodion pinnati* Hadač et Klika in Klika et Hadač 1944[b]
Community:	*Festuca pratensis*-[Cirsio-Brachypodion pinnati]-community

Selected synonyms:

[a] *Brometalia erecti* Koch 1926 *nom. ambig. rejic. propos., Brometalia erecti* Br.-Bl. 1936 *nom. ambig. rejic. propos.*

[b] *Festucion sulcatae* Soó 1938, *Danthonio-Brachypodion* Boșcaiu 1970

The nomenclature and selected synonyms of the class, order, and alliance come from Mucina et al. (2016).

From the species identified as diagnostic for this vegetation type, none meet the formal criteria of valid character species for a certain plant association. Therefore, it is not possible to assign the vegetation type to any association. For instance, the species with the highest cover values, *Festuca pratensis,* has its ecological optimum in many plant communities, while character species have their main occurrence more or less clearly in one association (Dierschke 1994). *Festuca pratensis* occurs, for instance, in damp meadows and pastures of the class *Molinio-Arrhenatheretea* (Rothmaler 2005; Coldea et al. 2012), but also in semi-dry grasslands with alternating soil dryness (Rothmaler 2005).

Festuca pratensis does not fulfil the criteria for differential species related to the frequency class either (Dierschke 1994), as it is only diagnostic for this vegetation type according to the statistical fidelity value (phi-coefficient). The species occurs in six of the nine identified communities, with frequency classes between II and IV. In this vegetation type, it occurs with the frequency class of V, and it has also higher cover values than in the other communities (in seven of eight relevés 25 % cover or higher, see also Table 28 and Annex 1).

Five more species are diagnostic mainly for this vegetation type according to the frequency class or percentage frequency (see Table 28): *Cruciata laevipes, Clematis recta* (see Figure 72), *Gentiana cruciata* (see Figure 73), *Onobrychis arenaria,* and *Pyrus communis* subsp. *pyraster. Gentiana cruciata* is the host species for *Phengaris alcon 'cruciata'*. In the analysed data set, it is diagnostic only for this vegetation type, and occurs also in the *Polygalo-Brachypodietum*. In the study area it was generally observed more frequently in the (semi)dry grasslands of the south-facing slopes than in the north-facing hay meadows. *Pyrus communis* subsp. *pyraster* occurs only in two relevés of this vegetation type when referring to the entire vegetation table, but there are scattered specimens in all three *utilised hay meadows*.

Table 28: Fidelity values and preferential occurrence in plant communities of selected diagnostic species of the *Festuca pratensis*-community

	Festuca pratensis	***Cruciata laevipes***	***Clematis recta***	***Gentiana cruciata***	***Onobrychis arenaria***	***Pyrus communis* subsp. *pyraster***
	Fidelity values: perc (class) *fid*					
***Festuca pratensis*-comm.**	100 (V) *fid 46*	63 (IV) *fid 46*	75 (IV) *fid 58*	50 (III) *fid 64*	38 (II) *fid 48*	25 (II) *fid 48*
Molinietum caeruleae	25 (II)	25 (II)				
Calamagr. epigejos -comm.	50 (III)		20 (I)			
Brachypodio-Molinietum	60 (III)	10 (I)	20 (I)			
Polygalo-Brachypodietum	33 (II)	28 (II)	25 (II)	6 (I)	14 (I)	
Cirsium furiens- comm.	63 (IV)	13 (I)				
Braun-Blanquet-values	4, 3, +	+	+	+		+
Coldea et al. (2012)	p. 225-231: **class** *Molinio-Arrh.*	p. 275-281: **class** *Galio-Urticetea*	p. 110-115: **class** *Trifolio-Geranietea*	p. 110-115: **alliance** *Cirsio-Brachypodion* / **order** *Brachypodie-talia*	p. 110-115: **order** *Festucetalia valesiacae*	-

Perc = percentage frequency; class = frequency class; fid = statistical fidelity; empty cells = zero. The Braun-Blanquet-values are indicated for the *Festuca pratensis*-community. The fidelity measure is the phi-(Φ)-coefficient of association. Species with phi-coefficient values of at least 20 are considered diagnostic; species with phi-coefficient values of at least 45 are considered highly diagnostic (indicated by fid** and green colour).

All these diagnostic species, which belong to distinct sociological groups, mostly occur with low cover values (less than 1%) and are therefore, at most, weak differential species (see Table 28). Without good differential species it is also not possible to assign the vegetation type to any subassociation. Therefore, this vegetation type is defined here as an informal plant community as described by Dengler (2003), based on the concept of rank-free communities (see also Dierschke 1994).

Figure 72: *Clematis recta* near the Great Meadow (Borșa commune, 29.05.2013)

Figure 73: *Gentiana cruciata* in the Great Meadow (Borșa commune, 13.07.2009)

Dengler (2003) mentions the need of a preliminary classification as one of the justified cases for the application of an informal community. That means, as in this case, that there are still too few relevés available to decide whether the vegetation type is an independent association or, which seems more likely for now, whether it can be assigned to an existing association, for example as a variant or facies.

The informal plant community is named after the dominant species *Festuca pratensis*, which is recorded as *Schedonorus pratensis* in the Euro+Med PlantBase (Euro+Med 2006+) and *Lolium pratense* in the International Plant Names Index (IPNI 2000+).

Both abiotic site factors (water regime, soil) and management could play a role in the formation of the *Festuca pratensis*-community. For instance, there are several more nutrient-demanding diagnostic species *(Festuca pratensis, Cruciata laevipes, Arrhenatherum elatius)* and the mean Ellenberg indicator value for nutrient availability (N) is slightly higher compared to the *Brachypodio-Molinietum* and the *Polygalo-Brachypodietum* (see next chapter).

The following considerations concern the assignment of the informal community to a higher syntaxon: The vegetation type has several diagnostic species which are diagnostic for the class *Molinio-Arrhenatheretea* and its subunits and, at the same time, also diagnostic for the order of semi-dry grasslands *Brachypodietalia pinnati* according to Willner et al. (2019): *Festuca pratensis*, *Arrhenatherum elatius*, *Rhinanthus minor,* and *Ranunculus acris* (see Table 29)*.* On the other hand, there are diagnostic or constant species occurring mainly in semi-dry grasslands: *Campanula glomerata*, *Plantago media, Danthonia alpina,* and *Gentiana cruciata*.

Table 29: Selected diagnostic species of the *Festuca pratensis*-community (14 from a total of 16)

Diagnostic mainly for this vegetetation type	*Festuca pratensis, Cruciata laevipes, Clematis recta, Gentiana cruciata, Onobrychis arenaria, Pyrus communis* subsp. *pyraster*
Wet meadows	*Sanguisorba officinalis, Clematis integrifolia*
Mesic and semi-dry grassland communities	*Arrhenatherum elatius, Ranunuculus acris, Rhinanthus minor*
Basiphilous (semi-)dry grassland communities	*Campanula glomerata*
Fringe communities	*Veronica orchidea, Hieracium umbellatum*

Although the *Molinio-Arrhenatheretea* species are quite frequent in this vegetation type, including the dominant *Festuca pratensis*, the semi-dry grassland species are nevertheless present to a greater extent so that this vegetation type is included here into the subcontinental alliance of semi-dry basiphilous grasslands, the *Cirsio-Brachypodion pinnati.* Hence, the complete name of the vegetation type is *Festuca pratensis*-[Cirsio-Brachypodion pinnati]-community.

Based on the positioning of the vegetation type in the DCA biplot (see Chapter 3.3.1.3) and the course of the classification by TWINSPAN (see Chapter 3.3.1.1), the greatest similarity of this vegetation type is to the *Brachypodio-Molinietum arundinaceae*, of which it could be a *Festuca pratensis*-facies.

A comparison with plant communities dominated by *Festuca pratensis* known from the relevant literature did not reveal enough similarities with other existing associations to justify an assignment of this vegetation type. For example, the *Cirsio cani-Festucetum pratensis* Májovski et Ruzicková 1975 (synonym *Festucetum pratensis* Soó 1938) belongs to the *Deschampsion cespitosae* (Coldea et al. 2012), while the *Sanguisorbo-Festucetum pratensis* Blažková 1973 belongs to the *Molinion caeruleae* (Blažková 1973).

The syntaxonomical classification of the *Festuca pratensis*-[Cirsio-Brachypodion pinnati]-community and the correlation of the diagnostic species with this vegetation type need to be verified with more relevé data from all three hay meadows. In this way, methodological sources of error (proximity of the relevés to each other, targeted selection of the plots towards *Festuca pratensis*) can also be excluded.

3.3.7.3 Environmental and ecological conditions

All relevés for which the exposition has been recorded (seven of eight) are north-facing (see also Table 9, page 64). The plots have only a slight inclination (median: 1.5°), which indicates that the vegetation type is found on relatively flat parts within the hillslopes, comparable to the sites of the *Molinietum caeruleae* (median: 1.5°; see also Table 8, page 64).

The mean unweighted Ellenberg indicator value for soil moisture M = 4.3 for the studied relevés (see Table 3, page 57) reflects the favoured occurrence of species that grow in slightly dry locations (Dierschke and Briemle 2008). The moisture indicator value for this group corresponds to the value of the *Brachypodio-Molinietum* (4.3) and is higher than the value for the *Polygalo-Brachypodietum* (3.8). These values confirm the general classification as a semi-dry vegetation type with slightly more mesic character than the *Polygalo-Brachypodietum*, indicated by species like *Festuca pratensis* and *Arrhenatherum elatius*.

The mean unweighted Ellenberg indicator value for nutrient availability N = 3.6 for this vegetation type reflects the favoured occurrence of species that grow on N-poor to moderately N-rich sites (Dierschke and Briemle 2008). The value is slightly higher than the values of the *Brachypodio-Molinietum* and the *Polygalo-Brachypodietum* (3.4).

There are several diagnostic species which are characteristic for fringe communities (six of 16): *Cruciata laevipes, Clematis recta, Gentiana cruciata*, *Veronica orchidea*, *Campanula glomerata,* and *Hieracium umbellatum*, supplemented by frequent species like *Securigera varia, Centaurea phrygia, Galium verum* or *Dichoropetalum carvifolia*. The presence of these species could be an indicator of mowing abandonment.

Like most of the identified vegetation types, the *Festuca pratensis*-community also includes several indicator species for alternating soil moisture or dryness (four of 16 diagnostic species): *Festuca pratensis*, *Sanguisorba officinalis*, *Clematis integrifolia*, to some extent also *Arrhenatherum elatius* (Rothmaler 2005), as well as frequent species like *Stachys officinalis*, *Galium verum*, *Filipendula vulgaris,* or *Serratula tinctoria.*

3.3.7.4 Occurrence of the plant community in the study hay meadows

Seven of eight relevés were made in the Lord's Meadow (see Figure 36, page 55) and one relevé was recorded in the Great Meadow (see Figure 39, page 56). Only further studies can clarify whether the main occurrence of the *Festuca pratensis*-community is actually in the Lord's Meadow and to which extent it occurs in the other hay meadows. In any case, the vegetation type covers distinctly smaller areas than the *Polygalo-Brachypodietum* in the studied hay meadows.

3.3.7.5 Occurrence of the plant community in Romania

The vegetation type is provisionally described as an informal plant community and needs further investigation. No correspondences were found in the relevant phytosociological publications.

3.3.7.6 Conservation value and protection status

The mere fact that the *Festuca pratensis*-community is an extensively used type of meadow steppe endows it with a high conservation value. In total, six vascular plant species of national conservation concern have been found in the eight relevés made in this vegetation type, which is, together with the *Polygalo-Brachypodietum*, the highest amount of all vegetation types.

The following plant species, which are classified by Dihoru and Dihoru (1994) and Oltean et al. (1994) as rare or vulnerable, each appear in one relevé of the *Festuca pratensis*-community: *Adonis vernalis*, *Gladiolus imbricatus, Rosa micrantha,* and *Serratula coronata*. Two vulnerable or rare species each occur in two relevés of this vegetation type: *Gentiana pneumonanthe* and *Seseli peucedanoides* (see also Table 12, page 67).

Another important point for the definition of conservation and management objectives is the occurrence of three host plants of four different *Phengaris* taxa in the *Festuca pratensis*-community, especially *Gentiana cruciata*, the host plant for *Phengaris alcon 'cruciata'*. The other two host species are *Sanguisorba officinalis* (for *Phengaris nausithous* and *P. teleius*) and *Gentiana pneumonanthe* (for *Phengaris alcon 'pneumonanthe'*).

Since the *Festuca pratensis*-community is assigned to the alliance *Cirsio-Brachypodion pinnati*, it is included in Annex I of the EU Habitats Directive as part of the habitat type 6210 (Olmeda et al. 2019).

3.3.8 *Polygalo majoris-Brachypodietum pinnati* Wagner 1941

Vegetation type: Semi-dry basiphilous grassland

Names:

English:	Semi-dry grassland of large milkwort and tor-grass
Romanian:	Pajiște semi-uscată de *Brachypodium pinnatum* cu *Polygala major*
German:	Kreuzblumen-Fiederzwenkenrasen

Information relevés:

Number:	36
Type, size, year:	15 phytosociological relevés, 25 m^2, 2009
	21 diversity-relevés, 25 m^2 (n = 3) or 10 m^2 (n = 18), 2012 & 2013
Surveyors:	9 different persons / teams

Locations:

Dăbâca:	Lord's Meadow (5), Village Meadow (16), Meadow Hill (3)
Borșa:	Great Meadow (11), Jacob's Meadow (1)

3.3.8.1 Structure and species composition

With 36 relevés, this vegetation type is the best studied in the considered hay meadows. The relevés were carried out in all three *utilised* and both *former hay meadows* in the years 2009, 2012 and 2013. The surveyed parameters of vegetation structure are shown in Table 30.

The vegetation type is characterized by a dense vegetation cover; the mean total cover of vascular plant species amounts to 96.8 %. There are few dominant species, namely the three grass species *Brachypodium pinnatum, Festuca stricta* subsp. *sulcata,* and *Elytrigia intermedia,* which can be regarded as highly dominant, i.e. their cover value exceeds 25 % in at least 10 % of the relevés (following Chytrý 2007a).

Furthermore, there are 39 constant species, many of them herbs, which reach low cover values per relevé of 0.1 % to 5 %, more rarely up to 25 %. Highly constant species (frequency over 80 %) are, for example, *Achillea millefolium, Centaurea phrygia, Filipendula vulgaris, Galium verum, Medicago falcata, Plantago media, Ranunculus polyanthemos, Salvia pratensis,* and *Stachys officinalis*.

Some other constant herb species (frequency over 40 %) are *Adonis vernalis, Anthericum ramosum, Centaurea scabiosa, Lotus corniculatus, Scabiosa ochroleuca,* and *Trifolium montanum*. Due to the numerous herb species, the plant community is very colourful and flower-rich, especially in June and July (see Figure 74). Furthermore, six constant grass species have been identified, of which *Brachypodium pinnatum, Dactylis glomerata, Elytrigia intermedia,* and *Festuca stricta* subsp. *sulcata* are highly constant.

The vegetation can be subdivided into a dense low layer built up by the constant and dominant grass species *Brachypodium pinnatum* and *Festuca stricta* subsp. *sulcata* and the sedges *Carex michelii* and *C. filiformis*, and by many herb species like

Plantago media, Viola hirta, Adonis vernalis, Lotus corniculatus, or *Fragaria viridis,* as well as the lower leaves of higher growing herb species. The mean height of the lower herbs and grasses layer is 33 cm.

Table 30: Data on vegetation structure for the *Polygalo-Brachypodietum pinnati*

Total cover (n = 36)	mean +/- SD	96.8 % +/- 4.1 %
	min. - max.	80.0 % - 100.0 %
Cover bare ground (n = 21)	median	1.0 %
	min. - max.	0.0 % - 6.0 %
Cover bryophyte layer (n = 21)	median	0.5 %
	min. - max.	0.0 % - 50.0 %
Cover litter layer (n = 21)	median	80.0 %
	min. - max.	60.0 % - 100.0 %
Depth litter layer (n = 21)	median	0.8 cm
	min. - max.	0.1 cm - 4.0 cm
Mean hight of low herb layer (n = 21)	mean +/- SD	33 cm +/- 10 cm
	min. - max.	7 cm - 50 cm
Mean hight of tall herb layer (n = 21)	mean +/- SD	63 cm +/- 15 cm
	min. - max.	20 cm - 90 cm
Shrub cover (n = 2)	median	5.5 %
	min. - max.	4.0 % +/- 7.0 %
Shrub hight (n = 2)	mean +/- SD	0.7 m +/- 0.1 m
	max. +/- SD	0.8 m +/- 0.1 m
Share of relevés with: (n=36)	phanerophytes	47 %
	Crataegus monogyna	44 %
	Prunus spinosa	8 %
	Rosa canina	11 %

Secondly, there is a looser, higher vegetation layer characterized by taller growing species and the stems of species with rosettes, like *Elytrigia intermedia, Dactylis glomerata, Centaurea scabiosa, Salvia pratensis, Anthericum ramosum, Scabiosa ochroleuca, Knautia arvensis, Filipendula vulgaris,* or *Peucedanum oreoselinum* (see Figure 75). The mean height of the higher herbs and grasses layer is 63 cm.

Regarding the proportion of relevés with phanerophytes, 47 % of relevés contain at least one of the six considered woody species, mostly *Crataegus monogyna.* A shrub layer was recorded in only two releves, with a maximum height of 0.8 m and a median cover value of 5.5 % (see Table 30). The median cover value of bare ground amounts to 1.0 %, of the bryophyte layer to 0.5 %, and of the litter layer to 80.0 %. The measured median value of litter depth was 0.8 cm.

Figure 74: Flower-rich appearance of the *Polygalo-Brachypodietum pinnati* in the Village Meadow with *Peucedanum oreoselinum, Stachys officinalis, Centaurea phrygia, Jacobaea vulgaris, Clematis recta, Anthericum ramosum, Elytrigia intermedia,* etc. (Dăbâca commune, 19.07.2013)

Figure 75: *Polygalo-Brachypodietum pinnati* stand near the Great Meadow with *Dianthus carthusianorum, Filipendula vulgaris, Tragopogon pratensis* subsp. *orientalis, Salvia pratensis, Adonis vernalis, Galium verum, Brachypodium pinnatum,* etc. (Borșa commune, 29.05.2013)

3.3.8.2 Syntaxonomy and diagnostic species

Class:	*Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947
Order:	*Brachypodietalia pinnati* Korneck 1974 *nom. conserv. propos*.[a]
Alliance:	*Cirsio-Brachypodion pinnati* Hadač et Klika in Klika et Hadač 1944[b]
Association:	*Polygalo majoris-Brachypodietum pinnati* Wagner 1941[c]

Selected synonyms:

[a] *Brometalia erecti* Koch 1926 *nom. ambig. rejic. propos., Brometalia erecti* Br.-Bl. 1936 *nom. ambig. rejic. propos.*

[b] *Festucion sulcatae* Soó 1938, *Danthonio-Brachypodion* Boșcaiu 1970

[c] *Carici humilis-Brachypodietum* Soó 1949, *Danthonio-Brachypodietum* Soó 1949

The nomenclature and selected synonyms for the class, order, and alliance come from Mucina et al. (2016), and the nomenclature for the association follows Chytrý et al. (2007). Synonyms for the association were taken from Willner et al. (2019).

The vegetation type has been assigned to the association *Polygalo majoris-Brachypodietum pinnati* Wagner 1941. One of the reasons for this is that there are six species identified as diagnostic for this vegetation type which have been named as association character species by Wagner (1941) and Coldea et al. (2012) (see Table 31).

Of these, Wagner (1941) names *Brachypodium pinnatum, Polygala major, Carex michelii, and Cirsium pannonicum* as character species in his first description of the association for the north-eastern foothills of the Northern Limestone Alps (Vienna Woods) (see Table 31 and Table 32). Coldea et al. (2012) indicate *Polygala major* and *Cytisus albus* as association character species, which often reach cover values between 5 and 10 % in this association. In the studied dataset this is the case for *Cytisus albus*, while *Polygala major* reaches cover values of up to 1 %.

Coldea et al. (2012) also list *Rhinanthus rumelicus* (see Figure 76) as an association character species in the synoptic table fo the *Cirsio-Brachypodion* alliance (page 110 ff.). *Cytisus albus* and *Rhinanthus rumelicus* are referred to as regional Ponto-Balkanic elements of the *Cirsio-Brachypodion pinnati* in Romania by Coldea et al. (2012). Further character species for the *Polygalo majoris-Brachypodietum* named by Wagner (1941) occur only in few relevés of the *Polygalo-Brachypodietum,* like *Linum flavum, Galium glaucum* and *Phlomis tuberosa,* and were not identified as diagnostic for this vegetation type.

Table 31: Fidelity values and preferential occurrence in plant communities of selected diagnostic species of the *Polygalo-Brachypodietum pinnati*

	Brachypodium pinnatum	***Polygala major***	***Carex michelii***	***Cirsium pannonicum***	***Cytisus albus***	***Rhinanthus rumelicus***
	Fidelity values: perc (class) *fid*					
Polygalo-Brachypodietum	94 (V) *fid 37*	22 (II) *fid 25*	36 (II) *fid 44*	25 (II) *fid 28*	47 (III) *fid 62*	36 (II) *fid 36*
Caricetum vesicariae						
Mentho-Juncetum						
Molinietum caeruleae	19 (I)					
Calamagr. epigejos -comm.						
Brachypodio-Molinietum	60 (III)	10 (I)	20 (I)	10 (I)		
Festuca pratensis-comm.	38 (II)			13 (I)		
Cirsium furiens-comm.	69 (IV)	19 (I)		6 (I)	6 (I)	31 (II) fid 36
Danthonio-Stipetum	100 (V)					
Braun-Blanquet-values	5, 4, 3, 2, 1, +	+	2, 1, +	2, 1, +	3, 1, +	1, +
Wagner (1941), p. 50 ff.: table *Polygalo-Brachypodietum pinnati*	**association** *Polygalo-Brachypodietum*	**association** *Polygalo-Brachypodietum*	**association** *Polygalo-Brachypodietum*	**association** *Polygalo-Brachypodietum*	-	-
Coldea et al. (2012), p. 110 ff.: table *Cirsio-Brachypodion*	**alliance** *Cirsio-Brachypodion* / **order** *Brometalia*	**association** *Polygalo-Brachypodietum*	-	**alliance** *Cirsio-Brachypodion* / **order** *Brometalia*	**association** *Polygalo-Brachypodietum*	**association** *Polygalo-Brachypodietum*
Willner et al. (2019), p. 33 ff.: table alliances of *Brachypodietalia pinnati*	diagnostic species of association groups within *Mesobromion*	diagnostic species of **alliance** *Cirsio-Brachypodion*	putative character species of **alliance** *Cirsio-Brachypodion*	putative character species of **alliance** *Cirsio-Brachypodion*	-	putative character species **alliance** *Chrysopogono-Danthonion*
Chytrý et al. (2007) p. 432 ff.: *Polygalo-Brachypodietum*	diagnostic, highly constant, highly dominant	diagnostic	-	-	-	-

Perc = percentage frequency; class = frequency class; fid = statistical fidelity; empty cells = zero. The Braun-Blanquet-values are indicated for the *Polygalo-Brachypodietum pinnati*. The statistic fidelity measure is the phi-(Φ)-coefficient of association. Species with phi-coefficient values of at least 20 are considered diagnostic (indicated by fid* and yellow colour); species with phi-coefficient values of at least 45 are considered highly diagnostic (indicated by fid** and green colour).

Table 32: Selected diagnostic species of the *Polygalo-Brachypodietum* (23 from a total of 57)

Association character species	*Brachypodium pinnatum, Polygala major, Carex michelii, Cirsium pannonicum, Cytisus albus, Rhinanthus rumelicus*
Basiphilous semi-dry grassland communities	*Festuca stricta* subsp. *sulcata, Elytrigia intermedia, Scabiosa ochroleuca, Trifolium pannonicum, Ranunculus polyanthemos, Adonis vernalis, Trifolium montanum,* etc.
Mesic and semi-dry grassland communities	*Anthoxanthum odoratum, Veronica chamaedrys, Salvia pratensis, Bromopsis erecta, Agrostis capillaris,* etc.
Thermophilic forests & their fringes	*Potentilla alba, Anthericum ramosum, Origanum vulgare, Geranium sanguineum, Lathyrus latifolius,* etc.

The classification resulted in a large number of diagnostic species indicating meso-xeric conditions (30 of 57, see also Table 32), of which several species are diagnostic for the alliance *Cirsio-Brachypodion pinnati,* like *Festuca stricta* subsp*. sulcata, Elytrigia intermedia, Scabiosa ochroleuca, Trifolium pannonicum, Adonis vernalis* (see Figure 77), and *Linum nervosum*. This confirms the classification of the vegetation type in this alliance. Furthermore, there are many species diagnostic for the order of semi-dry grasslands *Brachypodietalia pinnati* (see also Annex 1).

Figure 76: Stand of *Polygalo-Brachypodietum pinnati* in the Village Meadow with *Rhinanthus rumelicus, Leucanthemum vulgare, Filipendula vulgaris,* etc. (Dăbâca commune, 24.06.2016)

Figure 77: *Adonis vernalis* in early spring in the Lord's Meadow (Dăbâca commune, 28.03.2012)

The relatively high number of mesophilic species and species of thermophilic forests and their fringes described for the *Polygalo-Brachypodietum* by Wagner (1941) and Coldea et al. (2012) is reflected also in the diagnostic species and overall species composition of this vegetation type. For instance, there are a number of species that occur in both semi-dry and mesic communities, such as the diagnostic species *Anthoxanthum odoratum*, *Salvia pratensis,* and *Veronica chamaedrys* (see also Table 32) as well as species which are usually restricted to mesic communities like *Centaurea phrygia, Equisetum arvense, Tragopogon pratensis* subsp. *orientalis,* and *Heracleum sphondylium.*

Finally, around 25 % of the diagnostic species are species of thermophilic herb fringe communities, especially the alliance *Geranion sanguinei*. In part, they also grow in dry and semi-dry grasslands, such as *Anthericum ramosum, Nepeta nuda* subsp. *nuda,* or *Bupleurum falcatum*. Furthermore, some of the species are diagnostic for basiphilous thermophilous oak forests, like *Potentilla alba* and *Cyanus triumfetti*.

According to Coldea et al. (2012), the presence of the *Trifolio-Geranietea*-species shows the secondary character of the association. According to Wagner (1941), the *Polygalo-Brachypodietum* replaces thermophilic oak forest communities of the *Quercion pubescenti-petraeae* alliance, like the *Lithospermum-Quercetum* and related associations. However, the presence of these species could also be a enhanced by the cessation of mowing.

Yet to be clarified is the relationship between the *Polygalo-Brachypodietum* and the *Festuco sulcatae-Brachypodietum pinnati* Soó 1927 described by Dengler et al. (2012) for the nearby nature reserve ‘Hay Meadows of Cluj’ and the ‘Nature Reserve of the Steppe Peonys’ (*Rezervaţia de bujori Zau de Câmpie*) in the northwest of the Transylvanian Plain.

Dengler et al. (2012) and Roleček et al. (2014) mention similarities in species composition and structure between these associations. Dengler et al. (2012) attribute their relevés to the *Festuco sulcatae-Brachypodietum pinnati* based on the presence of some typical species that the *Polygalo-Brachypodietum* would lack (e.g. *Cyanus triumfetti, Clematis integrifolia, C. recta, Pontechium maculatum, Linum nervosum, Paeonia tenuifolia, Veratrum nigrum*). These species may, however, only be regional character species or geographical differential species of the *Polygalo-Brachypodietum* in Transylvania.

The situation is complicated by the fact that some of the sites mentioned by Dengler et al. (2012) are placed within the *Brachypodio-Molinietum arundinaceae* by Roleček et al. (2019), just as the *Festuco sulcatae-Brachypodietum* is mentioned by Willner et al. (2019) as a synonym and the oldest valid name for the *Brachypodio-Molinietum arundinaceae*, and not for the *Polygalo-Brachypodietum* (see Chapter 3.3.6.2.3).

However, Roleček et al. (2014) also mention that the stands classified by Dengler et al. (2012) as *Festuco sulcatae-Brachypodietum pinnati* have higher numbers of drought-tolerant species than other *Brachypodio-Molinietum* sites, which again would speak for an assignment to a dry meadow-steppe type (like the *Polygalo-*

Brachypodietum pinnati) and not a mesic meadow-steppe type as in the case of the *Brachypodio-Molinietum arundinaceae* (see Chapter 3.3.6.2.3).

A narrow relation between the *Polygalo-Brachypodietum pinnati* and the *Brachypodio-Molinietum arundinaceae* is already indicated by Wagner (1941), who regards the *Brachypodio-Molinietum arundinaceae* described for the White Carpathians as being very close to the *Polygalo-Brachypodietum pinnati*, especially in ecology and evolution.

In fact, the description of the *Brachypodio-Molinietum arundinaceae* by Chytrý et al. (2007) for the Czech Republic and by Škodová et al. (2008) for the White Carpathians has many similarities with both plant communities which were identified in the studied hay meadows as *Brachypodio-Molinietum arundinaceae* and *Polygalo-Brachypodietum pinnati*. At the same time, the *Polygalo-Brachypodietum pinnati* described here and by Chytrý et al. (2007) for the Czech Republic have fewer similarities.

3.3.8.3 Environmental and ecological conditions

The directions of the relevés on the compass rose range from northwest to east, and the most common directions are north and northeast (see Table 9, page 64). The average inclination of the *Polygalo-Brachypodietum*-relevés (median: 5°, maximum 15°) is the second highest of all considered plant communities, after the *Cirsium furiens*-community, which indicates that the stands are located on more inclined parts of the hillslopes than the vegetation types discussed so far (see Table 8, page 64).

The unweighted Ellenberg indicator value for nutrient availability N = 3.4 for this vegetation type corresponds to the values of the *Brachypodio-Molinietum* and the *Cirsium furiens*-community, and reflects the occurrence of species that grow more frequently on nitrogen-poor sites than on sites moderately rich in nitrogen (Ellenberg et al. 2001).

The unweighted Ellenberg indicator value for soil moisture M = 3.8 for the surveyed *Polygalo-Brachypodietum* relevés is slightly smaller than the value of the other two meso-xerophilic communities, namely the *Brachypodio-Molinietum* and the *Festuca pratensis*-community (around 4.3, see also Table 3, page 57). This can be explained by the occurrence of a relatively high number of meso-xerophilous species in this vegetation type, including the dominant grass species *Brachypodium pinnatum* and *Festuca stricta* subsp. *sulcata*.

These findings also correspond to the subdivision of the *Cirsio-Brachypodion pinnati* alliance into association groups by Willner et al. (2019), who assign the *Polygalo-Brachypodietum* to the *dry* meadow steppes, and the *Brachypodio-Molinietum* to the *mesic* meadow steppes of Central Europe.

The changing moisture levels of the upper soil layers seem to be less pronounced than in other studied plant communities: of 57 diagnostic species, only five (around 9 %) are indicators for alternating soil moisture conditions: *Ranunculus polyanthemos, Trifolium montanum, Jacobaea vulgaris, Equisetum arvense,* and *Pulmonaria mollis*. In the *Brachypodio-Molinietum* around 45 % of the diagnostic species indicate alternating soil moisture, in the *Molinietum caeruleae* around 47 %, and in the *Festuca pratensis*-community around 25 %.

3.3.8.4 Occurrence of the plant community in the study hay meadows

The 36 relevés classified as *Polygalo-Brachypodietum pinnati* have been recorded in all three studied *utilised hay meadows* and both studied *former hay meadows*. At the time of data collection, in the years 2009, 2012 and 2013, the *Polygalo-Brachypodietum* was presumably one of the most widespread plant communities in the three *utilised hay meadows*. In the meantime, however, due to the increased grazing pressure, the area covered may have decreased in favour of vegetation types like the *Cirsium furiens*-community or transitional forms. Therefore, the current extent and condition of the *Polygalo-Brachypodietum* would need to be investigated.

Furthermore, there could be differences in the species composition of the *Polygalo-Brachypodietum* stands between the different hay meadows, partly also as a result of different successional processes. For example, during a 2019 site visit, a higher cover of *Elytrigia intermedia* was observed in parts of the Village Meadow than in the other two *utilised hay meadows.*

3.3.8.5 Occurrence of the plant community in Romania

According to Willner et al. (2019), the *Polygalo-Brachypodietum pinnati* includes meadow steppes on limestone and other calcareous bedrocks in the Pannonian Basin and Transylvania, perhaps also in Western Ukraine (see Figure 78).

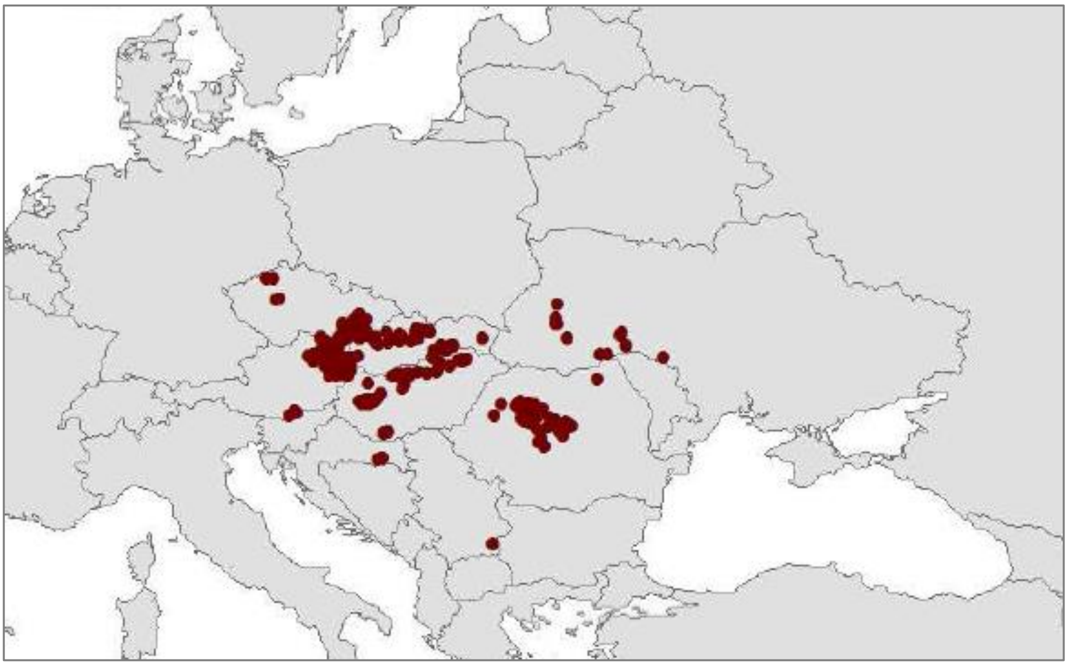

Figure 78: Locations of the relevés in Central and Eastern Europe classified as *Polygalo majoris-Brachypodietum pinnati*; from: Willner et al. (2019), electronic appendix 7, page 7

The *Polygalo-Brachypodietum pinnati* is listed in the Synopsis of the Anthoropogenic Plant Associations of Romania by Coldea et al. (2012), while Sanda et al. (2008) and Pop et al. (1999-2000) do not include the association in their synopses for Romania and Cluj County, respectively. However, all three Romanian sources list the two associations *Carici humilis-Brachypodietum* Soó 1949 and *Danthonio-Brachypodietum* Soó 1949, which are specified as synonyms of the *Polygalo-Brachypodietum pinnati* by Willner et al. (2019).

For this reason, the area where the *Polygalo-Brachypodietum pinnati* is supposed to occur in Romania according to Coldea et al. (2012) can be considered differently depending on whether the three names denote one and the same association or not. Coldea et al. (2012) indicate the range of the *Polygalo-Brachypodietum pinnati* the basins of the rivers *Târnava Mare*, *Târnava Mică* and *Gurghiu*, tributaries of the Mureş river in the Transylvanian Plateau. In this region, Oroian et al. (2007) also describe the *Polygalo-Brachypodietum pinnati* Wagner 1941 for many localities along the southern border of the Sighişoara-Târnava Mare SCI (ROSCI0227).

Contrarily, for the two synonymized associations, Coldea et al. (2012) indicate a larger distribution range. For the *Carici humilis-Brachypodietum* Soó 1949, the Transylvanian Plateau and the foothills of the Western Romanian Carpathians at an altitude of 350-900 m are indicated; for the *Danthonio-Brachypodietum pinnati* Soó 1949, the Translyvanian hillsides in general.

Considering the specifications and relevé localization of the *Polygalo majoris-Brachypodietum pinnati* by Willner et al. (2019), it is likely that the association occurs throughout Transylvania, including in the study area.

3.3.8.6 Conservation value and protection status

Six vascular plant species of conservation concern occur in the 36 relevés made in the *Polygalo-Brachypodietum pinnati* (see also Table 12, page 67). Frequent species are *Adonis vernalis* in 67 % of the relevés and *Seseli peucedanoides* in almost one quarter of the relevés. *Gentiana pneumonanthe, Mercurialis ovata, Nepeta ucranica,* and *Veratrum nigrum* occur only in one or two relevés*. Pontechium maculatum* occurs in one *Polygalo-Brachypodietum*-relevé, a species protected by the Habitats Directive (Council of the European Communities 2013).

The *Phengaris* spp. host plants do not reach high frequency values in the *Polygalo-Brachypodietum pinnati*. However, the host plants of all five *Phengaris* taxa found in the area occur occasionally in this plant community: *Origanum vulgare* (in 33 % of the relevés), *Thymus pulegioides* subsp. *pannonicus* (in 19 % of the relevés), *Sanguisorba officinalis* (in 14 % of the relevés), *Gentiana cruciata* and *Thymus odoratissimus* (in 6 % of the relevés), as well as *Gentiana pneumonanthe* (in 3 % of the relevés).

Besides the rare or vulnerable plant species and the *Phengaris* spp. host plants, the *Polygalo-Brachypodietum pinnati* has a very high ecological value, as it is an extremely species-rich semi-natural grassland type with a mean vascular plant species richness of 61 species per 10 m^2 (see Chapter 3.3.1.4 and Figure 79).

On the European red list of habitats by Janssen et al. (2016) the group of semi-dry perennial calcareous grasslands (EUNIS 2007 code E1.2a) is classified as vulnerable. Furthermore, the *Polygalo-Brachypodietum pinnati,* as part of the alliance *Cirsio-Brachypodion pinnati*, is included in Annex I of the Habitats Directive as part of the habitat type 6210 (Olmeda et al. 2019).

Figure 79: *Polygalo-Brachypodietum pinnati* stand in the Great Meadow with *Anthericum ramosum, Centaurea scabiosa, Onobrychis viciifolia,* etc. (Borșa commune, 08.07.2009)

3.3.9 *Cirsium furiens-Brachypodium pinnatum*-[Cirsio-Brachypodion pinnati]-community Dengler et al. 2012

Vegetation type: Informal community of semi-dry basiphilous grassland

Names:

English: Informal community of semi-dry grasslands with *Cirsium furiens* and *Brachypodium pinnatum*
Romanian: Comunitate informală de pajişti semi-uscate cu *Cirsium furiens* și *Brachypodium pinnatum*
German: Informelle Gesellschaft der Halbtrockenrasen mit *Cirsium furiens* und *Brachypodium pinnatum*

Information relevés:

Number: 16
Type, size, year: 2 phytosociological relevés, 25 m^2, 2009
14 diversity-relevés, 25 m^2 (n = 3) or 10 m^2 (n = 11), 2012 & 2013
Surveyors: 7 different persons / teams

Locations:

Dăbâca: Village Meadow (1), Meadow Hill (2)
Borșa: Great Meadow (7), Jacob's Meadow (6)

3.3.9.1 Structure and species composition

The following descriptions are based on 16 relevés in two *utilised hay meadows* (Village Meadow and Great Meadow) and both studied *former hay meadows*. The surveyed parameters of vegetation structure are shown in Table 33.

The mean total cover of vascular plant species amounts to 92.6 %, which is the third smallest value of the studied communities. There are two highly dominant grass species, *Festuca stricta* subsp. *sulcata* and *Brachypodium pinnatum.* Of these, *Festuca stricta* subsp. *sulcata* is the more frequent species and has the higher cover values; in the *Polygalo-Brachypodietum pinnati,* it is the opposite.

Highly constant species with frequency values over 80 % are *Festuca stricta* subsp. *sulcata, Dactylis glomerata,* and *Carex filiformis, Crataegus monogyna,* as well as many herb species like *Asperula cynanchica, Plantago media, Viola hirta, Ranunculus polyanthemos, Fragaria viridis, Euphorbia esula, Agrimonia eupatoria, Daucus carota, Thymus pulegiodies* subsp. *pannonicus, Securigera varia,* and *Thalictrum minus* (see Figure 80).

The vegetation can be subdivided into a lower layer built up by grass species like *Festuca stricta* subsp. *sulcata, Brachypodium pinnatum,* or *Danthonia alpina,* and the sedge *Carex filiformis*, as well as by a multitude of herb species. The mean height of the lower herbs and grasses layer is 17 cm, which is around half the size of the corresponding layer in the *Brachypodio-Molinietum arundinaceae* and the *Polygalo-Brachypodietum pinnati*.

Secondly, there is a higher vegetation layer characterized by taller growing species and the stems of species with rosettes with a mean height of 44 cm, again around half the size of the corresponding layer in the *Brachypodio-Molinietum arundinaceae* and the *Polygalo-Brachypodietum pinnati*. However, the height of the vegetation and the formation of one or more vegetation layers depends on the farming practiced on the stands.

Table 33: Data on vegetation structure for the *Cirsium furiens-Brachypodium pinnatum*-community

Total cover (n = 16)	mean +/- SD	92.6 % +/- 4.7 %
	min. - max.	85.0 % - 100.0 %
Cover bare ground (n = 14)	median	2.0 %
	min. - max.	0.3 % - 10.0 %
Cover bryopyhte layer (n = 13)	median	10.0 %
	min. - max.	0.1 % - 65.0 %
Cover lichen layer (n = 4)	median	0.06 %
	min. - max.	0.01 % - 10.0 %
Cover litter layer (n = 14)	median	80.0 %
	min. - max.	3.0 % - 99.0 %
Depth litter layer (n = 13)	median	0.9 cm
	min. - max.	0.4 cm - 2.3 cm
Mean hight of low herb layer (n = 14)	mean +/- SD	17 cm +/- 13 cm
	min. - max.	4 cm - 40 cm
Mean hight of tall herb layer (n = 14)	mean +/- SD	44 cm +/- 22 cm
	min. - max.	20 cm - 80 cm
Shrub cover (n = 6)	median	4.0 %
	min. - max.	0.3 % +/- 8.0 %
Shrub hight (n = 6)	mean +/- SD	0.4 m +/- 0.1 m
	max. +/- SD	0.8 m +/- 0.2 m
Share of relevés with: (n=16)	phanerophytes	100 %
	Crataegus monogyna	88 %
	Prunus spinosa	56 %
	Rosa canina	50 %

Regarding the proportion of relevés with phanerophytes, all relevés of this vegetation type contain at least one of the six considered woody species, mostly *Crataegus monogyna* (88 %), followed by *Prunus spinosa* (56 %) and *Rosa canina* (50 %). This vegetation type is thus the vegetation type with the highest frequency of phanerophytes in the relevés. In six of the 16 relevés a shrub layer was recorded, with a mean height of 0.4 m, a maximum height of 0.8 m and a median cover of 4.0 % (see Table 33).

The median value of bare ground cover amounts to 2.0 %. The median value of the bryophyte layer cover, 10 %, is clearly higher than in the *Brachypodio-Molinietum* *arundinaceae* (0 %) and *Polygalo-Brachypodietum pinnati* (0.5 %). The median value of the litter layer cover, 80 %, is similar to the value of the *Polygalo-Brachypodietum pinnati,* and lower than the value of the *Brachypodio-Molinietum arundinaceae* (97 %). The three communities do not differ much in the mean depth of the litter layer; the median value for this vegetation type is 0.9 cm.

Only in this vegetation type were there relevés in which lichens were recorded, namely in four relevés on wood. The median value of the lichen cover per relevé is 0.06 %; the values range between 0.01 % and 10 % per relevé.

Figure 80: *Cirsium furiens-Brachypodium pinnatum*-community in the Lord's Meadow with *Echium vulgare, Carlina vulgaris, Daucus carota, Centaurea phrygia, Filipendula vulgaris, Tragopogon pratensis* subsp. *orientalis,* etc. (Dăbâca commune, 21.08.2019)

3.3.9.2 Syntaxonomy and diagnostic species

Class:	*Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947
Order:	*Brachypodietalia pinnati* Korneck 1974 *nom. conserv. propos.*[a]
Alliance:	*Cirsio-Brachypodion pinnati* Hadač et Klika in Klika et Hadač 1944[b]
Community:	*Cirsium furiens-Brachypodium pinnatum*-[Cirsio-Brachypodion pinnati]-community Dengler et al. 2012

Selected synonyms:

[a] *Brometalia erecti* Koch 1926 *nom. ambig. rejic. propos.*, *Brometalia erecti* Br.-Bl. 1936 *nom. ambig. rejic. propos.*

[b] *Festucion sulcatae* Soó 1938, *Danthonio-Brachypodion* Boșcaiu 1970

The nomenclature and selected synonyms for the class, order, and alliance come from Mucina et al. (2016). The name of the community was taken from Dengler et al. (2012). In the thesis, the shorter form *Cirsium furiens*-community is also used.

The vegetation type described here is assigned to the informal *Cirsium furiens-Brachypodium pinnatum*-[Cirsio-Brachypodion]-community provisionally described by Dengler et al. (2012) for nearby areas in Transylvania. Dengler et al. (2012) indicate three infrequent diagnostic plant species for the community, namely the endemic *Cirsium furiens* (see Figure 81), *Agrimonia eupatoria,* and *Prunus spinosa*, which are also diagnostic for the vegetation type described here. Furthermore, they name two dominant grass species, *Brachypodium pinnatum* and/or *Festuca* ser. *Valesiacae*, which also corresponds to this vegetation type.

Figure 81: The endemic species *Cirsium furiens* in the Lord's Meadow (Dăbâca commune, 19.08.2019)

Other analogies are the above-average cover of the bryophyte layer and an extensive grazing regime in around half of the sites surveyed by Dengler et al. (2012), with the other other part being abandoned. One difference to the vegetation type described here is in the species richness of vascular plant species. While Dengler et al. (2012) describes the community as moderately species poor, the vegetation type described here is very species-rich (59 species / 10 m^2).

The analysed community consist of species from a remarkably large number of sociological groups (see Table 34 and Annex 1). The largest group (12 of 49) consists of species of the *Brachypodietalia pinnati*, including the dominant *Brachypodium pinnatum.* Other orders (e.g. *Festucetalia valesiacae*, *Origanetalia vulgaris*, *Arrhenatheretalia elatioris, Dauco-Melilotion, Prunetalia spinosae*) are each represented with a maximum of four to six species.

Table 34: Selected diagnostic species of the *Cirsium furiens-Brachypodium pinnatum*-community (29 from a total of 49)

Named by Dengler et al. (2012) as diagnostic	*Agrimonia eupatoria, Cirsium furiens, Prunus spinosa*
Basiphilous semi-dry grassland communities	*Festuca stricta* subsp. *sulcata, Fragaria viridis, Ranunculus polyanthemos, Dorycnium pentaphyllum* subsp. *herbaceum, Medicago lupulina, Potentilla heptaphylla,* etc.
Mesic to semi-dry grassland communities	*Galium mollugo, Plantago lanceolata, Knautia arvensis, Dactylis glomerata*
Dry European grass steppes	*Salvia nemorosa, Bothriochloa ischaemum, Potentilla incana, Thymus pulegioides* subsp. *pannonicus*
Thermophilic forests & their fringes	*Securigera varia, Veronica austriaca, Stachys recta, Trifolium ochroleucon, Teucrium chamaedrys,* etc.
Ruderally influenced grasslands / communities	*Convolvulus arvensis, Rubus caesius, Picris hieracioides, Carlina vulgaris, Daucus carota,* etc.
Shrub communities of the *Prunetalia spinosae*	*Crataegus monogyna, Rosa canina*

Dengler et al. (2012) denote the *Cirsium furiens-Brachypodium pinnatum*-community as a mainly negatively characterised central association within the Transylvanian *Cirsio-Brachypodion pinnati* communities. Willner et al. (2019) indicate the *Cirsium furiens*-community as a synonym of the *Polygalo majoris-Brachypodietum pinnati*. The analysed dataset also supports the assumption that the *Cirsium furiens*-community could be a management variant of the *Polygalo-Brachypodietum pinnati* formed by grazing. The close connection between the formation of this community and the factor grazing is shown in Chapter 5.3.6.

Dengler et al. (2012) indicate several synonyms of the *Cirsium furiens-Brachypodium pinnatum*-community, among others also the *Danthonio-Brachypodietum pinnati* Soó 1947, which is listed by Willner et al. (2019) as a synonym of the *Polygalo majoris-Brachypodietum pinnati.*

To decide whether the *Cirsium furiens-Brachypodium pinnatum*-community is a new association, or to which already existing association it could be attributed, more relevés from this and other areas are necessary, as well as the help of a larger database, such as the Romanian Grassland Database (Vassilev et al. 2018).

The comparison with associations described in the relevant literature reveals similarities with two plant communities. The first is with the *Carlino acaulis-Brometum erecti* Oberdorfer 1957 listed by Chytrý et al. (2007) for the Czech Republic. However, Chytrý et al. (2007) and Willner et al. (2019) assign the *Carlino acaulis-Brometum erecti* to the *Mesobromion erecti*, and not to the *Cirsio-Brachypodion pinnati*. Furthermore, in the classification of Willner et al. (2019), the *Carlino acaulis-Brometum erecti* is named only as a synonym for two associations of the *Mesobromion erecti,* namely the *Gentiano-Koelerietum* Knapp ex Bornkamm 1960 and the *Gentiano vernae-Brometum* Kuhn ex Oberd. 1957.

Another association which has similarities to the vegetation type described here is the *Festuco rupicolae-Brometum* Zielonkowski 1973, one of the similarities being the occurrence of *Festuca stricta* subsp. *sulcata* and *Brachypodium pinnatum* as highly constant grass species. Furthermore, the *Festuco rupicolae-Brometum* is also characterised by a low number of association character species, and sheep grazing and mowing as management types (Zielonkowski 1973).

The *Festuco rupicolae-Brometum* is placed into the *Mesobromion erecti* by Zielonkowski (1973) and into the *Cirsio-Brachypodion pinnati* by Willner et al. (2019), the latter being due the presence of *Festuca stricta* subsp. *sulcata* instead of *Festuca ovina* subsp. *guestfalica*. Within the *Cirsio-Brachypodion pinnati,* Willner et al. (2019) assign the association to the mesic meadow steppes, like the *Brachypodio-Molinietum arundinacea.* According to Willner et al. (2019), the *Festuco rupicolae-Brometum* occurs in several countries of Central and Central Eastern Europe, and relevés from the Romanian Grassland Database (Vassilev et al. 2018) have been assigned to this association in their classification (see Figure 82).

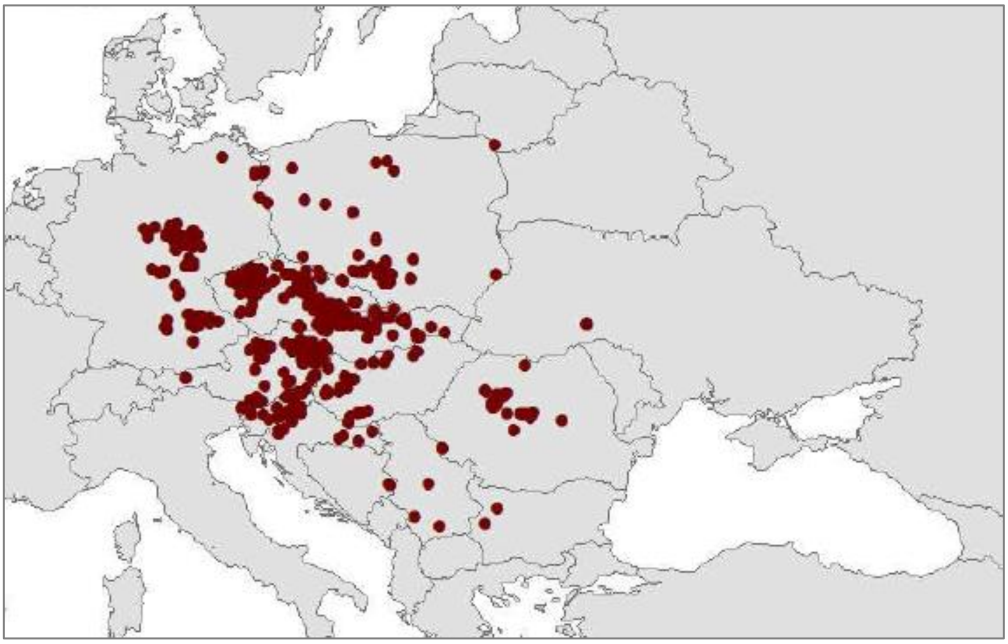

Figure 82: Locations of the relevés in Europe classified as *Festuco rupicolae-Brometum*; from: Willner et al. (2019), electronic appendix 7, page 10

3.3.9.3 Environmental and ecological conditions

The most frequent exposition of the relevés is north and northeast (see Table 9, page 64). The average inclination of the relevés (median: 7°, maximum 12°) is the highest of all considered plant communities, which indicates that the stands of this community are located on more inclined parts of the hillslopes than the other vegetation types (see Table 8, page 64).

The mean unweighted Ellenberg indicator value for nutrient availability N = 3.4 for this vegetation type (see Table 3, page 57) corresponds to the values of the *Brachypodio-Molinietum arundinaceae* and the *Polygalo-Brachypodietum pinnati,* and reflects the occurrence of species that grow more frequently on nitrogen-poor sites than on sites moderately rich in nitrogen (Ellenberg et al. 2001).

The mean unweighted Ellenberg indicator value for soil moisture M = 3.9 for the surveyed relevés is very similar to the value of the *Polygalo-Brachypodietum pinnati* (3.8) and smaller than the value of the other two meso-xerophilic communities, namely the *Brachypodio-Molinietum arundinaceae* and the *Festuca pratensis*-community (around 4.3).

Changing moisture levels of the upper soil layers do not seem to play a major role, similar to the *Polygalo-Brachypodietum pinnati*: Of 49 diagnostic species, only four species (around 8 %) are indicators for alternating soil moisture conditions: *Trifolium ochroleucon, Ranunculus polyanthemos, Galium verum,* and *Carex filiformis.*

The diagnostic species of thermophilic forests and scrubs and their fringes (six of 49 diagnostic species, 12 %) are not as strongly represented in this vegetation type as in the *Polygalo-Brachypodietum pinnati* (25 %). Instead, this community is unique among the studied communities in that it has three shrub species among the (highly) constant and diagnostic species: *Crataegus monogyna, Rosa canina,* and *Prunus spinosa,* as well as the highest frequency of phanerophyte species in the relevés (see Chapter 3.3.9.1). The occurence of lichens on wood only in this vegetation type also indicates that woody plants play a greater role here.

For the vegetation type described here, grazing most likely plays a role, since eight of 16 relevés were made in *former hay meadows* that had been used as rough sheep pastures at the time of data collection in the year 2013. The other half of the relevés were made in the *utilised hay meadows*, which are large, heterogeneous areas, partly mown regularly, but partly also grazed with varying intensity. The plots in the *utilised hay meadows* could therefore have been exposed to similar influences as the plots in the *former hay meadows*, that is, above all to unregulated grazing, characterized by overgrazed and under-grazed areas.

An indication that the community is at least partly shaped by grazing is the occurrence of plant species which are typical of overgrazed grasslands (Böhmer 1994; Schumacher et al. 1995) among the diagnostic, dominant and constant species: toxic, spiny, thistle-like, or unpalatable species.

In this vegetation type, the following diagnostic species can be included into these groups: *Crataegus monogyna, Rosa canina, Prunus spinosa,* and *Rubus caesius* as spiny shrubs, *Euphorbia esula, Securigera varia,* and *Linum catharticum* as toxic herbs, *Cirsium furiens, C. vulgare,* and *Carlina vulgaris* as thistle-like species, *Brachypodium pinnatum* and *Festuca stricta* subsp. *sulcata* as unpalatable species (when ripe), and finally species with basal rosettes which are more resistant to trampling, like *Plantago media* (Böhmer 1994; Pils 1994).

The following diagnostic species are also usually not eaten by the livestock (Schumacher et al. 1995): *Thymus pulegioides* subsp. *pannonicus* containing essential oils, easily overlooked species such as *Asperula cynanchica*, and lignifying plants such as *Teucrium chamaedrys* and *Dorycnium pentaphyllum* subsp. *herbaceum*.

According to Böhmer (1994), a further characteristic of overgrazed semi-dry grasslands is the formation of sheep tracks and erosion areas along paths and ridges, which are extended upslope by livestock trampling. These patches of bare ground play an important role as pioneer sites for plant species and sunny spots for insects (Böhmer 1994).

Examples for pioneer plant species belonging to the diagnostic species of the *Cirsium furiens*-community are *Sanguisorba minor, Thymus pulegioides* subsp. *pannonicus,* and *Asperula cynanchica*, as well as several species occurring in ruderally influenced semi-dry grasslands and ruderal places, like *Picris hieracioides, Daucus carota,* or *Cardamine hirsuta*. Some diagnostic species could also have their focus in this community due to the dispersal through epizoochory (e.g. *Agrimonia eupatoria, Daucus carota*).

The higher number of constant grass species in the *Cirsium furiens*-community compared to the *Polygalo-Brachypodietum* (11 versus six) could also indicate that grazing plays a greater role in this plant community (see also Chapter 5).

3.3.9.4 Occurrence of the plant community in the study hay meadows

From the 16 relevés classified as *Cirsium furiens*-community, eight have been carried out in *utilised hay meadows* (Village Meadow and Great Meadow) and eight in the two surveyed *former hay meadows*. Stands of the community were also observed in the Lord's Meadow. The exact area coverage of the community was not investigated. However, it can be assumed that the area has increased since the time of data collection (2013) due to the steadily increasing grazing in all hay meadows.

3.3.9.5 Occurrence of the plant community in Romania

Dengler et al. (2012) recorded the *Cirsium furiens*-community in the counties of Braşov, Cluj, and Sibiu, and assume that it is widespread throughout the Transylvanian Plateau.

3.3.9.6 Conservation value and protection status

Four vascular plant species of national conservation concern were identified in the relevés of this plant community, but only with low frequency (6 – 19 %): *Adonis vernalis*, *Jurinea transylvanica*, *Trinia kitaibelii,* and *Seseli peucedanoides* (see also Table 12, page 67).

The rare *Jurinea transylvanica* is an endemic species to Romania (Euro+Med 2006+), and the thistle *Cirsium furiens* is endemic to Romania and the eastern part of Hungary (Săvulescu 1952-1976; Euro+Med 2006+; Speta and Rákosy 2010). Furthermore, *Pontechium maculatum*, which occurs in two relevés, is protected by the Habitats Directive (Council of the European Communities 2013).

Concerning *Phengaris* spp. host plants, in 14 of 16 relevés thyme species as potential host plants for *Phengaris arion* can be found, mostly *Thymus pulegioides* subsp. *pannonicus,* and, in one relevé, *Thymus odoratissimus*. *Origanum vulgare* (host plant for *Phengaris arion*) and *Sanguisorba officinalis* (*Phengaris nausithous* and *Ph. teleius*) occur in only two relevés each. *Gentiana* species do not occur in the relevés. That means this vegetation type is especially important for the large blue *Phengaris arion*.

Besides the rare, vulnerable, or endemic plant species and the *Phengaris* spp. host plants, the ecological value of the *Cirsium furiens*-community lies especially in the high mean species richness, which is the second highest of the studied communities (59 +/- 9 vascular plant species on 10 m^2). Furthermore, the varying structure of higher and lower vegetation due to different grazing intensities, eaten and avoided plants, places with open ground, trampled areas and livestock trails, as well as ecotone structures with shrubs and their fringes can be the basis for a high diversity of animal species (Kratochwil and Schwabe 2001).

On the European red list of habitats by Janssen et al. (2016) the group of semi-dry perennial calcareous grasslands (EUNIS 2007 code E1.2a) is classified as vulnerable. Furthermore, the *Cirsium furiens*-community*,* as part of the alliance *Cirsio-Brachypodion pinnati*, is included in Annex I of the EU Habitats Directive as part of the habitat type 6210 (Olmeda et al. 2019).

3.3.10 *Danthonio-Stipetum stenophyllae* Ghişa 1941

Vegetation type: Dry subcontinental basiphilous grassland

Names:

English:	Dry subcontinental basiphilous grassland with *Stipa tirsa*
Romanian:	Pajişte ponto-panonică de *Stipa tirsa* şi *Danthonia alpina*
German:	Rossschweif-Federgras-Steppenrasen

Information relevés:

Type, size, year:	2 phytosociological relevés, 25 m^2, 2009
Surveyors:	1 person

Locations:

Borșa:	Great Meadow (2)

3.3.10.1 Structure and species composition

The following descriptions are based on two phytosociological relevés carried out in the year 2009 in the Great Meadow. The mean total cover of vascular plant species amounts to 92.5 %, which is the second smallest value after the *Caricetum vesicariae* (80 %).

Regarding the dominant species, grasses play a more important role than herb species. The relevés are characterized by a high dominance of the grass species *Stipa tirsa* (cover between 50 and 75 %). In second place is *Festuca stricta* subsp. *sulcata* with a cover between 5 and 25 % in both relevés, followed by *Brachypodium pinnatum*, *Festuca valesiaca, and Elytrigia repens* with a cover of up to 5 % in both relevés. Other less dominant grass species are *Stipa capillata, Briza media, Dactylis glomerata*, *Elytrigia intermedia,* and *Phleum montanum*.

The 23 herb species found in at least one of the two relevés are recorded only with cover values up to 1 %, except for *Teucrium chamaedrys*. The following herbs occur in both relevés: *Salvia nutans* (see Figure 83)*, Thymus pulegioides* subsp. *pannonicus, Linum hirsutum, Crepis setosa, Centaurea scabiosa, Plantago lanceolata,* and *Achillea millefolium.* However, there are presumably stands with *Stipa tirsa* that have a higher cover percentage of herbs.

Obviously, the two relevés can only give preliminary information on the typical species composition and structure of this vegetation type, and have to be complemented with further data.

Figure 83: *Salvia nutans* with *Stipa tirsa* in the Great Meadow (Borșa commune, 29.05.2013)

3.3.10.2 Syntaxonomy and diagnostic species

Class:	*Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947
Order:	*Festucetalia valesiacae* Soó 1947[a]
Alliance:	*Festucion valesiacae* Klika 1931 nom. conserv. propos.[b]
Suballiance:	*Stipenion lessingianae* Soó 1947
Association:	*Danthonio-Stipetum stenophyllae* Ghişa 1941[c]

Selected synonyms:

[a] *Festucetalia valesiacae* Soó 1940, *Festucetalia valesiacae* Br.-Bl. et Tx. 1943, Br.-Bl. et Tx. ex Br.-Bl.1950

[b] *Festucion sulcatae* Soó 1930 *nom. ambig. reji. propos.*, *Eu-Festucion valesiacae* Br.-Bl. et Tx. 1943, *Festuco-Stipion* (Klika 1931) Krausch 1962

[c] *Stipetum stenophyllae transsilvanicum* Soó 1947

The nomenclature and selected synonyms for the class, order, and alliance come from Mucina et al. (2016). The nomenclature and synonym for the suballiance and association were taken from Coldea et al. (2012).

Although only two relevés are at disposal for the syntaxonomical classification of this vegetation type, its assignment to the association *Danthonio-Stipetum stenophyllae*

Ghişa 1941 is possible due to the occurrence of several association character species, above all *Stipa tirsa (*synonym: *Stipa stenophylla)* (see also Table 35).

Table 35: Selected diagnostic species of the *Danthonio-Stipetum stenophyllae* (total n = 12)

Association character species	*Stipa tirsa, Salvia nutans, Phleum montanum, Pontechium maculatum, Thymus odoratissimus*
Dry European grass steppes	*Thymus pulegioides* subsp. *pannonicus, Festuca valesiaca, Stipa capillata, Linum hirsutum*
Ruderal vegetation	*Elytrigia repens, Crepis setosa*
Dry open steppic grasslands on rocks	*Teucrium montanum*

Apart from the association character species, there are also similarities in the site conditions. The association usually inhabits peaks and gentle hill slopes, generally north-facing or with slight westerly or easterly deviations, on hills up to 600 m above mean sea level, and on deep, black soils (Ghişa 1941; Coldea et al. 2012).

From the five association character species, *Salvia nutans* and *Thymus odoratissimus* occur mainly in dry European grass steppes (*Festucion valesiacae*) (Coldea et al. 2012; Chytrý et al. 2021). *Stipa tirsa* also occurs in semi-dry grassland communities of the *Cirsio-Brachypodion pinnati* (Rothmaler 2005; Chytrý et al. 2021), and *Phleum montanum* as well as *Pontechium maculatum* (see Figure 84) are *Cirsio-Brachypodion*-species (Coldea et al. 2012; Willner et al. 2019).

The species *Danthonia alpina*, which is named by Coldea et al. (2012) as a character species of the *Danthonio-Stipetum stenophyllae* and by Ghişa (1941) as a regional differential species of the association, is missing in the two relevés of this vegetation type, but is present in all four semi-dry vegetation types. More relevé data could clarify whether the species also belongs to this vegetation type in the study area.

Regarding the placement into higher-rank syntaxa, Ghişa (1941) places the *Danthonio-Stipetum stenophyllae* into the alliance *Festucion valesiacae.* Within the *Festucion valesiacae*, Coldea et al. (2012) classify the association into the suballiance *Stipenion lessingianae* Soó 1947, which is distinguished from the second suballiance *Festucenion valesiacae* Toman 1981 by a higher number of differential species occuring mainly in the centre of Romania, as well as by the dominance of *Stipa* spp. (Coldea et al. 2012).

Soó (1947) on the other hand places the association into the alliance *Danthonio stipion-stenophyllae* Soó 1947, which in turn is synonymized by Mucina et al. (2016) with the alliance *Cirsio-Brachypodion pinnati*.

According to Ghişa (1941), the *Danthonio-Stipetum stenophyllae* is a secondary vegetation type growing on former forest sites which have always contained patches of steppe vegetation. The presence of shrub species like *Prunus spinosa*, *Rosa gallica* and *Crataegus monogyna* would support this statement, and even more so the presence of mesophytic relics of forests and forest clearings, for example *Clematis* *recta, Campanula glomerata, C. persicifolia, Ferulago sylvatica,* or *Inula hirta* (Ghişa 1941).

Still to be clarified is the relationship of the associations *Danthonio-Stipetum stenophyllae* and *Stipetum tirsae* Meusel 1938. The latter is described by Willner et al. (2019) as *Stipa tirsa*-community within the semi-dry subcontinental alliance *Cirsio-Brachypodion* in Central Germany, N Bohemia, S Moravia, N Hungary, W Transylvania, and Serbia. According to Coldea et al. (2012), the *Danthonio-Stipetum stenophyllae* is differentiated from communities with *Stipa tirsa* of Central Europe by several Pontic and Submediterranean species, like *Cytisus albus, Peucedanum ruthenicum, Cyanus triumfetti* or *Ferulago sylvatica.*

Figure 84: *Pontechium maculatum* and *Salvia nutans* in the Great Meadow (Borșa commune, 09.06.2009)

3.3.10.3 Environmental and ecological conditions

Most of the environmental parameters which have been recorded or calculated for the *Danthonio-Stipetum* indicate a distinctive position of this vegetation type compared to the others. For example, the average altitude of 462 m is around 30 to 60 m higher than in the other communities. The data are confirmed by our observation that the vegetation type occurs in the upper slope of the meadows, close to or on the hilltop.

While the mean unweighted Ellenberg indicator values for light of the other vegetation types range between 6.9 and 7.3, the value of the *Danthonio-Stipetum stenophyllae* is L = 7.7 (see Table 3, page 57). This indicates the occurrence of more plant species that grow better with a higher relative illumination level (Ellenberg et al. 2001), such as *Stipa tirsa* (L = 8), *Salvia nutans* (L = 8), or *Pontechium maculatum* (L = 9).

Similarly, the mean unweighted Ellenberg indicator value for temperature of T = 6.5 is at least 0.4 higher than the values of the other communities, and indicates the presence of more thermophilic plant species (see Table 3, page 57). The pattern is repeated with the mean unweighted Ellenberg indicator value for continentality of C = 5.5, which is at least 0.6 units higher than the values of the other communities. The mean unweighted Ellenberg indicator value for moisture of M = 3.0 is at least 0.8 units lower than the values of the other communities (closest are the *Polygalo-Brachypodietum* with M = 3.8 and the *Cirsium furiens*-community with M = 3.9).

The mean unweighted Ellenberg indicator value for nutrient availability N = 2.9 is the lowest of all considered plant communities, with a difference of at least 0.5 units. The lower value is probably related to the greater dryness of the soils (Dierschke and Briemle 2008), and indicates the occurrence of species which are more frequent on nitrogen-poor sites (Ellenberg et al. 2001). Except for *Elytrigia repens* and *Crepis setosa*, all diagnostic species have an N value of 1 or 2.

Changing moisture levels of the upper soil layers, which play an important role in some of the studied plant communities, are not important in the two analysed relevés, since of the 33 species recorded in the relevés only *Elytrigia repens* and *Filipendula vulgaris* indicate such conditions (Ellenberg et al. 2001).

The occurrence of species of (semi)ruderal communities in this vegetation type like *Elytrigia repens*, *Crepis setosa*, *Agrimonia eupatoria, Carlina vulgaris,* and *Echium vulgare* could possibly be explained by the location of the stands at relatively exposed sites near the hilltop, which are often used as paths for the sheep flocks.

3.3.10.4 Occurrence of the plant community in the study hay meadows

According to observations made in the years of the data collection (2009-2013), the *Danthonio-Stipetum stenophyllae* is restricted to a few small sites on the upper slope of the Great Meadow. The sites are located on the upper parts of the hill ridges running north-south between the concave hill sections (see Figure 39, page 56). Here, there are probably particular conditions that favour the development of this driest vegetation type of studied hay meadows, such as shallower soils on steep slopes or greater weather exposure.

3.3.10.5 Occurrence of the plant community in Romania

Coldea et al. (2012) describe the *Danthonio-Stipetum stenophyllae* for the Transylvanian Plain and neighbouring regions. In their vegetation table containing the association (page 159 ff.), they use relevés from the surroundings of Cluj, such as from the nature reserve 'Hay Meadows of Cluj', from the Turda Gorge, and from several sites in the western Transylvanian Plain. Doniţă et al. (2005) mentions Southern Romania and Northeast Romania (Moldova) as area of occurrence for the *Danthonio-Stipetum stenophyllae*.

3.3.10.6 Conservation value and protection status

Two vascular plant species of national conservation concern occur in the two relevés of the *Danthonio-Stipetum stenophyllae*: *Salvia nutans* and *Teucrium montanum* (see also Table 12, page 67). Furthermore, the association character species *Pontechium maculatum* is protected by the Habitats Directive (Council of the European Communities 2013).

Concerning *Phengaris* spp. host plants, two thyme species as potential host plants for *Phengaris arion* can be found in the relevés, namely *Thymus pulegioides* subsp. *pannonicus* and *Thymus odoratissimus*.

The high conservation value of this plant community, apart from the occurrence of the above-mentioned protected species, is due to the rarity of the stands, which occur only on extreme sites on the north-facing hillsides. In addition, the community is characterised by numerous continental species which, like *Salvia nutans* and *Pontechium maculatum*, have a particularly beautiful flowering aspect.

On the European red list of habitats by Janssen et al. (2016), the habitat type 'Continental dry steppe' (code E1.2b) is indicated as near threatened. The association, as an element of the *Festucion valesiacae* alliance, is included in Annex I of the Habitats Directive as part of the habitat type 6240 (Sub-Pannonic steppic grasslands).

3.3.11 Flora of the meadows

3.3.11.1 Vascular plant species list of the meadows

In the phytosociological survey, 320 vascular plant species have been identified in the *utilised* and *former hay meadows*. This list is complemented by 15 species observed in the meadows outside the relevés (years 2008-2013). Among them are five orchid species and another 10 species, most of which flower in spring and early summer (see Table 36 and Figure 85 to Figure 99). The frequent observations of these species in the Lord's Meadow do not imply that the species do not exist in the other meadows, but were instead caused by more frequent field walks in the Lord’s Meadow.

Table 36: Species found in the meadows outside the relevés

Species	Figure	Time of observation	Place of observation	Endanger-ment
Anacamptis coriophora	83	June 2008, June 2011	LM	r (O)
Anacamptis morio	84	April 2010	LM	r (O)
Anacamptis palustris subsp. *elegans*	85	June 2008	LM	r (O)
		May 2013	near GM	
Anemone sylvestris	88	May 2009, 2011, 2012	LM	
Carex humilis		2011	LM, VM, GM	
Dactylorhiza incarnata subsp. *incarnata*	86	May 2009, June 2011	LM	r (O) / v (B)
		June 2009	GM	
Dictamnus albus	89	June 2009	GM	v / r (O)
Gymnadenia conopsea subsp. *conopsea*	87	May 2013	LM	r (O)
Iris graminea	90, 91	May 2009, May 2013	LM	
Iris variegata	92	June 2008	LM	
Nonea pulla	96	May 2013	GM	
Ornithogalum umbellatum agg.	93	May 2009, May 2012	LM	
Orobanche alba	94	June 2008	LM	
Salvia austriaca	95	May 2013	LM	
		May 2013	JM	
Silene flos-cuculi	97	May 2013	VM	

LM = Lord’s Meadow, VM = Village Meadow, GM = Great Meadow; r = rare, v = vulnerable; O = Oltean et al. (1994), B = Boşcaiu et al. (1994)

Annex 3 shows the full list of 335 vascular plant species with the valid species name (including the author), selected synonyms, family affiliation, conservation concern, and frequency in the relevés. The taxonomy follows the Euro+Med PlantBase (Euro+Med 2006+), except for *Festuca pratensis* and *Festuca arundinacea*.

Of the 335 species identified, 22 are of national conservation concern and two species are protected by the Habitats Directive (Council of the European Communities 2013) (see also Chapter 3.3.1.6 and Annex 3).

The 335 species belong to 43 families. The families with the most species are the *Asteraceae* (43), *Poaceae* (40), *Lamiaceae* (36), *Fabaceae* (25), *Rosaceae* (19), and *Apiaceae* (18) (see Table 37). The genera with the most species are *Carex* (10 species), *Trifolium* (10), *Galium* (8), *Potentilla* (7), and *Veronica* (7).

Table 37: List of plant families with number of species

Family	**No. species**	**Family**	**No. species**
Asteraceae	43	*Dipsacaceae*	4
Poaceae	40	*Primulaceae*	4
Lamiaceae	36	*Amaryllidaceae*	3
Fabaceae	25	*Convolvulaceae*	3
Rosaceae	19	*Equisetaceae*	3
Apiaceae	18	*Gentianaceae*	3
Ranunculaceae	13	*Geraniaceae*	3
Plantaginaceae	11	*Lythraceae*	2
Rubiaceae	11	*Onagraceae*	2
Cyperaceae	10	*Violaceae*	2
Boraginaceae	7	*Apocynaceae*	1
Caryophyllaceae	7	*Aristolochiaceae*	1
Euphorbiaceae	6	*Colchicaceae*	1
Iridaceae	6	*Cornaceae*	1
Juncaceae	6	*Hypericaceae*	1
Linaceae	6	*Melanthiaceae*	1
Orobanchaceae	6	*Rutaceae*	1
Polygalaceae	6	*Salicaceae*	1
Asparagaceae	5	*Santalaceae*	1
Campanulaceae	5	*Scrophulariaceae*	1
Orchidaceae	5	*Valerianaceae*	1
Brassicaceae	4	**Total**	**335**

Figure 85: *Anacamptis coryophora* in the Lord's Meadow (Dăbâca commune, 04.06.2011)

Figure 86: *Anacamptis morio* in the Lord's Meadow (Dăbâca commune, 27.04.2010)

Figure 87: *Anacamptis palustris* subsp. *elegans* near the Great Meadow (Borșa commune, 29.05.2013)

Figure 88: *Dactylorhiza incarnata* subsp. *incarnata* in the Lord's Meadow (Dăbâca commune, 04.06.2011)

Figure 89: *Gymnadenia conopsea* subsp. *conopsea* in the Lord's Meadow (Dăbâca commune, 19.05.2013)

Figure 90: *Anemone sylvestris* in the Lord's Meadow (Dăbâca commune, 10.05.2012)

Figure 91: Infructenscence of *Dictamnus albus* in the Great Meadow (Borșa commune, 09.06.2009)
Other visible species: *Salvia nutans, Salvia nemorosa, Stachys recta, Stipa tirsa,* etc.

Figure 92: *Iris graminea* (flower) in the Lord's Meadow (Dăbâca commune, 16.05.2009)

Figure 93: *Iris graminea* (plants) in the Lord's Meadow (Dăbâca commune, 16.05.2009)

Figure 94: *Iris variegata* in the Lord's Meadow (Dăbâca commune, 04.06.2008, picture: László Rákosy)

Figure 95: *Ornithogalum umbellatum* agg. in the Lord's Meadow (Dăbâca commune, 02.05.2009)

Figure 96: *Orobanche alba* in the Lord’s Meadow, parasitising on *Thymus* sp. (Dăbâca commune,04.06.2008, picture: László Rákosy)

Figure 97: *Salvia austriaca* in the Lord’s Meadow (Dăbâca commune, 19.05.2013)

Figure 98: *Nonea pulla* in the Great Meadow (Borșa commune, 29.05.2013)

Figure 99: *Silene flos-cuculi* and *Ranunculus acris* in the Village Meadow (Dăbâca commune, 19.05.2013)

3.3.11.2 Phytogeography

As described in Chapter 2.1, the study area is located in the north-west of the Transylvanian Plateau, in the eastern part of the Hills of Cluj. Approximately 6-8 km air-line distance from the meadows to the east lies the valley of the *Someş Mic* River, to which the Transylvanian Plain borders towards the southeast.

The interpretation of the map of Floristic Provinces of Romania by Borza and Boşcaiu (1965) (see Figure 100) leads to the assignment of the Hills of Cluj (within the Central European Floristic Region) to the Central European-Eastern Carpathian Floristic Province, the Transylvanian Plateau Floristic District, and the subunit of the Transylvanian Plain. However, the study area borders or even lies partially within the Apuseni Mountains Floristic District (equated to Biharia s. l.) with the subunit Centre of Biharia.

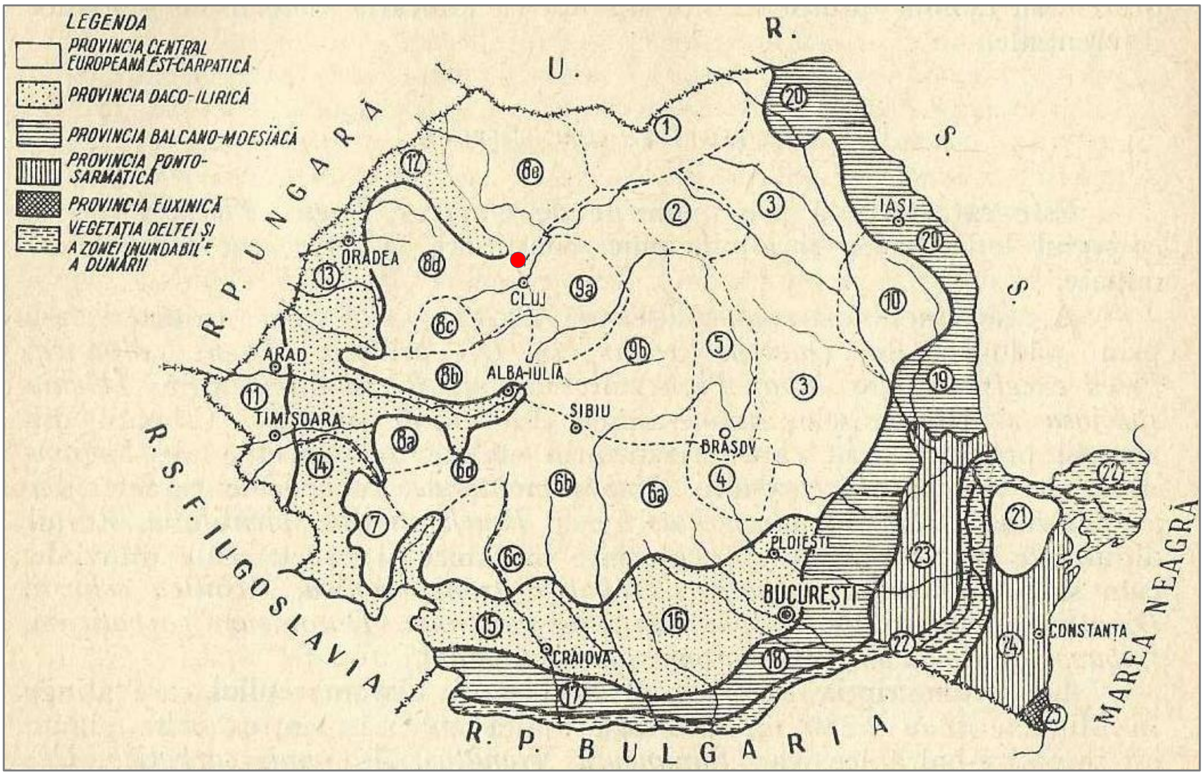

Figure 100: Floristic Provinces of Romania, from: Borza and Boşcaiu (1965), page 301
White unit: Central European-Eastern Carpathian Floristic Province; unit 9: Translyvanian Plateau Floristic District; subunit 9a: Translyvanian Plain. Unit 8: Apuseni Mountains Floristic District (equated to Biharia s. l.); subunit 8d: Centre of Biharia. The red circle shows the approximate position of the communes Borşa and Dăbâca.

In contrast, according to the map of the phytogeographical classification of the Alps and Carpathians by Meusel and Jäger (1992a), the Hills of Cluj are located adjacent to, but outside the Bihar Floristic District, and belong to the Pontic-South Siberian Floristic Region, the Pannonic Province, and the Transylvanian Subprovince (see Figure 101). Interestingly, Fekete et al. (2016), who carried out a delineation of the Pannonian Vegetation Region based on the potential natural vegetation, also include at least the western part of the Hills of Cluj into the Pannonian Vegetation Region, based on the range of the forest community *Quercetum petraeae-cerridis*.

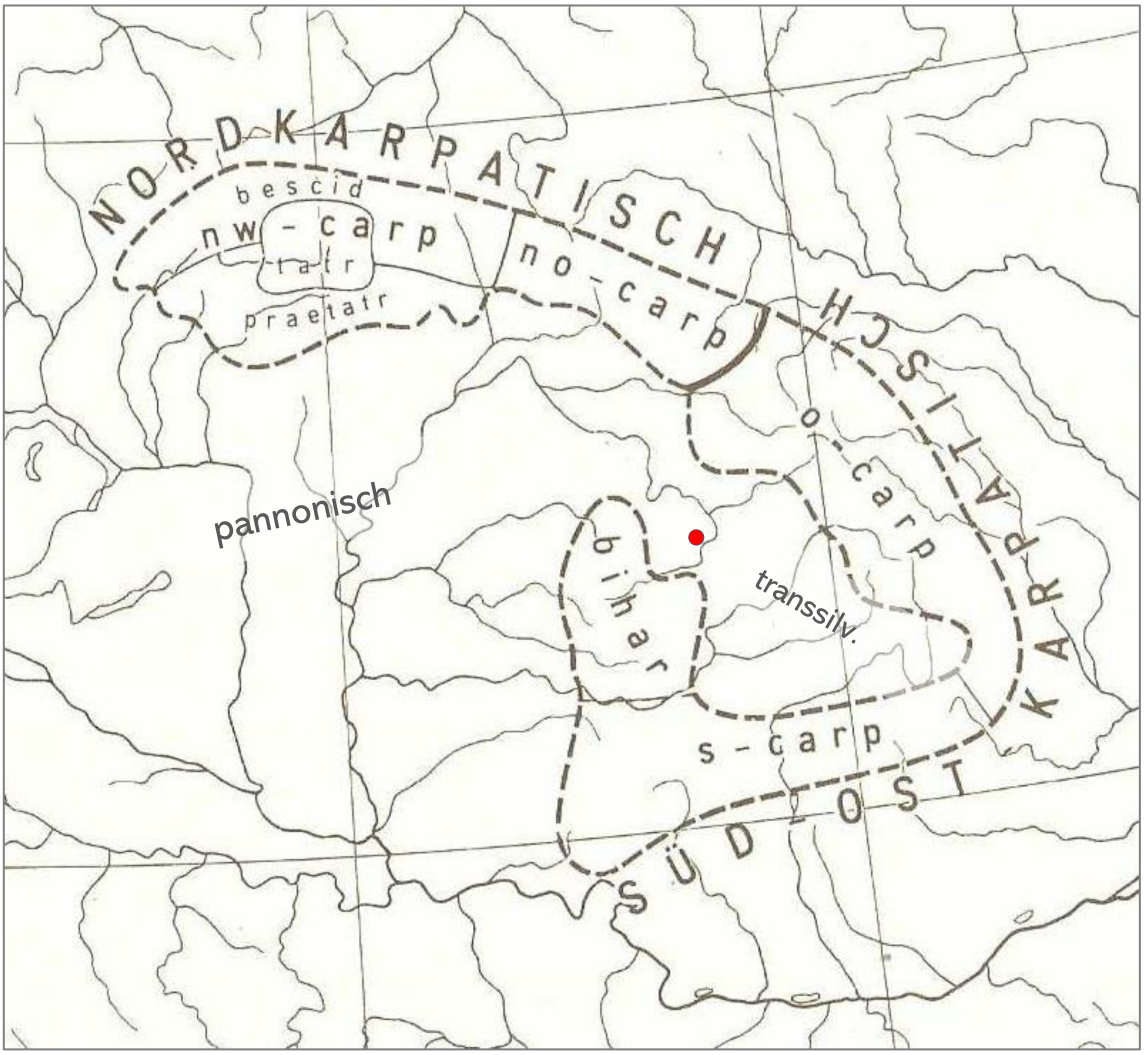

Figure 101: The structure of the floristic units of the Carpathians, modified from Meusel and Jäger (1992a)
The red circle shows the approximate position of the communes Borşa and Dăbâca.

Soó emphasises in his Geobotanical Monography of Cluj (1927) that the 'region around Cluj is a transitional contact zone not only between forest and steppe vegetation, but also between the Floristic Districts of the Eastern Carpathian Mountains (respectively the Bihar) and the Transylvanian Plain Floristic District', which he considered a secondary steppe region.

Looking at the ranges of the surveyed species, this transitional character is confirmed since there are many floristic elements from the Central European Region and numerous floristic elements from the (sub-)Pontic-South Siberian Region. These are accompanied by further floristic elements, for example from the Balkans and the sub-Mediterranean region. In the following, examples of the different floristic elements are given.

As Central European floristic elements in a wider sense Walter and Straka (1970) list the following species: *Arrhenatherum elatius, Briza media, Carex hirta, Potentilla heptaphylla, Rosa canina, Genista tinctoria, Cornus sanguinea, Lysimachia nummularia, Symphytum officinale, Stachys officinalis, Salvia pratensis, Galium* *mollugo, Plantago lanceolata, Knautia arvensis, Serratula tinctoria, Centaurea jacea,* and *Leontodon hispidus*. Central European floristic elements in a narrower sense are present to a smaller extent: *Anacamptis morio, Trifolium ochroleucon* and *Carlina vulgaris* (Walter and Straka 1970).

From the group of species with a Pontic centre of distribution, according to Soó (1927), the following occur in the studied hay meadows: *Stipa tirsa, Salvia nutans, Pontechium maculatum, Klasea radiata (*synonym: *Serratula radiata), Nepeta ucranica*, *Linum nervosum, Trinia kitaibelii, Phlomis tuberosa,* and *Iris aphylla.* In addition to these, Walter and Straka (1970) name the following species as Pontic floristic elements: *Festuca stricta* subsp. *sulcata*, *Adonis vernalis, Thesium linophyllon, Potentilla inclinata, Lembotropis nigricans, Lathyrus pallescens, Onobrychis arenaria, Linum perenne, Linum flavum, Linum hirsutum, Eryngium planum, Thymus pulegioides* subsp. *pannonicus, Verbascum chaixii, Veronica austriaca, Galium glaucum, Scabiosa ochroleuca, Campanula sibirica,* and *Inula hirta*.

Furthermore, the following species with a Pontic-Pannonic centre of distribution were found in the meadows: *Clematis recta* (FloraWeb 2000-), *Cirsium canum* (FloraWeb 2000-), and *Salvia austriaca* (Fischer et al. 2023).

The term sub-Pontic is used by Walter and Straka (1970) for species that represent the transition from the Pontic to the Central European elements; they are sometimes also referred to as Sarmatic or subcontinental elements by other authors. Sub-Pontic floristic elements according to Walter and Straka (1970) are: *Elytrigia repens, Phleum phleoides, Ranunculus polyanthemos, Potentilla alba, Anemone sylvestris, Potentilla recta, Potentilla argentea, Filipendula vulgaris, Prunus spinosa, Medicago falcata, Trifolium alpestre, Trifolium montanum, Securigera varia, Peucedanum oreoselinum, Vincetoxicum hirundinaria, Nonea pulla, Nepeta nuda, Stachys recta, Veronica spicata,* and *Tanacetum corymbosum.*

Additionally, *Euphorbia epithymoides* (synonym: *Euphorbia polychroma*) is classified as Sarmatic floristic elements by Borza and Boşcaiu (1965) as well as *Carex montana, Seseli annuum, Prunella grandiflora* and *Anthericum ramosum* by Haffner (1990).

Elements of the South Siberian Floristic Region occur in a region between the boreal taiga in the north and the true steppes in the south, which stretches roughly from the Urals to the Altai, and is covered typically by birch forest-meadow steppe (Walter and Straka 1970). In the studied meadows, the following South Siberian floristic elements were found: *Carex humilis* and *Tragopogon pratensis* ssp. *orientalis* from the group of species reaching as far as Central Europe; furthermore, from the group of species which are fairly widespread in Europe, *Brachypodium pinnatum, Carex filiformis, Polygonatum odoratum, Silene flos-cuculi, Rubus caesius, Fragaria viridis, Viola hirta, Pimpinella saxifraga, Inula salicina* and *Leontodon autumnalis* were also found. There is also the species *Veratrum nigrum* as a South Siberian floristic element with a disjunct range (Walter and Straka 1970).

Two species occurring in the hay meadows are listed as Balcanic and South-East-European floristic elements by Borza and Boşcaiu (1965): *Pulsatilla montana* and

Clematis integrifolia. The range of *Clematis integrifolia* reaches as far as Western Siberia (Kästner and Fischer 2011); the species is listed as a Pontic floristic element by Walter and Straka (1970).

Four of five character species of the *Polygalo-Brachypodietum* have a centre of geographical distribution in South-East Europe: *Polygala major* (east-Mediterranean-Balcanic-Pannonic-Pontic range; Raab-Straube 2018+), *Carex michelii* (Illyric-Balcanic and Pontic centre of distribution; FloraWeb 2000-), *Cirsium pannonicum* (south-(east-)Alpic-Illyric-Balcanic-Carpathian range; Meusel and Jäger 1992b), *Cytisus albus* (Balcanic-east-Alpine-Carpathian range; Borza and Boşcaiu 1965), and *Rhinanthus rumelicus* (Pannonic-Balcanic centre of distribution; FloraWeb 2000-).

The species *Danthonia alpina* and *Dorycnium pentaphyllum* subsp. *herbaceum* have an east-(sub-)Mediterranean geographical distribution (FloraWeb 2000-), while the range of *Elytrigia intermedia* extends from the Mediterranean area up to Siberia (Borza and Boşcaiu 1965; FloraWeb 2000-). Another species occurring in the Mediterranean area up to Caucasia is *Xeranthemum cylindraceum*, a disturbance indicator which has recently appeared in the hay meadows. As sub-Mediterranean floristic elements Walter and Straka (1970) list the following species*: Anacamptis coriophora, Lathyrus latifolius, Euphorbia platyphyllos, Salvia verticillata, Cruciata glabra,* and *Cruciata laevipes*.

In addition, the following species are Pontic-Mediterranean floristic elements according to Walter and Straka (1970): *Stipa capillata, Asparagus officinalis, Rosa gallica, Dictamnus albus, Eryngium campestre* s. l., *Peucedanum cervaria,* and *Dipsacus laciniatus*.

Finally, there are two endemic species recorded in the hay meadows, as already mentioned: *Jurinea transylvanica* (synonym: *Jurinea mollis* subsp. *transylvanica*), endemic to Romania (Euro+Med 2006-), and *Cirsium furiens,* endemic to Romania and the eastern part of Hungary (Săvulescu 1952-1976; Speta & Rákosy 2010; Euro+Med 2006-).

3.4 Discussion of the methodology and outlook

3.4.1 Selection method, representativity and currentness of the data

The targeted (preferential) selection method of the plots resulted from the focus of the vegetation survey on certain vegetation types (harbouring host plants of *Phengaris* spp., stands with *Molinia arundinacea* or meadow steppes, see also Chapter 3.1. Alternative selection methods to the preferential sampling are stratified-random sampling or gradient-oriented transects (Dengler et al. 2008). One aspect that would have to be considered in the hay meadows regarding stratified-random sampling is that the meadows consist of a small-scale mosaic of various site conditions when considering factors such as soil moisture, clay content or slope inclination.

Gradient-oriented transects may be a suitable option to survey the occurring vegetation complexes along gradients of soil moisture, such as the sequence of moderately moist *Molinietum caeruleae* (with *Molinia arundinacea*), more mesic *Brachypodio-Molinietum arundinaceae* ‘with alternating moisture indicators’ and semi-dry *Polygalo-Brachypodietum pinnati* (see Chapter 3.3.6.2.3). Other transects could run from the interior of scrubs to open grasslands.

Regarding the applied targeted sampling method, it should also be noted that some vegetation types were sampled in mainly one hay meadow. This concerns the *Molinietum caeruleae* in the Lord's Meadow (10 of 16 relevés), the *Festuca pratensis*-community in the Lord's Meadow (7 of 8 relevés), and the *Calamagrostis epigejos*-community in the Great Meadow (9 of 10 relevés), in addition to the plant communities with only one or two relevés. Based on the land use history of the hay meadows, it could at least be hypothesised that the vegetation of the Lord's Meadow shows differences from the vegetation of the other hay meadows, since the Lord’s Meadow was the only one of the meadows used as cattle pasture between the 1950s and 1990 (see Chapter 4.3.1).

Furthermore, some vegetation types are also associated with specific surveyors; this concerns the *Calamagrostis epigejos*-community, the *Festuca pratensis*-community, and the *Danthonio-Stipetum stenophyllae*, while different surveyors contributed to the other vegetation types.

Other points are that the number of relevés compared to the total area of the hay meadows is relatively small, and that the relevés are sometimes concentrated in some parts of the meadows and underrepresented in others (e.g. the eastern part of the Lord's Meadow; see Figure 36, page 55). This uneven distribution of plots, which can occur with preferential sampling, could be addressed in future studies by one of the mentioned alternative sampling methods, for example stratified-random sampling.

It is important to emphasise that the description of the nine plant communities is not a complete survey of the vegetation types present in the hay meadows at the time of data collection. Furthermore, it was not an aim of the study to determine units of lower rank than associations (subassociations, variants, facies, etc.). However, as already mentioned, the *Festuca pratensis*-community could be a facies of the *Brachypodio-*

Molinietum arundinaceae, and the *Cirsium furiens*-community could be a management form of the *Polygalo-Brachypodietum pinnati.*

Despite all limitations, the results provide valuable information about the most important plant communities of the studied meadows and the vegetation types in which the *Phengaris* spp. host plants occur, which is important for successful management.

The relevé data analysed in this thesis were collected in the years 2009 to 2013, and therefore the results reflect the state of the vegetation at that time. Since then, already existing land use changes in the hay meadows have continued or intensified, which could have changed the floristic composition and structure of the plant communities, at least in part. These trends were observed in sporadic field visits by the thesis author in the years 2014-2019, and reported by colleagues up to the present (year 2023). The changes regarding the land use are reported in Chapter 4.3.3, and the effects of mowing, cessation of mowing and grazing on plant diversity and vegetation are shown in Cahpter 5.

3.4.2 Heterogeneity of the data

The phytosociological relevé data show heterogeneity in some regards, which theoretically could cause bias in the results. In the following the heterogenous factors are listed and reasons are given why the data can nevertheless be used:

- Different persons (or teams) carried out the relevés (see Annex 2). Since they all were experienced vegetation ecologists, the deviations in the estimation of the species cover values and other parameters are assumed to be negligible.
- Different cover scales were used for data collection (Braun-Blanquet scale, Londo scale and percentage values). However, for the data analysis, all values have been converted into cover values based on the Braun-Blanquet scale (see Chapter 3.2), so that the bias should be minor.
- Different header data parameters were recorded, such as those regarding the vegetation height. However, only similar parameters were compared to each other.
- The relevés of two different plot sizes were analysed together: 10 m^2 (n = 38) and 25 m^2 (n = 64). In the case of four vegetation types, the plot size differed within the vegetation type, while the other five vegetation types consisted only of 25 m^2-relevés (see Annex 1). This means that the groups compared to each other differed in their average plot size.

  The plot size however has an influence on the constancy values, as discussed for example by Dengler (2003) and thus also on statistical fidelity values, which indirectly also use the constancy values (Dengler et al. 2009). This means that the determination of diagnostic species is affected by the plot size of the relevés. Dengler et al. (2009) state ‘that serious problems are to be expected when mean plot sizes between compared units differ by more than a factor of two, or when constancy columns are based on relevés whose plot sizes vary by much more than a factor of five’.

Regarding the analysed data, if the mean plot sizes per vegetation type are considered, the plot sizes between the units differ in one case by the factor 2.1 (between the *Cirsium furiens*-community and the communities with only 25 m^2-plots); in all other cases the factor is smaller than 2. The plot size variation within the groups reaches, at most, the factor 2.5. Therefore, the joint analysis of the relevés of two different plot sizes seems justifiable. However, for future studies the application of uniform plot sizes as proposed in literature (e.g. Chytrý and Otýpková 2003, Dengler et al. 2009) is recommended.

- There were differences in the accuracy of the entire species list per plot. The diversity relevés have more complete lists due to a higher time investment per relevé. While a phytosociological classification is nevertheless possible, the calculation of detailed diversity parameters was therefore performed only for the diversity plots (see Chapter 5).

As a conclusion, a uniform survey design is recommended for future phytosociological research in the hay meadows, especially regarding the plot size.

3.4.3 Outlook

The following topics are possible starting points for further studies of the hay meadow vegetation:

- Further research on the *Molinietum caeruleae* with *Molinia arundinacea,* and comparison with other *Molinion* sites in Romania and adjacent countries.
- Further research on the *Brachypodio-Molinietum arundinaceae* in the region and its relationship to the *Molinietum caeruleae* (with *Molinia arundinacea*) and the *Polygalo-Brachypodietum pinnati.*
- Final syntaxonomical classification of the preliminary communities: *Calamagrostis epigejos*-[Molinietalia caeruleae]-community, *Festuca pratensis*-[Cirsio-Brachypodion pinnati]-community, *Cirsium furiens-Brachypodium pinnatum*-[Cirsio-Brachypodion pinnati]-community.
- The variation of plant communities due to the occurrence in different hay meadows.
- Changes of the floristic composition and the structure of the meadow vegetation compared to the survey period 2009-2013.
- Importance of the pattern of individual or grouped trees and shrubs growing on the meadow surface for the vegetation and phytodiversity.
- Description of vegetation complexes within the meadows.
- Influence of climate warming / a potential fertilisation on the vegetation.
- Comparison with the vegetation of other traditional hay meadows from the region or Transylvania.

3.5 Summary Chapter 3

The vegetation survey was aimed at identifying the most important grassland vegetation types of the study hay meadows and to give an overview of their structure and ecological characteristics. The emphasis was on certain grassland types selected in advance, mainly steppe meadows and *Molinia* meadows with *Sanguisorba officinalis* and *Gentiana pneumonanthe*, two host plants for several of the *Phengaris* species. Field work was carried out in the years 2009 and 2011-2013 in Borşa and Dăbâca communes. It covered three *utilised hay meadows* which are in part still mown and which ranged in size from 42 to 200 ha, and two *former hay meadows* already converted into permantent sheep pastures at the time of data collection, with an area of 14 and 26 ha respectively.

For the identification of the vegetation types, 102 phytosociological relevés of either 25 m^2 or 10 m^2 were carried out applying the Braun-Blanquet-approach. The program TWINSPAN embedded in the program JUICE was used for the classification of the relevés. This was followed by the identification of diagnostic species, mainly based on the phi-coefficient of association as a measure of statistical fidelity. Finally, the vegetation types were assigned to plant communities described in literature or newly defined units.

The hay meadows are characterised by heterogenous site conditions, resulting from a complex slope relief, which lead to a small-scale mosaic of different vegetation types. The nine grassland communities identified belong to three different syntaxonomical classes: base-rich semi-dry and dry grasslands *(Festuco-Brometea)*, agricultural grasslands *(Molinio-Arrhenatheretea)* and reeds and tall-sedge marshes *(Phragmito-Magnocaricetea)*. Six of the nine plant communities have the rank of associations, the other three are dominance or informal communities.

The syntaxonomical alliance represented by the most plant communities in the meadows is the *Cirsio-Brachypodion pinnati* Hadač et Klika in Klika et Hadač 1944, that is, an alliance of semi-dry basiphilous grasslands of Central and Eastern Europe. This includes the *Polygalo majoris-Brachypodietum pinnati* Wagner 1941 with the highest share of relevés and the highest mean species richness values (61 species / 10 m^2). As well as meso-xerophilic species, the association is characterised by many mesophilic species and species of thermophilic forests and their fringes.

Another identified community of semi-dry grasslands is the *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939, an association restricted to the Carpathian fringes. The association has so far been mentioned for Romania only by few publications in the 2010s. The assignment of relevés to this association is supported by correspondences between the diagnostic species and site characteristics of the stands in the hay meadows in the study area and stands of the association in the White Carpathians. A characteristic feature of the association in the study meadows is the high share of plant species indicating seasonally-alternating soil moisture conditions.

On European level, the *Brachypodio pinnati-Molinietum arundinaceae* is often associated with the highest values of plant species richness on a small scale. It is closely related to the already mentioned *Polygalo majoris-Brachypodietum pinnati* and also to the third identified community of semi-dry grasslands, the *Cirsium furiens-Brachypodium pinnatum*-[Cirsio-Brachypodion]-community provisionally described by Dengler et al. (2012).

The major similarities between the stands in the study meadows and the stands surveyed by Dengler et al. (2012) are several diagnostic species, the cover of the bryophyte layer above average and the important role of grazing. Actually, the data analysed in this thesis suggests that the *Cirsium furiens-Brachypodium pinnatum*-community could be a management variant of the *Polygalo-Brachypodietum pinnati* formed by grazing. While Dengler et al. (2012) indicate the community as moderately species poor, the vegetation type described here is very species-rich (mean richness of 59 vascular plant species / 10 m^2), with species from a large number of sociological groups represented.

The last community of semi-dry grasslands is a new informal plant community named after the dominant species, the *Festuca pratensis*-[Cirsio-Brachypodion pinnati]-community. This vegetation type is most similar to the *Brachypodio-Molinietum arundinaceae*, of which it also could be a *Festuca pratensis*-facies. Both abiotic site factors like water regime or soil features and factors relating to management could play a role in the formation of the *Festuca pratensis*-community. It is characterised by several more nutrient-demanding diagnostic species.

The *Danthonio-Stipetum stenophyllae* Ghişa 1941 was identified based on two relevés. This is a community of dry subcontinental basiphilous grasslands belonging to the alliance *Festucion valesiacae* Klika 1931 nom. conserv. propos. It was found only on restricted sites on the upper slope of one meadow, probably favoured by shallower soils and greater exposure to the weather.

Around 2-3 % of the meadow area, manifested as numerous isolated stands, were covered by the association *Molinietum caeruleae* Koch 1926, with *Molinia arundinacea* from the *Molinia caerulea* species aggregate. While the *Molinietum caeruleae* has been described for Romania by several authors, it is not named in recent vegetation synopses; this is the first description of the association for Romania which explicitly mentions *Molinia arundinacea.*

The relevés have been assigned to the *Molinietum caeruleae* following a broadly defined association concept allowing only few associations, which are then subdivided into subtypes like subassociations or land use-related subunits. Had a narrower association concept been used, the vegetation type identified in the meadows might have been related to the *Gentiano pneumonanthis-Molinietum litoralis* Ilijanić 1968, which was firstly described from Croatia and is also characterised by the occurrence of *Molinia arundinacea*.

In the meadows, the *Molinietum caeruleae* with *Molinia arundinacea* seems to be part of a vegetation complex along a gradient of humidity. On this gradient, the *Molinietum caerulaea* on moderately moist sites with alternating soil moisture is followed by the

Brachypodio-Molinietum arundinaceae on more mesic sites with alternating soil moisture and this by the *Polygalo-Brachypodietum pinnati* on meso-xeric sites.

This vegetation survey indicates that, in general, soil moisture is a key site factor in the study meadows. Furthermore, six of the nine identified communities featured a large number of diagnostic species indicating alternating wet and dry conditions (e.g. *Carex filiformis*, *Galium boreale, Sanguisorba officinalis, Inula salicina, Ranunculus polyanthemos* and *Serratula tinctoria*). This frequent occurrence of indicator species for alternating moisture can be explained by the soil properties, for example the high clay content.

An association with many alternating soil moisture indicators is the *Calamagrostis epigejos*-[Molinietalia caeruleae]-community, a dominance community preliminarily described in this thesis. An aspect that probably plays a role in the formation of this community is the absence of regular mowing in parts of the study meadows, which can lead to increasing dominance of expanding species like *Calamagrostis epigejos*. The community is furthermore characterised by the frequent occurrence of the rare species *Serratula coronata* (=*Serratula wolffii*), for which the meadows are a new location in Romania and one of the westernmost populations regarding the entire distribution area.

Two associations found on sites with moist to wet soil conditions are the *Mentho longifoliae-Juncetum inflexi* Lohmeyer ex Oberdorfer 1957 nom. invers., a community of flooded grasslands and creeping plants, and the *Caricetum vesicariae* Chouard 1924, a tall-sedge community. The area covered by the *Mentho-Juncetum inflexi* may have increased since the data collection, as it is promoted through sheep grazing, especially soil disturbance by trampling.

Sanguisorba officinalis, the host plant species of *Phengaris teleius* and *Ph. nausithous*, occurred in the widest range of plant communities in the study meadows, including communities of moist sites and semi-dry grasslands, especially if latter were characterised by alternating soil moisture.

Gentiana pneumonanthe, the host plant species of *Phengaris alcon 'pneumonanthe',* occurred with a smaller frequency in the relevés than *Sanguisorba officinalis* and was related mainly to the *Molinietum caeruleae* and the *Brachypodio-Molinietum arundinaceae.* In the *Polygalo-Brachypodietum pinnati,* the host plants of five *Phengaris* taxa were found at least occasionally.

The plant communities identified in general grow on soils with low to moderately high nitrogen content. In the study meadows, the soil nutrient content is positively influenced by marl as parent rock, high topsoil re-enrichment and very high humus content, and negatively influenced by drought stress due to high clay content or steep slopes. Another important factor is the traditional mowing once a year without the addition of organic or mineral fertilizers.

According to the European Red List of Habitats by Janssen et al. (2016), almost all identified plant communities are considered vulnerable or endangered. Six of the nine plant communities are protected by the Habitats Directive as habitat types 6210

(*Polygalo-Brachypodietum pinnati*, *Brachypodio-Molinietum arundinaceae*, *Cirsium furiens-Brachypodium pinnatum*-community, *Festuca pratensis*-community), 6240 (*Danthonio-Stipetum stenophyllae)* and 6410 (*Molinietum caeruleae*).

In the five study meadows, 335 vascular plant species have been identified, which belong to 43 families. Twenty-two of these species are of national conservation concern and one species is protected by the Habitats Directive, namely *Pontechium maculatum*. Furthermore, two species endemic to Romania were found, *Jurinea transylvanica* (syn.: *Jurinea mollis* subsp. *transylvanica*), endemic to Romania, and *Cirsium furiens,* endemic to Romania and the eastern part of Hungary. Phytogeographically, the study area has a transitional character between the Central European Floristic Region and the Pontic-South Siberian Floristic Region.

Despite the survey data having some limitations due to the targeted selection method or heterogenous elements in data collection, the results provide valuable information about the most important plant communities of the study meadows and the vegetation types in which the *Phengaris* spp. host plants occur, which is not least important for successful management. It is important to emphasise that the description of the nine plant communities is not a complete survey of all the vegetation types occurring in the hay meadows. Furthermore, the relevé data was collected in the years 2009 to 2013 and therefore the results reflect the state of the vegetation at that time. Since then, land use changes which were already evident to some extent in the hay meadows have continued or intensified; this is likely to have further altered the floristic composition and structure of the plant communities, at least in part.

4 Past and present land use and tenure

4.1 Introduction

4.1.1 Why to consider the history of land use and tenure

There are several reasons why it is important to consider the land use history of grassland areas. Studies could show, for example, that the present-day diversity patterns of grasslands can sometimes be explained better by the historical land use than by the current land use (Gustavsson et al. 2007).

Additionally, there is growing evidence that the age of grasslands is a very important factor for their plant diversity, number of grassland specialists and other related features (Johansson et al. 2008, Raduła et al. 2020). Gustavsson et al. (2007) for example could show that grassland sites with a long continuity of land use had higher plant diversity values than sites with a shorter continuity. If old grasslands have a higher ecological value than younger grasslands, identifying them, not least to protect them, becomes important (Feurdean et al. 2017). This requires, among other things, knowledge about past land use.

Furthermore, 'traditional' grassland management, that is, management which has been applied over a long period, is often the management to which the grassland ecosystem, flora and fauna is best adapted. One example is the traditional period of hay making. Knowledge about the traditional or historical land use can help in the selection of appropriate conservation management practices (Kuhn et al. 2021). However, despite the importance of land use history, it is often not considered in ecological studies due to the difficulty of ascertaining the historical management practices (Kuhn et al. 2021).

One of the factors that influence the former and current land use as well as conservation planning is the structure of land tenure. This includes the type of ownership (private, commonly owned, owned by the state), the size of the property (small versus large plots) and the distribution of the property units. For example, the size of the individually managed plots has an influence on the heterogeneity of the landscape.

This being so, the aim of this part of the thesis is to gather information about the land use and land tenure history of the three utilised hay meadows starting from the time of the first available cadastral maps (ca. 1880s) and thus to shed light on the continuity of use of the areas as meadows. Details of the historical meadow management and an initial investigation of the land use changes which were encountered during the data collection period (2009-2014) can then be used to design appropriate conservation measures.

Since many hay meadows in Transylvania share similar historical land use and tenure features and are subjected to similar land use changes (see e.g. Demeter and Kelemen 2011), the survey presented here can serve as an example of the factors which need to be taken into account if traditional hay meadows are to be protected as one of the most valuable elements of cultural landscapes in Transylvania.

4.1.2 Short background information for understanding the history of land ownership

The communes Dăbâca and Borșa, being part of Transylvania, belonged to the Kingdom of Hungary and its successor the Habsburg Empire from medieval times until 1918. In 1848, manorialism was abolished in the Habsburg Empire and the transition to peasant private property began (Thelen 2003). However, the distribution of the land proceeded slowly, and some aspects of the feudal system persisted, for example through feudal duties. After the reallocation of land property, land registers were introduced in 1853 and cadastral maps were issued around the 1880s (Thelen 2003).

After 1918, Transylvania was no longer part of Hungary, but of Romania. A land reform was carried out in 1921 which expropriated large landowners and distributed the land amongst the peasants (Organisation for Economic Co-operation and Development (OECD) 2000).

The land tenure established in the hay meadows (along with the rest of the agricultural land) in 1848 and 1921 was radically altered with the process of communist collectivisation of agriculture which started in Romania in 1949 and completed in 1962 (Thelen 2003). Collective and state farms were founded and most of the private agricultural land was expropriated.

The communist system in Romania collapsed in December 1989 and the decision to privatise agriculture was one of the first made by the new government. The resulting 1990/1991 legislation was based on the historical justice presumption, that is, it restored the ownership and property rights of the owners of the pre-communist era and their heirs (reference date 06.03.1945), especially small-scale individual farmers (Organisation for Economic Co-operation and Development (OECD) 2000).

This, together with the restrictions on the maximum restituted area and the disposal of land, often resulted in the reestablishment of the property structure of the 1940s/1950s, which has had an important impact on the agricultural landscape. The laws and circumstances of the Romanian post-communist land reform, which was different in each of the former Eastern Bloc countries (see for example Giovarelli and Bledsoe 2001), accounts for what is an uniquely Romanian path, which has resulted in pronounced land fragmentation and an extremely high number of small scale farms (see Chapter 1.4).

A national systematic land registration has been running since 2015, the National Cadastre and Land Registry Programme (*Programul Național de Cadastru şi Carte Funciară, PNCCF*) carried out by the Romanian National Agency for Cadastre and Real Estate Publicity (Agenţia Naţională de Cadastru şi Publicitate Imobilară 2015-2023). In the first step of the programme, area-wide surveying and registration was carried out in a selection of 118 communes by 2023 (Agenţia Naţională de Cadastru şi Publicitate Imobilară 2023). Among these is the municipality of Borșa, but not the municipality of Dăbâca. In the selected communes, landowners could register their land for free.

4.2 Methodology

To investigate the historical land use and tenure from the 1880s onwards, to learn about aspects of the traditional meadow use and to survey aspects of the ongoing land use change, interviews as well as observations and mapping in the field were used, but the focus was mainly in maps. In the following, a detailed list of the information sources is provided.

4.2.1 Land tenure and land use categories in selected periods

4.2.1.1 Land use and tenure in the 1880s

Cadastral maps for the *utilised hay meadows* from 1878 (Lord's and Village Meadow) and 1883 (Great Meadow), obtained from the Agency of Cadastre and Land Registration (OCPI) Cluj. The maps were georeferenced in ArcGIS Desktop 10.1 (ESRI - Environmental Systems Research Institute 2012). The maps contain land parcel boundaries and numbers as well as place names; the language of the maps is Hungarian. The map showing the Lord's and Village Meadow also contains land use categories coded by letters. However, there is no map legend explaining the land use categories, thus their meaning was deduced using Hungarian dictionaries and an ethnobotanical study by Rab (1996).

4.2.1.2 Land reform of 1921

Cadastral map of the Lord's Meadow in the year 1921 and list of the parcel owners, obtained from the municipal office of the commune Dăbâca in the year 2010. The map was georeferenced in ArcGIS Desktop 10.1 (ESRI - Environmental Systems Research Institute 2012).

4.2.1.3 Communist period

Cadastral maps (scale 1:25,000) of all three *utilised hay meadows* created by the former Institute of Geodesy, Photogrammetry, Cartography and Territorial Organization (IGFCOT) between the years 1971 and 1990, obtained from the Agency of Cadastre and Land Registration (OCPI) Cluj. The maps provide information about the parcel boundaries, land use category, some owners (collective farms) and some place names. The maps were georeferenced in ArcGIS Desktop 10.1 (ESRI - Environmental Systems Research Institute 2012).

4.2.1.4 Post-communist period

To investigate the land use and tenure in the post-communist period, the following sources were used:

- Cadastral map of the Lord's Meadow in the year 2018 and list of parcel owners, obtained from the municipal office of the commune Dăbâca.
- Cadastral map of the Great Meadow in the year 2012 and list of parcel owners for the sections *Sekelişte* and *Bortoloşeia*, obtained from the municipal office of the commune Borșa.
- Cadastral geoportal showing the parcels of land already registered, freely accessible (Agenţia Naţională de Cadastru şi Publicitate Imobilară 2019-).
- Discussions with local farmers and experts (e. g., landownership officers, current or former mayors), mainly in the period 2009-2013, with the following focuses: Main land use category before, during and after collectivisation and course of the land restitution process starting 1990/1991.

4.2.2 Traditional meadow use

Details about the traditional meadow use were gathered in interviews with local farmers, mainly the participants of a pilot agri-environment programme for hay meadows carried out 2011-2014 in the *utilised hay meadows* (Paulini 2012, 2015). The questions were integrated into the control procedure for the plots mown.

In 2011, semi-structured interviews were carried out by the thesis author, following a general interview guide in an open conversation. Six persons from Borșa commune (Great Meadow) and five persons from the village Luna de Jos (Dăbâca commune, Lord's and Village Meadow) were interviewed. Additionally, a semi-structured interview with the mayor of Dăbâca in 2010 was also included in the evaluation.

In 2013, structured interviews were carried out by Vasile Rus Jr. in Luna de Jos village about the Lord's and Village Meadow, asking all the participants the same questions in the same order (13 persons).

The questions in both, the semi-structured and structured interviews, concerned:

- The traditional mowing period for the three *utilised hay meadows*. 'Traditional' refers to the time before collectivisation, because at that time the mowing date was not influenced by factors like the imposed course of activities of the collective farms or the abandonment of farming after 1989.
- For the Lord's and the Village Meadow, the mowing period during and after the communist period was surveyed.
- Fertilisation of the Lord's and Village Meadow before, during and after the communist period. Information about the fertilisation of the Great Meadow come from two interviews with farmers in the years 2012 and 2013.
- Additionally, several semi-structured interviews and conversations with local farmers during the period 2009-2013 addressed further aspects of meadow management, like the grazing of the meadows in spring and autumn, maintenance work, share of fallow plots etc.

4.2.3 Situation 2010-2014 and subsequent developments

Aspects of meadow use in the period 2010-2014 and beyond were surveyed through various methods, which are listed in the following:

- Mapping of the mown plots in the field at the end of the mowing period in all three *utilised hay meadows* in the years 2010 to 2014, in the Lord's and Village Meadow also in the years 2018 and 2019, using GPS devices. The mapping in the field was partly carried out by persons other than the author of the thesis (indicated below the figures in Chapter 4.3.3.1.1). The data were processed in ArcGIS Desktop 10.1 (ESRI - Environmental Systems Research Institute 2012), Google Earth Pro (Google LLC 2022) and EXCEL 2019 (Microsoft Corp. 2018).
- Frequent observations in the field in the period 2009-2014, for example during the vegetation and diversity surveys and the mapping of mown areas.
- Several interviews and conversations with local farmers during the period 2009-2013.
- Occasional site visits in the period 2016-2019 as well as information on the condition of the meadows from colleagues to the year 2023.

4.3 Results and discussion

4.3.1 Land tenure and land use categories

4.3.1.1 Results

4.3.1.1.1 Situation in the 1880s

In the cadastral map of the village Luna de Jos of the year 1878, the Lord's Meadow consists of one big, undivided unit (except for a small plot in the south) with the land use specification 'R', which is interpreted as the Hungarian word *rét* (see Figure 102). According to Rab (1996), *rét* is used for 'meadow, which can be mown'.

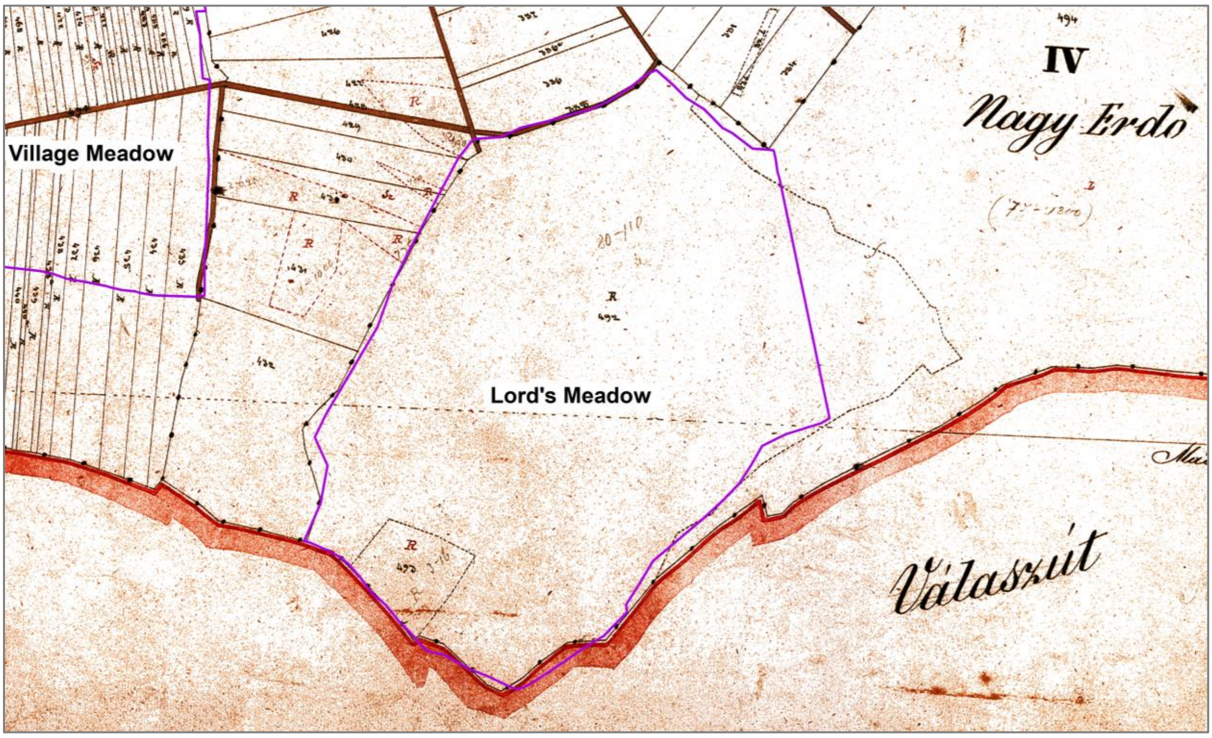

Figure 102: The Lord's Meadow on a cadastral map of Luna de Jos from the year 1878 (Dăbâca commune)
The map is displayed without scale. Violet outlines: current contour of the hay meadows; interpretation of the inscription *Nagy Erdő* (in Hungarian): place name, meaning 'Big Forest'; *Válaszút*: Râscruci (neighbouring village); the letters indicate land use categories (in Hungarian), interpreted as: R = *rét* (hay meadow), Sz = *szántóföld* (arable land), L = *legelő* (pasture); map source: Agency of Cadastre and Land Registration Cluj (OCPI)

In the same cadastral map, the Village Meadow consists of one large part with elongated land parcels arranged in two rows parallel to the slope, followed by two bigger plots extending over the entire north-south length of the meadow (see Figure 103). The higher row consists of 22 parcels, the lower of 37 parcels, some of them very narrow. The Village Meadow is designated with the place name *Szenafű*, an Hungarian word for hay meadow (Rab 1996), and furthermore all the parcels have the land use specification 'R' for Hungarian *rét*, that is, another word for hay meadow (see above).

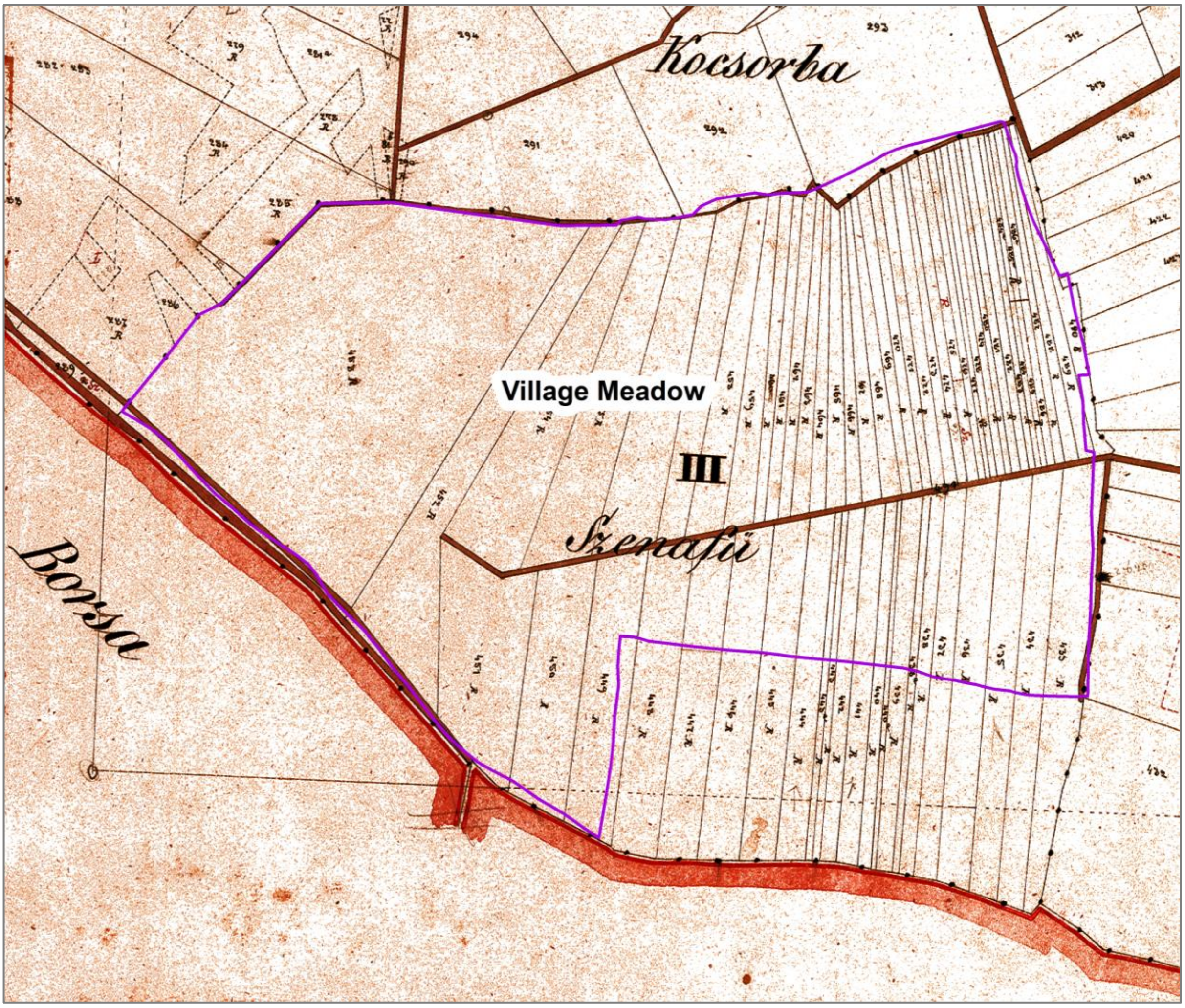

Figure 103: The Village Meadow on a cadastral map of Luna de Jos from the year 1878 (Dăbâca commune)
The map is displayed without scale. Violet outline: current contour of the Village Meadow; interpretation of the inscriptions (in Hungarian): *Kocsorba*: place name, *Szenafű*: place name, meaning hay meadow; the letters indicate land use categories (in Hungarian), interpreted as: R = *rét* (hay meadow), Sz = *szántóföld* (arable land); map source: Agency of Cadastre and Land Registration Cluj (OCPI)

The cadastral map of 1883 showing the Great Meadow in Borșa commune does not, in contrast to the previous map, detail the land use categories of the single parcels by means of letters (see Figure 104). However, it seems very likely that the brownish-green colour indicates grasslands, and the white colour indicates arable.

Within the area of what is nowadays defined as the Great Meadow, the designation '*9 Fináj*' is noted. It is probably a place name, considering the other names written in the same way (*8 Pakulái, 13 Rét*), however, also with reference to land use, since *Fináj* is most probably derived from the Romanian word '*fân*' for hay. Interestingly, a part of the Great Meadow is called *Fânaia* also nowadays (see Chapter 2.9.2.1). Regarding the ownership structure, the map shows no subdivisions of the area referred to as '*Fináj*', like in the map of the Lord's Meadow in Luna de Jos. The area designated as '*Fináj*' is larger than the present Great Meadow.

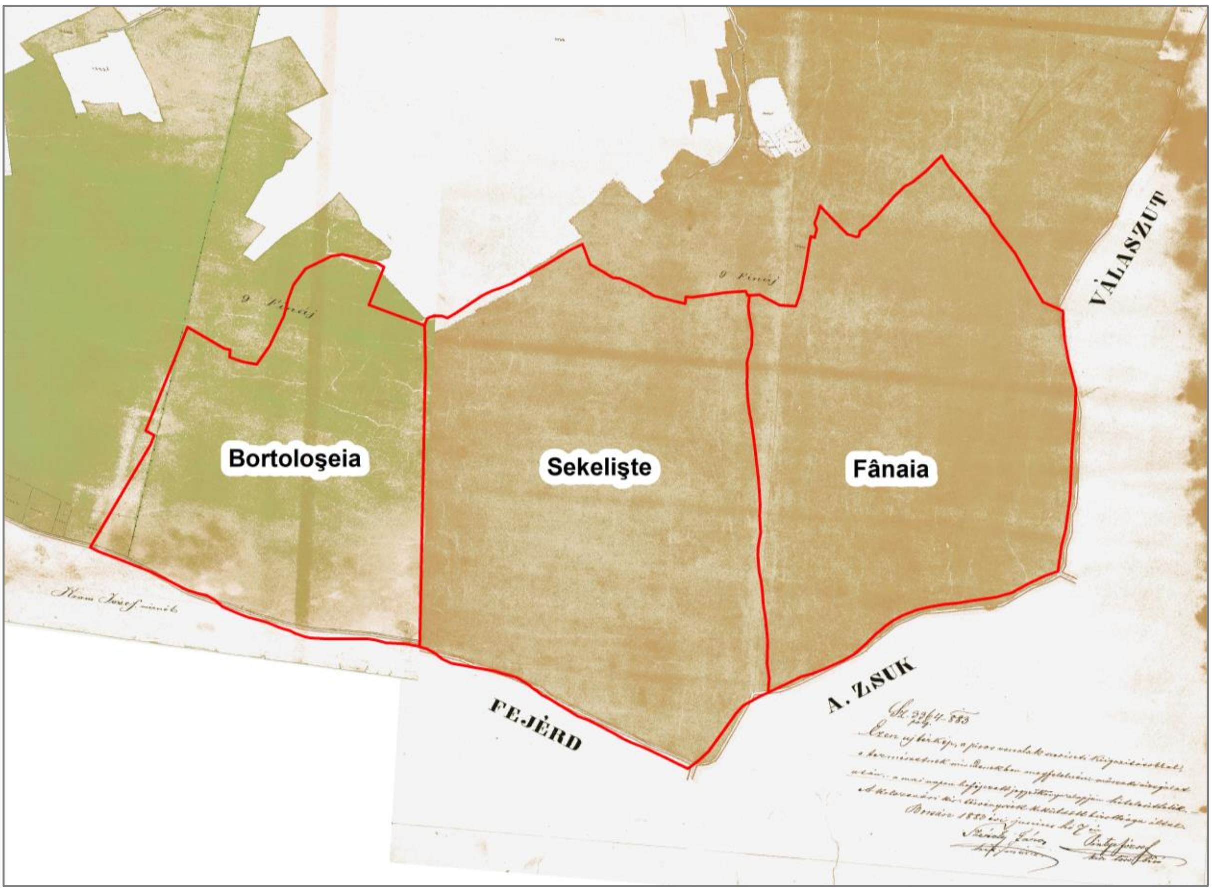

Figure 104: The Great Meadow on a cadastral map from the year 1883 (Borșa commune)
The map is displayed without scale. Red outlines: current contour of the Great Meadow and separation of the sections; names of neighbouring communes/villages (in Hungarian): *Fejérd*: Feiurdeni, *A. Zsuk*: Jucu, *Válaszút*: Râscruci; the indication '*9 Fináj*' is interpreted as place name, most probably derived from the Romanian word '*fân*' for hay; map source: Agency of Cadastre and Land Registration Cluj (OCPI)

4.3.1.1.2 The land reform of 1921

The cadastral map of the Lord's Meadow from the year 1921 (see Figure 105) shows a new subdivision of the formerly undivided property into 109 plots. The plots are arranged in five rows, four of them at right angles to the slope and one parallel to the slope. Each row contains 13 to 27 plots, the mean is 22 plots per row. The plots are rectangles, in most of the cases with a significantly greater length than width, the largest ratio being 16 with a plot length of 213 metres and a plot width of 13 metres.

All except two land parcels measure 0.29 ha, which corresponds to half a '*jugăr cadastral*'. The '*jugăr cadastral'* (0.58 ha) is a commonly used historical unit of area measurement in Transylvania, which is identical with the Austrian '*Joch*' (Dugheanu 2006). The table of the parcel owners (not shown) indicates that the 109 plots had 108 different owners and that the land use category of all plots was hay meadow.

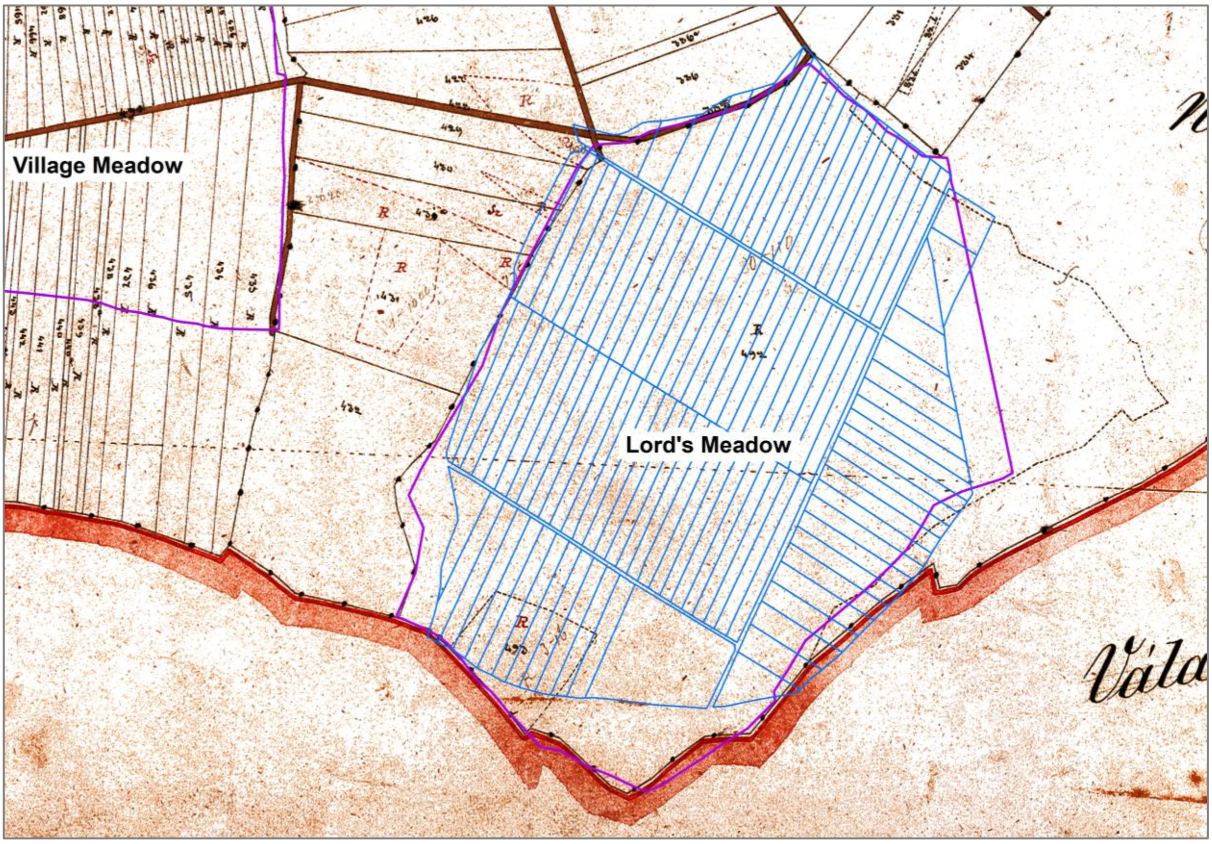

Figure 105: The land tenure structure of the Lord's Meadow after the land reform of 1921 (blue lines), superimposed on the cadastral map from the year 1878
The map is displayed without scale. Violet outlines: current contour of the hay meadows; map sources: the cadastral map of 1921 was obtained from the municipal office of the commune Dăbâca in the year 2010; the cadastral map of 1878 was obtained from the Agency of Cadastre and Land Registration Cluj (OCPI)

4.3.1.1.3 The communist period

The cadastral map (1:25,000) of Dăbâca commune from the beginning of the 1970s shows that the Lord's Meadow is no longer divided into land parcels and is part of a large pasture reaching down the valley, indicated by the letters '*Pş*' for Romanian *păşune* (see Figure 106).

The cadastral map also shows that the Village Meadow is still used as hay meadow ('*F*' for Romanian *fâneață*) but neither divided any longer into plots. The map indicates that the new owner is the Agricultural Production Co-operative of Dăbâca (C.A.P. Dăbâca). In the south-eastern corner of the original Village Meadow an area covering around 15 ha is indicated as arable in the map. A comparison with the map of 1887 (see Figure 103, page 191) shows that around one fifth of the original meadow surface was lost thereby.

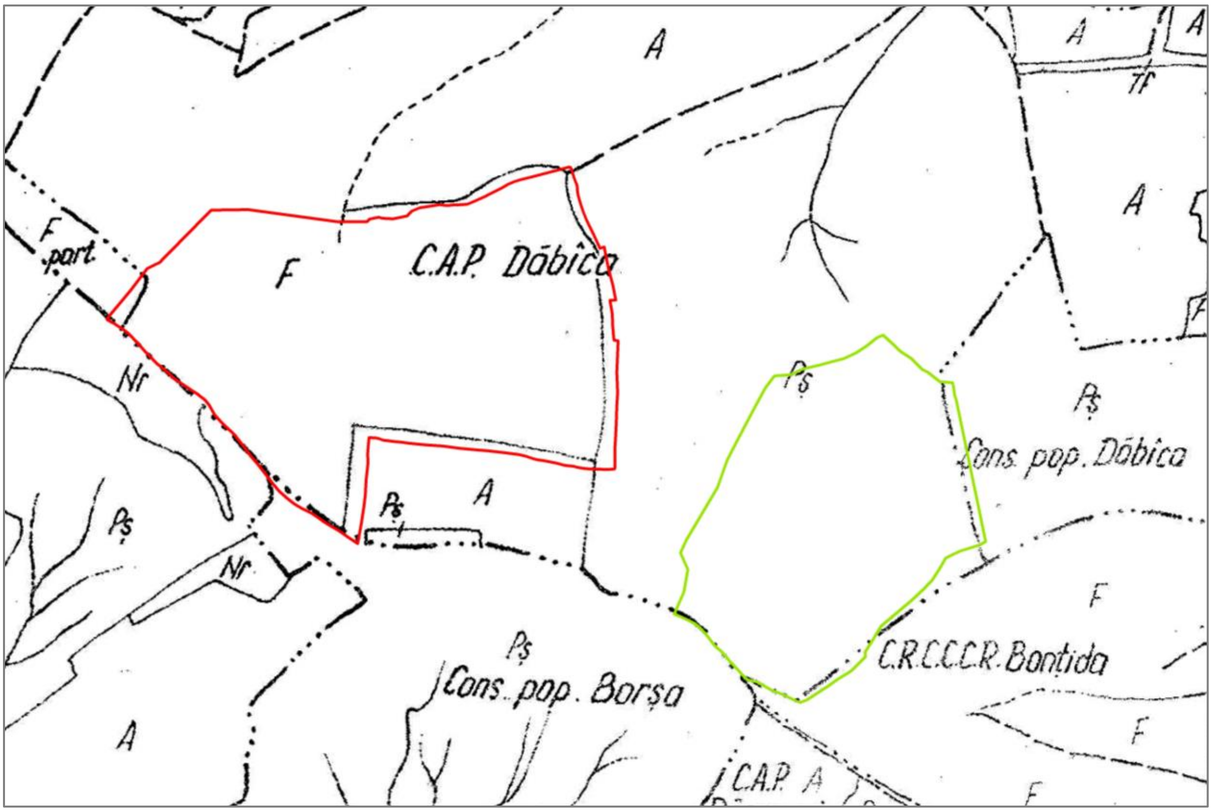

Figure 106: Cadastral map (1:25,000) of the Lord's and Village Meadow in the communist period (Dăbâca commune)
The map is displayed without scale. Green outline: current contour of the Lord's Meadow; red outline: current contour of the Village Meadow; explanation of selected abbreviations indicating the land use: A: arable *(arabil),* Cc: constructions *(construcţii),* F: hay meadow *(fâneaţă),* Nr: steep gradient *(râpi),* Pd: forest *(păduri),* Pş: pasture *(păşune),* Tf: shrubs *(tufărişuri);* explanation of selected ownership information: C.A.P. Dăbâca: Agricultural Production Co-operative of Dăbâca, Cons. pop. Dăbâca: People's Council of Dăbâca, part.: privately owned *(particular)*; map source: cadastral map L-34-48-A-b (1:25,000) created by the former Institute of Geodesy, Photogrammetry, Cartography and Territorial Organization (IGFCOT) (1971-1990)

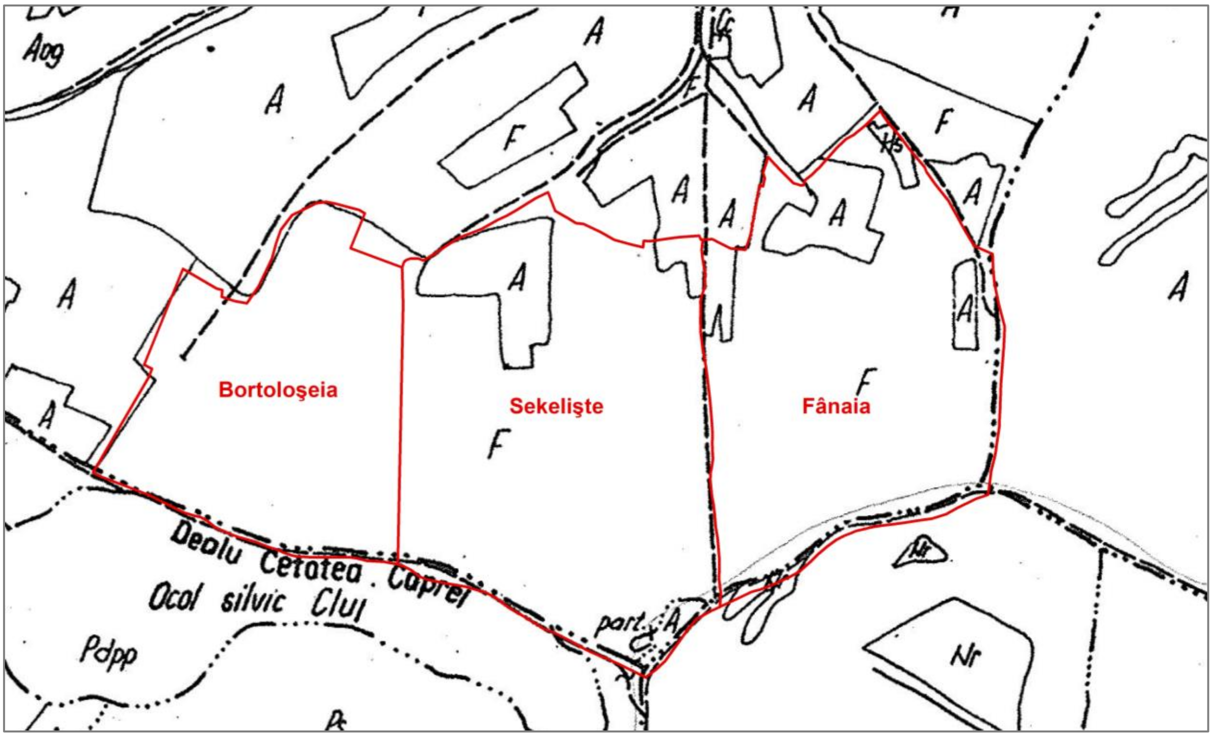

Figure 107: Cadastral map (1:25,000) of the Great Meadow in the communist period (Borșa commune).
The map is displayed without scale. Red outline: current contour of the Great Meadow; explanation of selected abbreviations indicating the land use: A: arable *(arabil),* Cc: constructions *(construcţii),* F: hay meadow *(fâneaţă),* Hs: reed *(stufăriş),* Nr: steep gradient *(râpi),* Pd: forest *(păduri),* Pdpp: forest plantation *(plantaţii),* Pş: pasture *(păşune),* Tf: shrubs (tufărişuri); explanation of selected ownership information: *Ocol silvic Cluj:* forestry district Cluj, part.: privately owned *(particular)*; map source: cadastral map L-34-48-A-d (1:25,000) created by the former Institute of Geodesy, Photogrammetry, Cartography and Territorial Organization (IGFCOT) (1971-1990)

The cadastre for Borșa commune from the communist period proves that the Great Meadow, like the Village Meadow, was no longer divided in ownership plots and remained to be used as hay meadow (see Figure 107). There are also some large plots downhill which are designated as arable in the map.

The lack of subdivision of the surveyed hay meadows into ownership parcels is also evident from the 1:5,000 scale cadastral maps from the 1970s (not shown).

4.3.1.1.4 The post-communist period

The land restitution restored the ownership of the former owners of the three *utilised hay meadows* in 1945 or their heirs. In case of the Lord's Meadow, this resulted in exactly the same layout as in 1921 (i.e. 109 parcels of 0.29 ha, each in the same location), but in the hands of the heirs of the former owners, as evidenced by comparing the cadastral maps of 1921 (see Figure 105, page 193) with the map and (incomplete) list of owners obtained 2018 from the municipal office of the commune Dăbâca (not shown).

The tenure structure in the cadastral map of the Great Meadow, which was obtained in the year 2012 by the municipal office of Borșa commune (not shown), corresponds to the tenure structure indicated in the cadastral geoportal (Agenţia Naţională de Cadastru şi Publicitate Imobilară 2019-) (see Figure 108): The meadow surface is divided into four to five rows at right angles to the slope, which in turn are subdivided into numerous parcels parallel to the slope, thus showing the same ownership pattern found also in the Lord's Meadow and the Village Meadow.

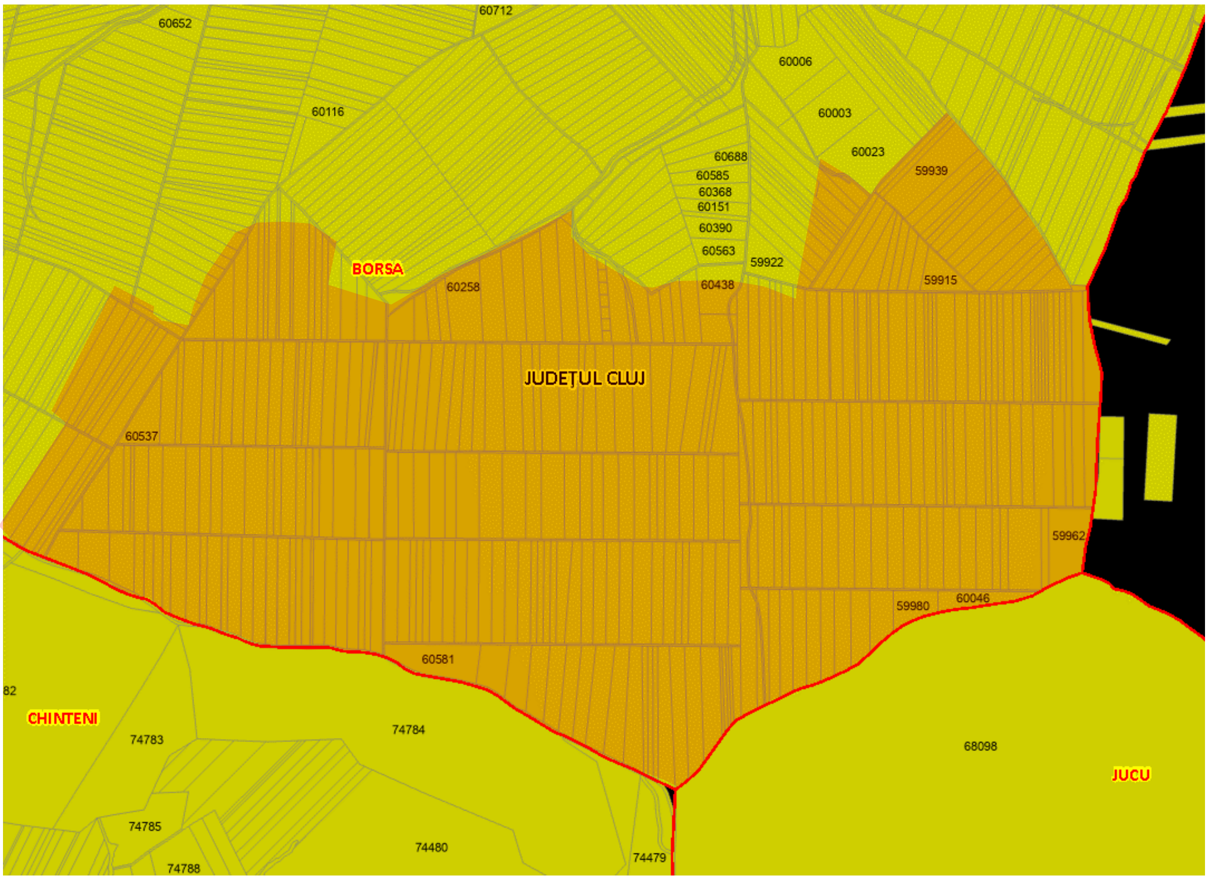

Figure 108: View of the Great Meadow (orange area) in the cadastral geoportal (Agenţia Naţională de Cadastru şi Publicitate Imobilară 2019-), accessed 10.08.2023
Yellow plots are surveyed and registered in the land register.

For the Village Meadow it is concluded from discussions with owners and the findings from the mapping of the mown plots (see Chapter 4.3.3.1.1) that the tenure structure corresponds to that of 1887 (see Figure 103, page 191). However, changes of the exact location and size of the ownership parcels in 1878 most likely occurred through pooling or splitting of parcels by inheritance (before the land expropriation in the 1950ies and after the restitution starting 1990).

Discussions with owners and experts (e.g. landownership officers) about the restitution process have also revealed that the path from the application for restitution to the surveying of the plots and entry in the land register involves many steps, which are often complicated by the inheritance situation and the costs incurred, and partly also by the lack of a single person in the municipal offices responsible for assisting the heirs during the process.

In the commune of Dăbâca (Lord's Meadow and Village Meadow), this has led to the situation that for many plots no owners can be identified or where the owners do not have valid documents (especially in the Lord's Meadow). Only a fraction of the occupiers possesses a land title and only a few have had their plot surveyed and registered in the land register: in the Lord's Meadow 5 plots of 109, in the Village Meadow 9 plots (see Figure 109 and Figure 110; status: 19 March 2023). In the commune of Borșa, which participated in the National Cadastre and Land Registry Programme, all plots are surveyed and registered in the land register (see Figure 108).

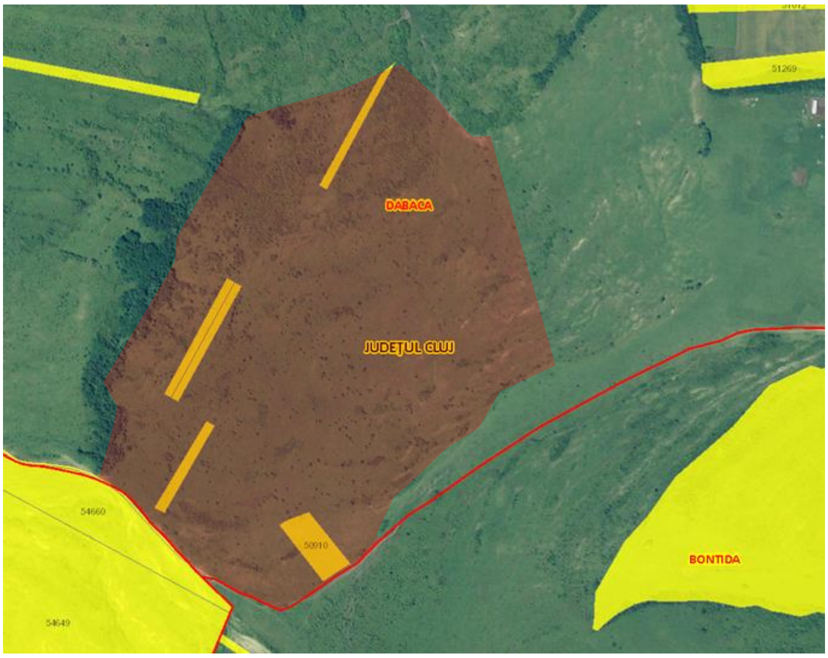

Figure 109: View of the Lord’s Meadow (orange area) in the cadastral geoportal, accessed 19.03.2023
Yellow plots are surveyed and registered in the land register.

Figure 110: View of the Village Meadow (orange area) in the cadastral geoportal, accessed 19.03.2023
Yellow plots are surveyed and registered in the land register.

4.3.1.1.5 Main land use categories

Regarding the main land use categories of the *utilised hay meadows*, the statements of all the interviewed persons (extending to the time before collectivisation) and the information on all of the cadastral maps presented so far were in agreement: the Village Meadow and the Great Meadow have been used as hay meadows at least since the 1880s up to today. The Lord’s Meadow has been used as hay meadow at least since the 1880s up to the 1950s. Then, in the communist period, it has been used as pasture for steers and dairy cattle of the local collective farm (*CAP*) for around 40 years.

According to the local farmer Vasile Rus Sr. (personal communication, August 2016), the transformation from hay meadow to pasture took place at the beginning of the 1950s, when the collective farm took the animals from the farmers and needed a pasture for them. According to the local farmer Adrian Biriş (personal communication, cited in Sunder-Plassmann 2016), the Lord’s Meadow was partially overgrazed during the period when it was used as pasture.

Since the 1990s, the novel land use practice of grazing sheep throughout the year has emerged in the meadows, alongside the traditional meadow use, as has the complete abandonment of land use; the significane and distribution of grazed and abandoned areas varies over time and between the meadows (see Chapter 4.3.3).

Furthermore, in the Village Meadow and the Great Meadow some plots have been used as arable at different times. Regarding the meadows in Dăbâca commune, Mr. Vasile Rus Sr. stated that in the Village Meadow, some parcels were used for arable before collectivisation and for two to three years after 1990, including his own parcel and one to two parcels nearby. Regarding the Lord’s Meadow he stated that there have never been arable parcels in this meadow (personal communication, December 2011). In the period 2009-2023, no parcels were ploughed in the Village Meadow or the Lord’s Meadow.

In the Great Meadow, a few ploughed plots were observed in the bottom row of parcels of *Sekelişte* in the period 2009-2016 and, according to the landownership officer of Borșa commune, there were also some in the top row of parcels before 2009 (Mr. N. Ioan Vultur, personal communication, February 2012).

4.3.1.2 Discussion

4.3.1.2.1 Deriving the land tenure history from the maps

Figure 111 summarises the interpretation of the results regarding ownership since the 1880s, which is also described here in more detail. The way the Lord’s Meadow (Dăbâca commune) is shown in the cadastral map of 1878 as one undivided land parcel suggests that it was privately owned by one person at that time, most probably a Hungarian nobleman. The following indications strengthen this hypothesis: the name of the meadow itself, the location of the meadow near a manorial estate in the village Luna de Jos and not least statements of the local farmers.

Figure 111: Interpretation of the results regarding ownership and main land use categories of the *utilised hay meadows* during the last 140 years
The x-axis shows the years back from today until 1883 (the date of the earliest cadastral map of the Great Meadow), zero refers to the year 2023. Meaning of the colours and patterns: green: hay meadow; blue: cattle pasture; sandy: mix of hay meadow, grazing area for sheep, and abandonment of use. Vertical stripes indicate multiple private owners; unstriped areas with framing indicate a single private owner, unstriped areas without framing indicate the collective ownership during communism. The start of the collective farming is drawn in simplified as starting 1955.

The same might be true of the Great Meadow in Borșa commune at the end of the 19th century too, since it too is shown as an undivided area on the 1883 map. A possible owner was the Bánffy family, who owned Bánffy Castle in Borșa village until after the 2nd World War (Enciclopedia Maghiară din România 2012).

In contrast, the Village Meadow (Dăbâca commune) was already divided into many small ownership parcels in the year 1878, most probably privately owned by peasants from Luna de Jos. The place name of the meadow strengthens this assumption. The fact that many parcels are very narrow could be due to the law of succession (gavelkind), which sometimes led to excessive land fragmentation. The land reform of 1921 likely did not change the basic tenure structure of the Village Meadow, since only large properties were expropriated.

Not so at the Lord’s Meadow: in the 1921 land reform, the meadow was divided into numerous plots and ownership passed from a single noble to many peasant owners. Although no cadastral map of the Great Meadow (Borșa commune) from that period could be obtained, it is assumed here that the same happened in the Great Meadow too, since the hay meadow is nowadays also characterized by the same pattern of numerous small plots like the other meadows.

The next upheaval which affected the ownership structure of the meadows took place in the 1950s. With the foundation of collective and state farms and the expropriation of most of the privately owned agricultural land, the property passed from the numerous owners of the hay meadows to a centralized ownership of the so-called collective farms, meaning that the ownership pattern of many small plots was abandoned in all *utilised hay meadows*.

Due to the last change, the land restitution starting 1990/1991, not only private ownership but also the small-scale parcelling characteristic of the period around 1950 was restored in the hay meadows; this pattern has persisted until today, with no large-scale land consolidation having taken place in the interim.

The process of land restitution involves surveying of the plots and registration in the land registry, which is at very different stages in the different hay meadows. While it is completed for the Great Meadow in Borșa commune through the National Cadastre and Land Registry Programme, the process is far from complete in the Village Meadow and even more so Lord's Meadow (Dăbâca commune). Over time, due to succession and loss of knowledge, it becomes increasingly difficult to prove ownership. This brings with it an increased risk of ownership rights no longer being enforceable, something which is already having an impact on management and protection options, at least in the Lord’s Meadow.

4.3.1.2.2 General considerations about the land tenure structure

When divided into small ownership parcels, the meadows all feature the same spatial pattern: two to five rows, in most cases at right angles to the slope, with each row containing two to several dozen elongated plots parallel to the slope. The size of the plots is in almost all cases much smaller than one hectare, usually 0.29 ha or its double or triple, due to the historical unit of area measurement in Transylvania. This results in a large number of ownership parcels for each hay meadow, exceeding one hundred in the Lord’s and Village Meadow, and even 300 in the Great Meadow.

In other words, an administrative-political decision made one century ago, namely choosing the plot size of half a ‘*jugăr cadastral’* (0.29 ha) for all the plots in the Lord’s Meadow, is having an impact on today's management and protection opportunities. For agricultural subsidies of the European Union including the agri-environment payments, Romania has chosen to make only parcels of 0.3 ha size or more eligible, which means that for most of the plots in the Lord's Meadow, and also a part of the plots in the other hay meadows, a possible protection instrument is either not available or very difficult to access.

Since at least the end of the 19th century the plots in the three study meadows have always been, except for the communist era, in private property, that is, each parcel, whether large or small, has been subject to the decision-making of a single person or organisation. This distinguishes the hay meadows from the traditional pastures, some of which (75% of the pasture area in Borșa commune, 50% in Dăbâca commune) have been owned commonly before and after the collectivisation (for more details see Paulini et al. 2011).

In fact, it seems to be a general pattern that traditional hay meadows often are grassland units divided into smaller (sometimes very small) plots, which are owned privately:

- Netting (1981) describes the traditional mountain hay meadow management in the village Törbel, Switzerland (canton of Valais). In 1925, the mean size of a hay meadow parcel was 0.12 ha and one owner held on average 8 parcels in different meadow sites.
- Fischer and Wipf (2002) studied traditional subalpine meadows (*Mähder*) of Davos, Switzerland. These hay meadows sized between two and a few hundred hectares, subdivided into parcels of 0.03 to 0.5 ha.
- Huband (2008) studied the hay meadows of a mountain village in the Southern Carpathians (Romania). The structure of land tenure of the meadows is characterised by several hundred small plots (often less than a hectare in size) belonging to around 230 smallholdings in the village.
- Demeter and Kelemen (2011) mapped the mown and unmown mountain hay meadows of two communes on 60 km^2 in the Csík Mountains (Eastern Carpathians, Romania). They describe the land tenure of the mountain hay meadows as private property, divided into plots from 0.2-0.3 ha to more than 5 ha.

Important to notice is, that the separation of the hay meadows from the grazed area and the right of private property and land titles for peasants are relatively new historical developments of the last centuries, so that the 'traditional' hay meadows and their 'traditional' private small-scale land tenure developed especially since the 18th century (Luick et al. 2012). However, the management of hay meadows in allotments, which can be compared to the ownership parcels, may be much older (see for example Cricklade Court Leet Charity 2023). Also, the commonly used parcel size of 0.58 ha in Transylvania is close to the surface of 0.5 ha, which a person can scythe on average during a day (Dierschke and Briemle 2008).

Finally, it should be mentioned that this study about the past and present land tenure is just a first step in shedding light on this aspect of the agricultural history of the communes and cannot pretend to be a comprehensive historical or ethnological study.

4.3.1.2.3 Continuity of use and age of the hay meadows

On the communal territories of Dăbâca and Borșa there are a range of archaeological sites such as settlement remains, tumuli and a fortress, which span a period from the Neolithic through to the Middle Ages, some of which are in the immediate vicinity of the hay meadows (Institutul Naţional al Patrimoniului 2023). These indicate an early and continuous settlement; according to the findings of Feurdean et al. (2015), and a Middle Bronze Age forest clearing phase can be assumed for the surroundings of the study meadows.

The earliest document that proves that the study *utilised hay meadows* were open land free of forest is the first comprehensive military land survey of the Habsburg Empire, the Josephinian Land Survey carried out 1763-1773 in Transylvania (Austrian State Archives 2023a). They are also shown as open land on the map of the second military land survey of the Habsburg Empire in Transylvania (1853-1858; 1869-1870) (Austrian State Archives 2023b). According to the map legend, the study meadows were rough pastures at that time.

The subsequent cadastral maps published in 1878 and 1883 are the first known evidence of their use as hay meadows. In summary, this means that the *utilised hay meadows* of this study have been open land continuously for at least 250 years and hay meadows for at least 140 years (see Figure 111, page 199). However, there is a possibility that the study meadows have a history as grasslands which reaches back many centuries or even thousands of years (see Chapter 6.1).

The intervals when other uses prevailed must of course not be ignored; they also may have had a significant impact on the vegetation, flora and fauna. For instance, the grazing period of around 40 years in the Lord's Meadow could have a still detectable impact on the vegetation and flora of the meadow, compared to the Village and Great Meadow. The vegetation data collected in this thesis is not suitable to answer this question, but it is certainly an interesting issue for future research.

Overlying the layers of past management is the present use, which in parts differs greatly from traditional use, for example through sheep grazing in the summer period, or abandonment (see Chapter 4.3.3). Chapter 5 examines one aspect of the change in use, permanent grazing by sheep, and how it affects vegetation and plant diversity.

Finally, with regard to the individual, temporarily occurring arable plots in the meadow matrix, for example in the Village Meadow, it must be assumed that the vegetation structure and plant species composition of the surrounding meadow was restored to them after the abandonment of ploughing. Prerequisites for this were most probably appropriate meadow management practices as well as the seed dispersal and vegetative reproduction from the adjacent meadow plots. The topic of arable plots in the meadows also needs further research.

4.3.2 Traditional meadow use

4.3.2.1 Results

4.3.2.1.1 Traditional period of hay making

The results from the standardised interviews regarding the mowing period indicate that July and August were traditionally the months for hay making in all three *utilised hay meadows*, as well as June to a lesser extent (see Figure 112); 'traditional' here refers to the time before the 1950s, when collectivisation started. August as a month for hay making apparently was more important in the meadows of Luna de Jos (Lord's and Village Meadow), where 18 of the 19 interviewees mentioned it, compared to the Great Meadow (3 out of 6 people).

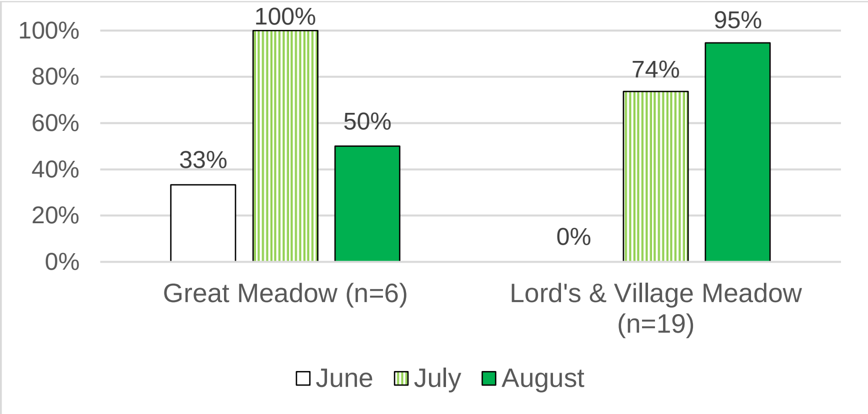

Figure 112: Traditional mowing period in the *utilised hay meadows*
Y-axis: percentage of responses received (several options possible); question asked: when were the meadows mown traditionally (before communism)?

The results concerning the months in which mowing traditionally started or ended point in the same direction (see Figure 113): July is the main traditional starting month for mowing in both communes. From the interviews could be extracted that it was especially the second half of July. Additionally, one third of the interviewed persons mentioned June for the Great Meadow, and one quarter of the asked persons mentioned August as starting month for the meadows of Luna de Jos village, especially the Lord's Meadow. The pattern is repeated when considering the end of the mowing period, which in the Great Meadow traditionally is in July or August, while for the Lord's and Village Meadow only August was named.

In Borșa commune, two farmers mentioned that the start of the mowing season was linked to certain events or Saint's Days, namely the 'Cherry market' in the neighbouring commune Bonţida on 29 June and the Feast of Elias on 20 July, respectively. Similarly, Vasile Rus Sr. indicated that in the Village and Lord's Meadow mowing was usually completed by the 15th of August, the Feast of the Assumption of the Virgin Mary (personal communication, April 2023).

Most of the farmers said that the hay making season in general lasted around one month, but several farmers also indicated a period of two weeks, given suitable weather.

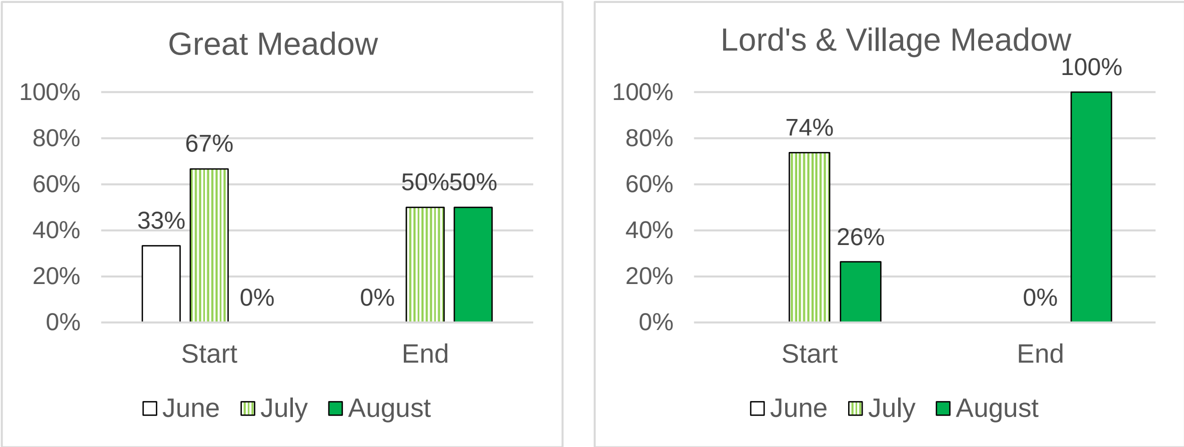

Figure 113: Traditional starting and ending month for mowing in the Great Meadow (left) and the Lord's and Village Meadow (right)
Y-axis: percentage of responses received; questions asked: when did mowing start /end traditionally (before communism)?

4.3.2.1.2 Grazing in spring and autumn

In addition to the hay production in summer, the *utilised hay meadows* have traditionally been (and still are) grazed in spring and autumn by sheep, and in former times also by cattle. The grazing takes place before the field is 'shut-up', that is, protected for the growth of the sward in summer, and after the harvest respectively. In the following, details about this practice will be given for the meadows of Luna de Jos, that is, the Lord's and Village Meadow, as outlined by local farmer Vasile Rus Sr. over several interviews in the period 2010-2012:

- Sheep grazing in spring and autumn was a constant factor in the meadows of Luna de Jos during all the considered time periods (before, during and after collectivisation). The flocks consisted of the small-scale farmers' own sheep and sheep belonging to the professional sheep farmers, in varying proportions.
- The period of spring grazing with sheep traditionally lasted from around 20-22 April to 10 May. The starting date is linked to the Saint George's Day (in Romania called *'Sângeorz'*), on 23 April, which is an important feast in the culture of pastoralism. After the 10th of May, the meadows were 'shut up' until after the mowing had been finished.
- After the 're-opening' of the meadows for grazing, they were traditionally first grazed by cattle. During the time of communist collective agriculture, the cattle of the Dăbâca Agricultural Production Co-operative grazed the aftermath of the Village Meadow from August or September until the beginning of November (the Lord's Meadow was at this time a pasture for dairy cattle). Vasile Rus Sr. assumes that cattle grazing was carried out on both meadows in the same way also before the collectivisation.

- During the 1990s, autumn grazing with cattle on the meadows stopped, because cattle numbers decreased and there was no longer any need for autumn pasture over and above what the common cattle pasture provided.
- Sheep grazing in the Lord's and Village Meadow was traditionally carried out after cattle grazing, that is, starting at the beginning of November. Since the 1990s, sheep grazing has started directly after the mowing period in August or September. Traditionally, the meadows were not grazed during the winter period. The period of sheep grazing ended with the first snow or at the latest on the 18th of December. However, this traditional winter break is no longer respected (see Chapter 4.3.3).

4.3.2.1.3 Other aspects of management

Information about fertilisation of the meadows of the village Luna de Jos (Lord's Meadow and Village Meadow) was gathered in the year 2013 by means of standardized interviews with farmers. The results indicate that the Lord's and Village Meadow were not fertilised before, during and after the communist period, neither with organic nor with mineral fertilisers (answer of 12 persons of a total of 14, two persons stated that they didn't know).

For the Great Meadow, the statements of two farmers (Gheorghe Jucan, village Borşa-Cătun, July 2012, and Alexandru Mărginean, village Borșa, September 2013) provided useful infomation, but there were no interviews focussing on this topic as there had been for the Lord's and Village Meadow. According to the two farmers, the Great Meadow was not fertilised in the periods before and neither after communism, but during the communist era it had been fertilised with mineral nitrogen.

The usual number of cuts per year in the study meadows was not included in the standardised interviews but was brought up in several conversations with local farmers and experts. The unanimous consensus was that usually all three meadows are cut just once per year, very rarely for a second time in autumn (aftermath, *otavă* in Romanian); this has always been so, to the best of the informants' knowledge.

The suggestion that traditionally parts of the meadow plots might have been exempted from mowing for short periods as part of regular management was rejected by several farmers in both communes (e.g. Vasile Rus Sr., personal communication, December 2011).

Furthermore, the conversations with the farmers revealed that as well as the haymaking itself, meadow management traditionally also included maintenance works, for example, the clearing of shrubs and molehill levelling, which were carried out every year in the spring.

According to local farmers, the Lord's and Village Meadow have been completely free of woody plants with minor exceptions. This was the case during communist agriculture and before collectivisation, back to the earliest memories of their parents. The entire surface has been mown every year and no woody plants would be allowed to come up. Vasile Rus, Luna de Jos, confirmed that ever since he can remember, the only woody plants in the meadows have been four to five thickets of grey willow (*Salix* *cinerea*) in the Village Meadow, and they were present before abandonment started after 1990. During the communist period, the Lord's Meadow, used as pasture, would also have been regularly cleared from shrubs.

4.3.2.2 Discussion

4.3.2.2.1 Traditional period of hay making

Farmers usually decide when to mow based on two major factors: the maturity of the crop and the likelihood of good weather conditions which would allow the mowing, turning, carting and storing of the the hay without major losses (Gamble and St. Pierre 2010; Suttie 2000). The maturity and quality of the crop depends on the start and length of the growing season, the type of grassland and the phenology of the main fodder species. While in theory the ideal time to make hay is when the yield or nutritional value is highest, suitable weather is often the over-riding consideration and other factors have to be considered, too, like the availability of labour (Suttie 2000). Traditional mowing dates or periods usually indicate the best combination of a good yield and a high probability of good weather for a certain area.

July as the month in which mowing usually started in the *utilised hay meadows* usually corresponds to the phenological stage 7 (*Cirsium palustre-Galium album*-stage, see Dierschke and Briemle 2008), when many good fodder grasses, e.g. *Festuca pratensis, Phleum pratense, Trisetum flavescens* or *Briza media,* are in flower in the meadows. The higher share of statements about a later start and end of the cutting period in the meadows of Luna de Jos (Lord's and Village Meadow), compared to the Great Meadow must be verified through further research, for example through the study of farm diaries. The range in the starting dates mentioned for the meadows, amounting up to one month, may be explained by different locations of the ownership parcels in the meadow (e.g., moister versus drier soil conditions) or differences in organising the farming year.

Before modernisation of meadow farming, the length of the hay making period was usually influenced mainly by the weather. If crop maturity coincided with hot and dry weather, the process of hay making was completed quickly, while poor drying conditions in a wet summer delayed the hay time until September (see also Gamble and St. Pierre 2010). The length of the mowing season cited by the informants - of two to four weeks - fits this proposition.

The delay of mowing in case of a wet season was not an issue covered by the interviews, but it would be an interesting complement, because intermittent late cutting may be important to allow occasional seed set in late-flowering perennials such as *Sanguisorba officinalis* (Smith and Jones 1991) and may have an influence on the populations of the *Phengaris* species with a late flight period. Generally, the survey about the mowing period should ideally be supplemented by further studies.

4.3.2.2.2 Grazing in spring and autumn

Pre- and post-mowing grazing of meadows is a common practice in many traditional European hay meadows (Luick et al. 2012), for example described for the hay meadows of the Yorkshire Dales by Gamble and St. Pierre (2010) or for the hay meadows of the Csík Mountains in the Eastern Carpathians by Demeter and Kelemen (2011). Cattle grazing before sheep seems to be a widespread rule (for example in Northwest Transylvania, see Goia 2012).

From an economical point of view, there are several advantages accruing from the spring and autumn grazing of hay meadows: In spring, the availability of new grass is an additional and valuable source of forage for the livestock. Autumn grazing on the other hand is an important maintenance practice for the meadows: uncut edges and slopes are grazed and tussocky grasses are prevented from taking over (Gamble and St. Pierre 2010). Furthermore, autumn grazing serves as a way to fertilise the meadows with the dung and urine of the livestock (Gamble and St. Pierre 2010; Demeter and Kelemen 2011). From an ecological point of view, there is some evidence, that spring and autumn grazing plays a role in the maintenance of meadow biodiversity, as Smith and Rushton (1994) could show for meadows in Northern England or Janišová et al. (2023) for hay meadows in the Carpathians (see also Chapter 5.4.1).

It is therefore welcome for several reasons that pre- and post-grazing continues in the *utilised hay meadows*, provided that the grazing intensity is not too high. But the replacement of cattle grazing in autumn by sheep grazing since the 1990s may already have had an effect on the meadow vegetation, as browsing and trampling differs between grazing animals.

4.3.2.2.3 Other aspects of management

The meadows have traditionally been subject to nutrient removal by one, or rarely two, annual cuts and the only source of nutrient supply has been spring and autumn grazing with cattle and / or sheep (see previous chapter). One exception is a presumed period of mineral nitrogen fertilisation in the Great Meadow during the communist era. The hay that the smallholders or collective farms harvested from the usually unfertilised meadows was used as the main fodder for their livestock over winter.

The absence of fertilisation with manure from the farms can be explained by the fact that arable farming has played an important role in the agriculture of the villages over the years, at least during the 20th century, so the manure was needed on the cultivated fields. Furthermore, the meadows are situated on the upper and middle parts of the hillslopes and at some distance from the villages (between two and eight kilometres) and the transport of manure would have been laborious. In the post-communist era, the gradual abandonment of small-scale farming in the villages rendered fertilisation with manure even more unlikely.

The increased availability of chemical fertilisers could theoretically have permitted the use of mineral fertilisers from the 1960s onwards (Simionescu et al. 2016), something made even more feasible by the increased mechanisation of agriculture in the communist period. To what extent exactly and for how long the option of mineral nitrogen fertilisation was used in the Great Meadow, and the detail of any use, is something which remains to be determined by future studies. In the post-communist era, the small-scale farmers lacked the financial resources to allow the use of mineral fertilisers on grassland.

In some regions, leaving a share of the meadow area fallow is part of the regular traditional management, described for example for mountain meadows in the Eastern Carpathians (Csergö and Demeter 2011a) and meadows in the Maramureş region which are located further from the settlements (Dahlström et al. 2013). This seems not to be the case for the study meadows.

However, the statement of the farmers that before the start of mowing abandonment in 1990 the entire meadow surface was mown as a rule probably does not mean that there were no unmown fields at all, for example due to a wet summer or unforeseen events. Furthermore, the peculiarities of relief or wet soil conditions may have led to small unmown plots.

The statements of the farmers indicate that the physiognomy, at least of the Lord's and Village Meadow, differed from their present appearance, in that they were almost completely free of woody plants until 1990. Nowadays they have a savannah-like appearance due to shrubs and trees scattered over the meadow surface (see Chapter 4.3.3.1.4).

4.3.3 The situation from 2009-2014 and subsequent developments

To understand the results, it is important to know about two nature conservation projects during the survey period, which were led by the thesis author and financed by the German Federal Environmental Foundation (Paulini 2012, 2015). These projects, also called ‘Mozaic Project I and II’, were aimed at the protection of the *utilised hay meadows*. This was to be realised, among other things, through the projects’ own pilot subsidy programme, which financially rewarded the mowing of the plots in the years 2011-2014.

Furthermore, in the communes of Dăbâca and Borșa (and others), a package within the national agri-environment programme that financially rewarded mowing after the date of 25 August, called ‘Package for grasslands important for butterflies (*Maculinea* [=*Phengaris*] spp.)’ was introduced in 2012. Thus the two subsidy types were never available at the same time for the same plots.

4.3.3.1 Results

4.3.3.1.1 Mown area

Table 38 shows the extent of mown area in the *utilised hay meadows* in the years 2010-2014, for the Lord’s and Village Meadow also in 2018 and 2019. Furthermore, in the table and in Figure 114 the proportion of mown area of the total meadow surface is indicated, as well as the proportion of mown area in the total meadow surface which was included in the subsidy programme of the Mozaic Projects (Paulini 2012, 2015).

The results show, that in all the years and meadows under consideration, the mown area was substantially smaller than the total area of the hay meadows. The various hay meadows also differ in terms of the proportion of their area mown. The highest values were achieved in the Village Meadow (measuring 67 ha): between 17 % (11 ha) in 2010 and 53 % (35 ha) in 2012. The Great Meadow (measuring 200 ha) shows the second highest values: between 19 % (38 ha) in 2010 and 42 % (84 ha) in 2012. The Lord's Meadow (measuring 42 ha) was almost completely unmown in 2010 (0.2 %, 0.1 ha) and the largest proportion was mown in 2013, namely 13 % (5.4 ha).

The proportion of the total area mown changed from year to year (see Figure 114). At the beginning of the period considered, in 2010, the proportion was at its lowest, then it increased to its maximum value, which, as already mentioned, was found in 2012 and 2013. This was followed by a decrease in the mown area, in the Great Meadow by up to 35 % in 2014, when the survey ended in this hay meadow.

The 2018 and 2019 values for the other two hay meadows show a further decline in mown area, so that in the Village Meadow, about 10 years after recording began, the proportion was back to about just under 20 %, and in the Lord's Meadow it was 4 % instead of 0.2 % (see Table 38 and Figure 114). The Great Meadow is also likely to having experienced a further decline of the mown area in the years after 2014, as observations in the field 2018 and 2019 as well the testimony of a local farmer (Vasile Şerdean, personal communication, August 2019) indicated.

Table 38: The surface and proportion of mown area in the *utilised hay meadows* in the years 2010-2014, for the Lord's and Village Meadow also in 2018 and 2019

	Village Meadow (67 ha)			Great Meadow (200 ha)			Lord's Meadow (42 ha)		
Year	Area (ha)	*Share*	Mozaic Projects	Area (ha)	*Share*	Mozaic Projects	Area (ha)	*Share*	Mozaic Projects
2010	11.2	*17%*		37.7	*19%*		0.1	*0.2%*	
2011	20.3	*30%*	10%	59.9	*30%*	6%	1.9	*5%*	3%
2012	35.3	*53%*	5%	83.6	*42%*	5%	4.9	*12%*	10%
2013	29.2	*44%*	0%	68.4	*34%*	0%	5.4	*13%*	13%
2014	30.2	*45%*	0%	70.4	*35%*	0%	4.7	*11%*	5%
2018	20.5	*31%*					1.9	*4%*	
2019	12.6	*19%*					1.9	*4%*	

Mozaic Projects: the proportion of mown area of the total meadow surface for which mowing was financially rewarded in the Mozaic Projects (Paulini 2012, 2015)

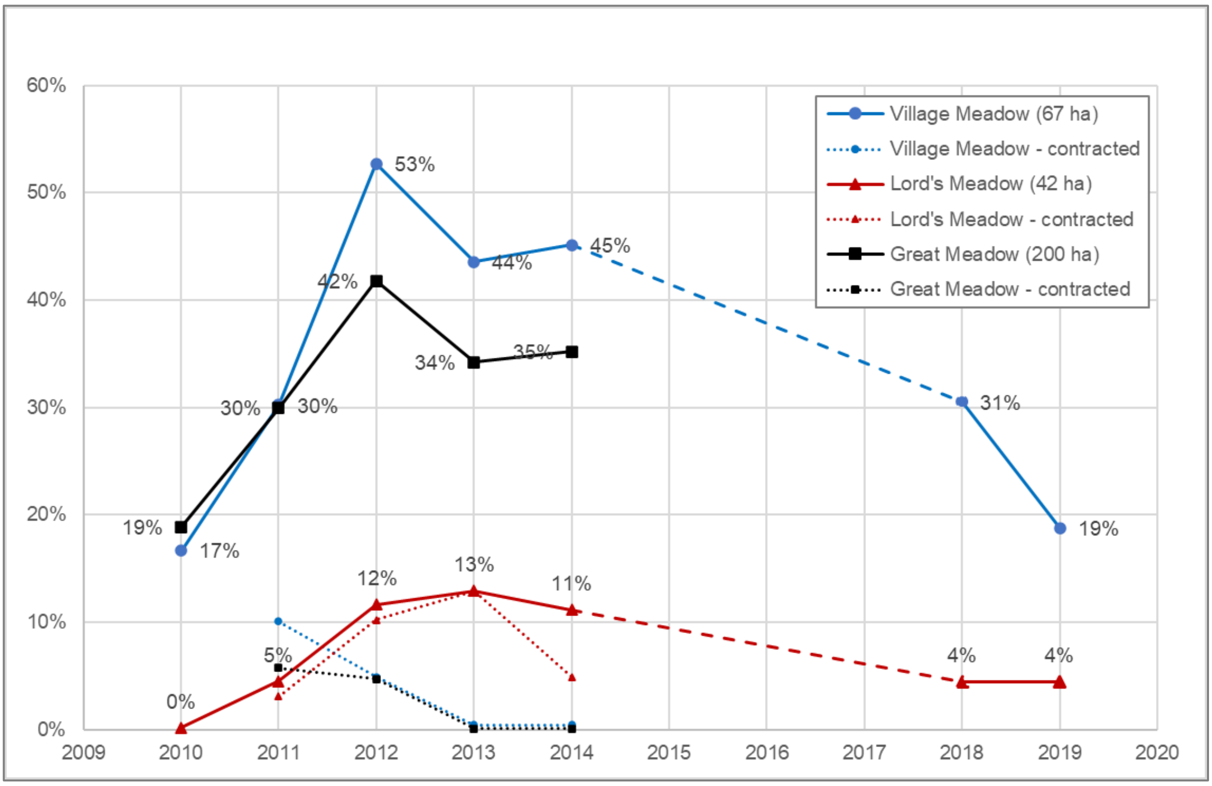

Figure 114: The proportion of mown area of the total surface of the *utilised hay meadows* in the years 2010-2014, for the Lord's and Village Meadow also in 2018 and 2019
The small symbols connected with dotted lines show the proportion of mown area of the total meadow surface for which mowing was financially rewarded in the Mozaic Projects (Paulini 2012, 2015). The dashed lines between the years 2014 and 2018 indicate that the mown proportion is not known for this period.

The proportion of mown area covered by the Mozaic Projects' subsidy programme (years 2011-2014) differs between the Village and Great Meadow on the one hand and the Lord's Meadow on the other. While the proportion in the Village and Great Meadow was highest at the beginning of the programme in 2011, at a maximum of 10 %, decreased the next year and played almost no role in 2013 and 2014, it accounted for almost the entire share of mown area in the Lord's Meadow between 2011 and 2013, and still around half in 2014 (see Table 38 and Figure 114).

Figure 115 to Figure 117 show the mown plots during selected years in the *utilised hay meadows* as well as an overlay for all recorded years, which also illustrates the areas that were not mown during this period. The latter comprise about 33% of the Village Meadow's and about 70% of Lord's Meadow's total area in the years 2010-2104, 2018 and 2019 as well as about 37% of Great Meadow's total area in the years 2010-2014.

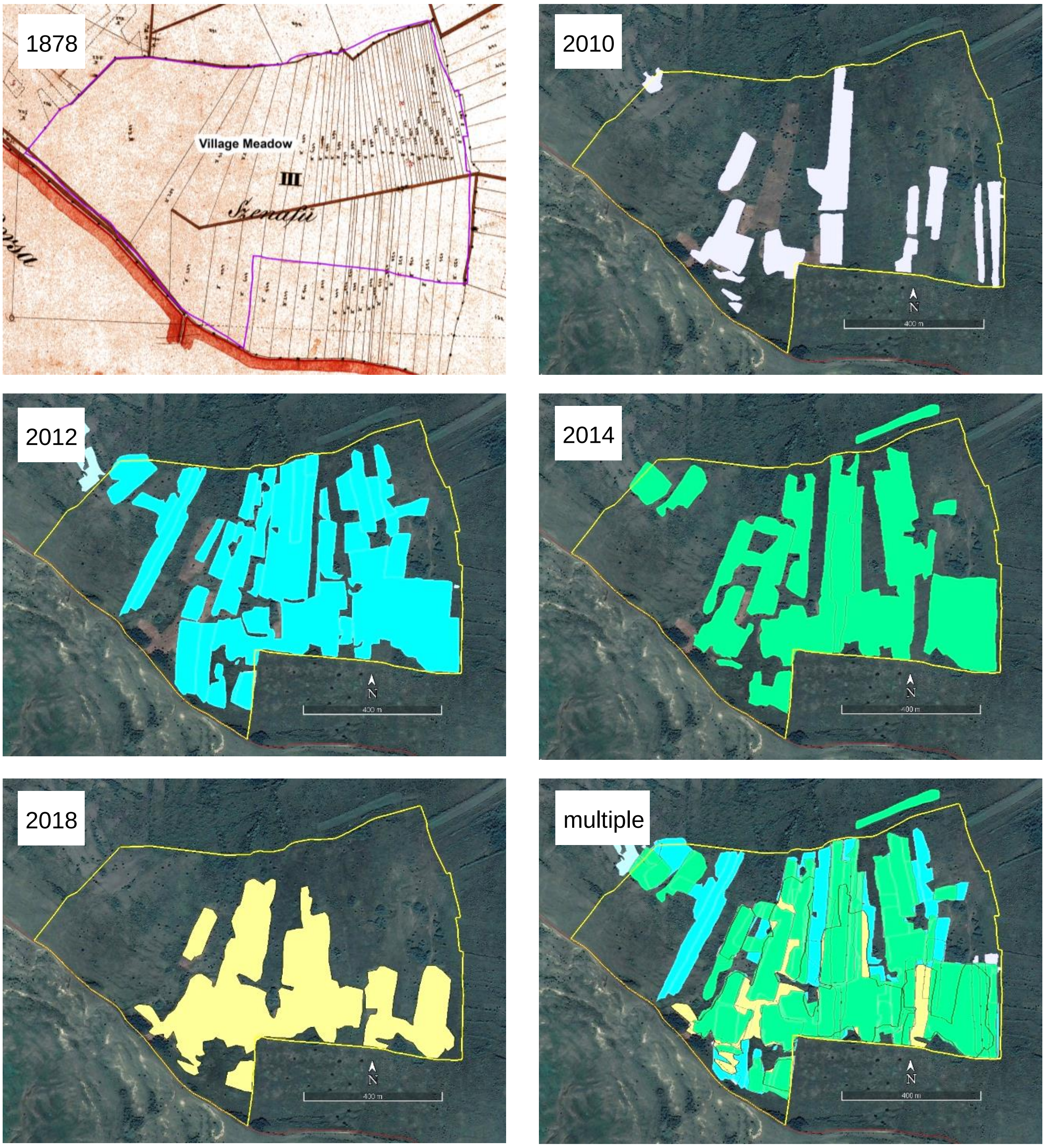

Figure 115: Land tenure structure of the Village Meadow from 1878 and the mown plots in the years 2010, 2012, 2014, 2018 (shown by different colours) and all years combined Surveyors: 2010: Inge Paulini (IP), Andrei Crişan (AC); 2012: IP, AC, Vasile Rus Jr. (VR), Adrian Hedeşiu (AH), Dan Borşan (AB); 2014: VR, AH, DB; 2018: Gabriel Sunder-Plassmann; sources of the background maps: 1878: Agency of Cadastre and Land Registration Cluj (OCPI); others: Google LLC, © 2023 Maxar Technologies

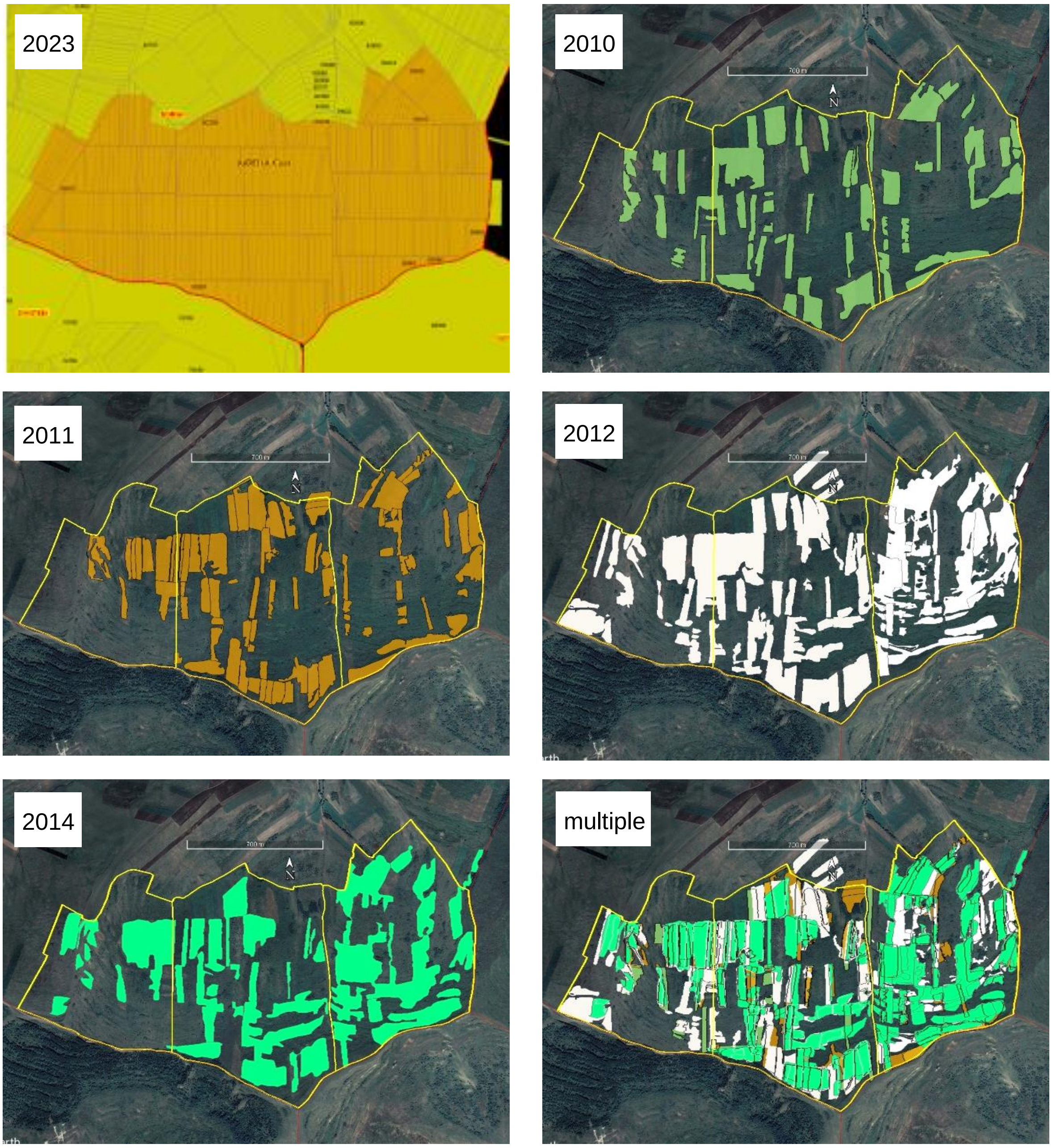

Figure 116: Land tenure structure of the Great Meadow from 2023 and the mown plots in the years 2010, 2011, 2012, 2014 (shown by different colours) and all years combined Surveyors: 2010, 2011: Inge Paulini (IP), Andrei Crişan (AC); 2012: IP, AC, Vasile Rus Jr. (VR), Adrian Hedeşiu (AH), Dan Borşan (DB); 2014: VR, AH, DB; red lines: communal borders; sources of the background maps: 2023: Cadastral geoportal (Agenţia Naţională de Cadastru şi Publicitate Imobiliară 2019-); others: Google LLC, © 2023 Maxar Technologies

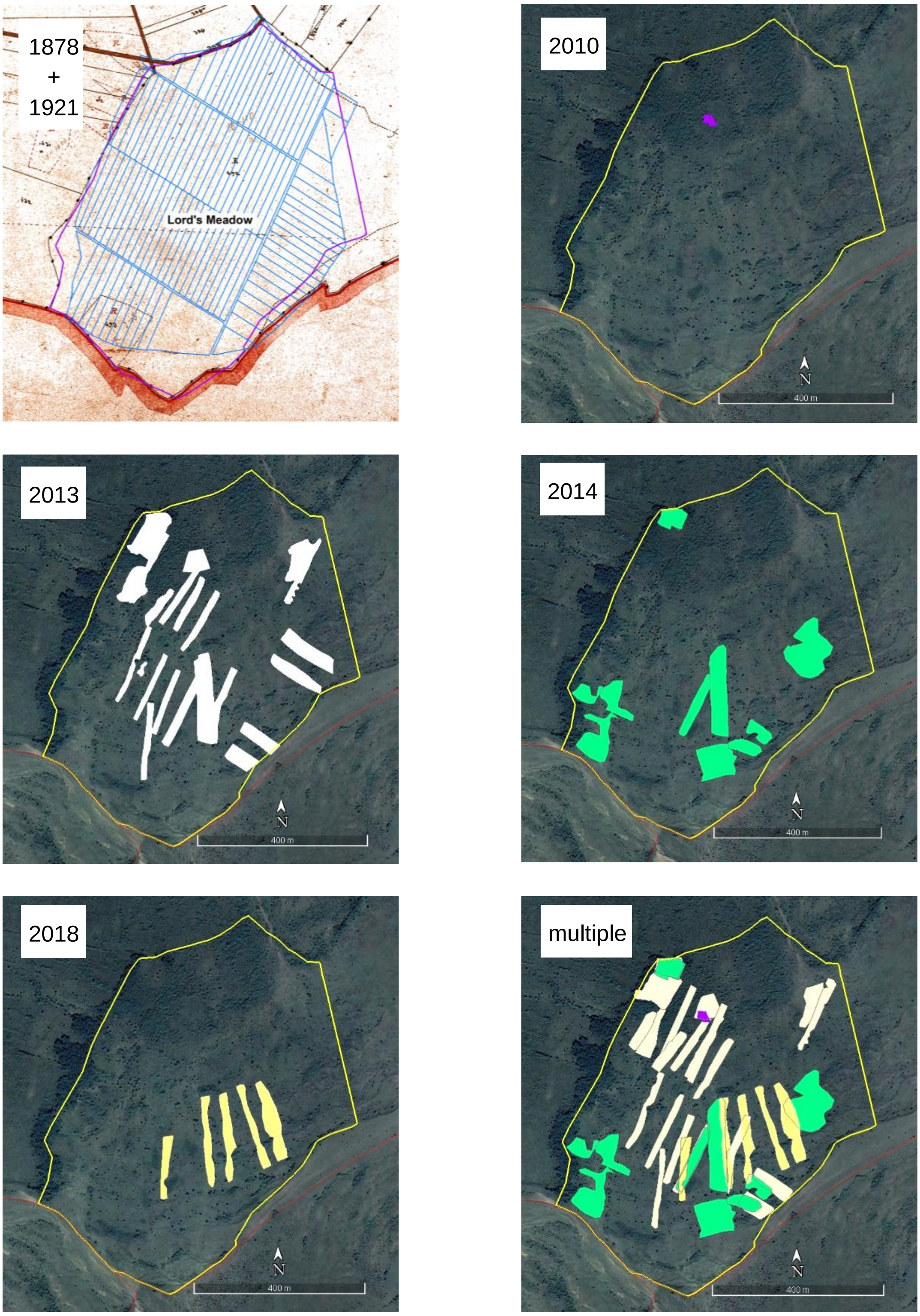

Figure 117: Land tenure structure of the Lord’s Meadow from 1878 and the mown plots in the years 2010, 2013, 2014, 2018 (shown by different colours) and all years combined
Surveyors: 2010: Inge Paulini; 2013, 2014: Vasile Rus Jr., Adrian Hedeşiu, Dan Borşan; 2018: Gabriel Sunder-Plassmann; red lines: communal borders; map sources: 1878: Agency of Cadastre and Land Registration Cluj; 1921: municipal office Dăbâca commune; others: Google LLC, © 2023 Maxar Technologies

The mown area should correspond to the cadastral maps also shown in Figure 115 to Figure 117, were the property boundaries to be respected. However, the results show that there are large differences between the ownership pattern and the mowing pattern, which seem to increase with the years in all hay meadows. It should be noted, however, that a small part of the differences in the shape of the mapped polygons between years could also be due to different surveyors.

Despite the deviations of the mowing pattern from the ownership pattern, the basic tenure pattern is still recognisable. For example, in the Village Meadow in 2012, the two rows of plots are visible, as well as one of the elongated plots in the west (see Figure 115). In the Great Meadow, the five rows of plots can be recognised, as well as some plots in the shape and size of the ownership plots, for example in the year 2010 or 2011 (see Figure 116).

Often relatively large plots are mown in the Village and Great Meadow, which can be several hectares in size. There seems to be a tendency to mow across the slope, rather than up and down along the ownership parcel, best visible on the upper slope of the Great Meadow (see Figure 116).

In the Lord's Meadow, the ownership pattern is best visible in 2013, when the organisation of mowing was largely taken over within the Mozaic Project II, and the cadastral map was used to identify the plots (see Figure 117 and Paulini 2015). Even by 2014, when some plots were mown by tractor independently of the subsidy programme, the ownership pattern was becoming less visible.

4.3.3.1.2 Mechanisation

Information about the mechanisation of hay making is drawn from several interviews and conversations with locals, supplemented by the author’s own observations in the field (2009-2013), mapping in the field in 2014 and knowledge from activities carried out by the Mozaic Association, a local NGO dedicated to nature conservation (themselves organised by the author).

In the Village and Lord’s Meadow, mechanisation of the activities on the meadows (mowing, baling, transport) started not earlier than the end of the 2010s (Vasile Rus Sr., personal communication, April 2023). In the Great Meadow, at least a part of the haymaking work was apparently carried out with tractors in the communist period (personal communication of the farmer Gheorghe Jucan, village Borşa-Cătun, July 2012).

After the collapse of the communist regime, many agricultural buildings and machines were destroyed in the area (personal communication of the mayor of Dăbâca, Valer Petrindean, May 2011). Manual haymaking prevailed during the 1990s, because the number of privately owned tractors was very low and few people could afford to hire a tractor or pay for wageworkers. During the last two decades, the number of tractors in the communes increased and manual haymaking was gradually replaced by mechanised work. Linked to the subsidy programme of Mozaic Project II (2012-2014), motor scythes - small hand-mowing machines - (see Figure 118) were provided for mowing of the *utilised hay meadows* (Paulini 2015).

Figure 118: One of the motor scythes provided in the Mozaic Project II ready for use in the Village Meadow (Dăbâca commune, 14.08.2012)

The author's own observations in the period 2009-2013 were that the mowing was carried out predominantly by tractors; mowing with scythes was rarely encountered (see Figure 119).

Figure 119: Scythe mowing in the Village Meadow (Dăbâca commune, 27.09.2011)

This is confirmed by data from 2014, when the type of mowing was recorded when mapping the mown areas (see Table 39). In the Village and Great Meadow, 87 or 85 % of the mown surface were mown by tractor, the remaining area by motor scythe (in the Village Meadow) or scythe (in the Great Meadow). In the Lord's Meadow motor scythe prevailed (62 %), but there was also tractor mowing (32 %) and scythe mowing (6 %). Since the year 2016, in the Lord's Meadow only motor scythes have been used for mowing, as part of conservation measures organised by the Mozaic Association (status: 2023).

Table 39: Type of mowing in the year 2014 in the surveyed meadows

Mowing type	Village Meadow (30 ha)	Great Meadow (70 ha)	Lord's Meadow (5 ha)
Scythe (%)	0	15	6
Motor scythe (%)	13	-	62
Tractor (%)	87	85	32

The figures after the meadow name indicate the mown area in 2014.

Mechanized baling of the hay, instead of putting it into hay cocks in the field, and the transport of hay by tractors from the meadows could also be observed (see Figure 120). Here, however, the proportion done manually in the period 2009-2013 was higher than in the case of mowing (see Figure 121).

Figure 120: Mechanised transport of hay bales in the Great Meadow (Borșa commune, 06.08.2011)

Figure 121: Vasile Rus Sr. and Vasile Rus Jr. load the dry hay onto a horse-drawn cart in the Lord's Meadow (Dăbâca commune, 23.08.2012)

4.3.3.1.3 Sheep grazing during late spring and summer

In this section, the situation regarding sheep grazing in the *utilised hay meadows* during the summer resting period, when grazing traditionally was excluded, will be described (May-August/September, see Chapter 4.3.2.1.2). The information is gleaned from the author's own observations in the field during the period 2009-2013 and subsequent occasional site visits as well as information from colleagues to the year 2023. The study hay meadows have been and remain affected to different degrees by this late spring/summer sheep grazing, with the most impacted being the Lord's Meadow. As mentioned, grazing mostly takes place by sheep, but sometimes a few goats are also included in the flocks.

In the Lord's Meadow in the period 2009-2013, there were two professional sheepkeepers who let their sheep flocks graze the meadow throughout the year, one owning around 500-600 sheep in two flocks and one around 100 sheep in one flock. The flocks were guarded by hired shepherds and shepherd dogs.

Both sheepkeepers had rented or used traditional pastures or permanent grassland on former arable bordering the Lord's Meadow to the north-east, north and west. The upper part of the Lord's Meadow in particular was used as a shortcut between two grazing areas (see Figure 122). The use was based in part on unwritten short-term agreements with several locals, whereby a larger area than the one actually orally contracted area was grazed.

Figure 122: Heavily grazed part on the upper slope of the Lord's Meadow (Dăbâca commune, 16.08.2013)

During the 2010s, the sheepkeeper with the smaller flock gave up his sheep farming, so that only one sheep holder remained. Nevertheless, grazing intensity has increased continuously on the Lord's Meadow until today (2023), as confirmed by Natalia Timuş and Andrei Crişan (personal communications, summer 2021, 2022).

In the Village Meadow, the impact of late spring/summer grazing in the observed period (2009-2013) was less pronounced than in the Lord's Meadow, considering the size of affected area and frequency of grazing. Most affected were the marginal areas, to the west, north-east and the near the top of the slope, which were also grazed by flocks from Borșa commune in passing. The central, frequently mown parts remained largely ungrazed in the summer resting period, at least thus far (2023) (see Figure 123).

Figure 123: Impact of different grazing intensity and frequency on the grassland physiognomy of the Village Meadow (above) and Lord's Meadow (below) (Dăbâca commune, 29.07.2021, pictures: Natalia Timuş)

The Great Meadow was also less affected by sheep grazing during the resting period than the Lord's Meadow in the period (2009-2013). Here too, however, the edges were affected by grazing, especially the western part, so that, for instance, plots could not be mown (Paulini 2015). Furthermore, the year-round presence of sheep on the Great Meadow has continuously increased in recent years. For example, since 2017, three shepherd's huts and sheep pens have been installed, one below *Fânaia* section (2019), one below *Sekelişte* section (2017) and one on the middle slope of *Sekelişte* (2022) (the last according to the personal communication of Natalia Timuş, May 2022, see also Figure 124).

Figure 124: Sheep pen on the middle slope of the Great Meadow (Borșa commune, 04.05.2022, picture: Natalia Timuş)

Overall, the area of the meadows was and is irregularly affected by grazing, ranging from light grazing to intense browsing and heavy trampling on some areas. The frequency of passage or grazing by the flocks ranges from infrequent to several times a day. Visible signs of the presence of livestock on the meadows are traces of trampling, browsed plants and dung, as well as a lower vegetation hight and the increase of ruderal species such as *Daucus carota* and pasture weeds (see also Chapter 5). Note also that scrub encroachment is highest in the Lord’s Meadow, despite the highest grazing frequency by sheep (see next chapter).

4.3.3.1.4 Woody plants, burning in spring and other observations

The *utilised hay meadows* are nowadays (2023) in large parts characterised by the occurrence of solitary or grouped shrubs and trees scattered over the meadow surface (see Figure 125). However, there are also areas that are completely free of phanerophytes, as well as areas that have become increasingly overgrown by shrubs since 1990. These can be several hundred square metres to several hectares in size. Scrub encroachment is found in all three study meadows, but the Lord's Meadow is the most affected, especially in the lower, northern part (see Figure 126). It is estimated here that 15 % - 40 % of the surface of the studied meadows is covered by woody plants nowadays (2023).

Figure 125: Savannah-like landscape structure of the Village Meadow (Dăbâca commune, 20.07.2011)

Figure 126: Area of scrub encroachment in the lower part of the Lord's Meadow (Dăbâca commune, 19.08.2019)

Connected to the increasing occurrence of woody species on grasslands in the wider study area is the sporadic burning down of the plant material in spring, observed in the period 2009-2013 and beyond. This is carried out by shepherds with the aim of pushing back the spreading shrubs and removing litter on the grazing area. In some years, the study meadows have been affected, too.

For instance, traces of fires in the studied meadows were observed by the thesis author in spring 2011 in the Lord's Meadow, in the area with *Molinia arundinacea* (see Figure 127). The fire apparently only skimmed over the surface and the shrubs on the surface were almost not affected. Furthermore, Sunder-Plassmann (2016) reports an extensive fire in the western part of the Lord's Meadow in spring 2013. On a Google Earth image from April 2015, the traces of another extensive fire which affected around one third of the Village Meadow are visible (see Figure 128). Natalia Timuş (personal communication, May 2022) reports a burnt surface in the Great Meadow in spring 2022.

A phenomenon seen for the first time in the Lord's Meadow in June 2021 are noticeable soil disturbances caused by wild boars (Natalia Timuş, personal communication, June 2021; see Figure 129).

Figure 127: Traces of a fire in spring 2011 in the Lord's Meadow (Dăbâca commune, 17.05.2011)

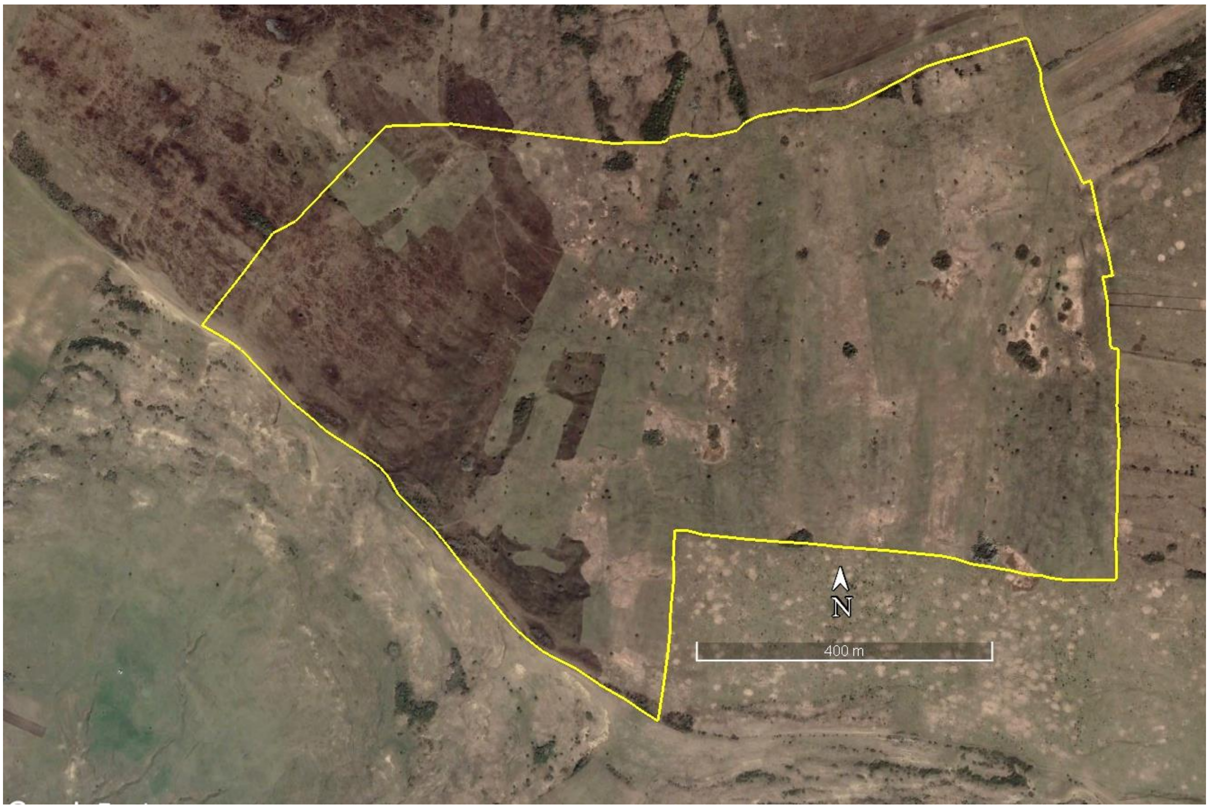

Figure 128: Google Earth image of burnt area in spring 2015 in the Village Meadow and adjoining area to the west (Dăbâca commune)
The Google Earth image is from April 2015 (Google LLC, © 2023 Maxar Technologies).

Figure 129: Traces of wild boar in the Lord’s Meadow (Dăbâca commune, 08.06.2021, picture: Natalia Timuş)

4.3.3.2 Discussion

4.3.3.2.1 Mown area

The data gathered about the mown proportion of the *utilised hay meadows* show that the Village Meadow (Dăbâca commune) was the most frequently used meadow, followed by the Great Meadow (Borșa commune) with somewhat lower values. In the Lord's Meadow (Dăbâca commune) hay making was almost completely abandoned in the first year of the survey period. However, the Lord's Meadow was placed in the same category of the *utilised hay meadow* in this thesis since a total of 30% of the meadow surface was mown, taking all the survey years together.

The proportion of the area mown found in the Village and Great Meadow in the year 2012 (54 % and 42 %), is higher than the average proportion of 36 % of mown area in selected traditional meadows in the SCI 'Eastern Hills of Cluj' surveyed in the same year (Paulini et al. 2012).

The reasons for the variation in the proportion mown over the years recorded can only be guessed at here. For instance, the low share at the start of the survey period in 2010 and the higher values during the years 2011 to 2014, including the peak in 2012 in the Village and Great Meadow, could be in relation to the introduction of subsidies for mown plots. These started in Dăbâca and Borșa communes in the year 2011 with the Mozaic Project I and in the year 2012 with the introduction of the 'Package for grasslands important for butterflies (*Maculinea* spp.)' of the national agri-environment programme.

Through the information activities in the Mozaic Projects, which also included raising awareness of the '*Maculinea*-package', the farmers were already relatively well informed at the beginning of the application period (Paulini 2012, 2015). Assuming many farmers applied for these subsidies for the first 5-year period but not afterwards, this could explain the decrease in mown areas between 2012 and 2018 in the Village Meadow, which is similarly assumed for the Great Meadow.

However, also the weather during the single years could have had an influence on the proportion of mown area. For instance, in the year 2010 the annual precipitations were significantly higher than the annual mean in the period 1971-1990, namely 808 mm (Tutiempo Network 2023) versus 548 mm (Deutscher Wetterdienst 2023), which may have resulted in a lower share of mown area in that year. Finally, it is assumed based on our observation and informants that the numbers of cattle livestock on the small-scale farms decreased after 2010, that is, the year of the last General Agricultural Census for which data are available. If true, this may also have contributed to the decline in mown area, since for these farms, hay is the main fodder source.

The proportion of mown area and pattern of mown plots in the Lord's Meadow in the period 2010-2013 and in the years 2018 and 2019 depended almost entirely on mowing under the Mozaic Projects subsidy programme and mowing activities organised by the Mozaic Association.

4.3.3.2.2 Mowing pattern

Based on the information about the past tenure structure of relatively small plots (less than one hectare in every case, and often much smaller), a fine-grained, spatio-temporal heterogenous mowing pattern is assumed for the period from the 1880s / 1921 until the 1950s and at least partly after 1990 in all the *utilised hay meadows*. The long duration of the entire mowing period as well as the large number of ownership plots suggests a great heterogeneity of mown and unmown plots in the hay meadows, which provides good conditions for high habitat and species diversity (see Figure 130).

Figure 130: Diversity of habitats caused by a heterogenous mowing pattern and plot boundaries in the Great Meadow (Borșa commune, 24.08.2011)

Land use mosaics in traditional hay meadows have been described by other authors, too, for example Huband (2008), who links an extremely high butterfly diversity with a mosaical mowing pattern of meadows in the Southern Carpathians. Page et al. (2012), mention spatial and temporal differences in the management of Romanian hay meadows as a source of wide varieties of niches and vegetation communities.

The fine-grain ‘traditional’ pattern of the study meadows was presumably already altered in the communist period when the work tasks were centrally distributed within the agricultural cooperatives. After land restitution starting 1990, it is likely that a part of the meadows was mown again by the smallholders according to the ‘traditional’ pattern and some remnants of it have still been found in the survey period. However, the ‘traditional’ pattern is increasingly being replaced by a pattern of short- to long-term unmown and more or less regularly mown plots, often significantly larger than one hectare, determined less by tenure rights than by accessibility for mechanised mowing.

Mown plots larger than 0.87 ha (one and a half times a *jugăr*) usually comprise more than one tenure plot. Towards the end of the recording period, most of the plots take this form. It is possible that individual farmers have leased larger areas, but it also certainly happens that adjacent abandoned plots are simply mown as well. The mowing pattern of larger plots will most likely also affect the vegetation, flora and fauna of the hay meadows.

4.3.3.2.3 Mechanisation

The diverse relief of the hay meadows makes for varying accessibility for heavy machinery; some parts can easily be mown by tractors while others are too steep and/or, in some cases, too wet. This leads to a situation where accessibility for tractors increasingly determines whether an area of the meadows will be mown or not and the shape of the mown areas, often regardless of ownership boundaries (see previous chapter).

On the one hand, the increasing share of tractor mowing is likely to have a negative impact on the meadow fauna and flora, for example through a faster course of mowing compared to scything, mentioned e.g. by Staub et al. (2004). Moreover, the use of heavy machines in the meadow is likely to cause damage to the soil structure and water balance of the slopes, as mentioned for the Lord’s Meadow by Sunder-Plassmann (2016).

On the other hand, the meadows would remain almost completely unmown if no tractors were allowed for mowing, baling and transport, because only a few are still willing to do the work, especially the mowing, manually. Alternative solutions would be the use of low pressure tyres for conventional tractors and the increased use of motor scythes, which have a lower weight than tractors but can still mow faster than hand scything.

4.3.3.2.4 Sheep grazing during late spring and summer

In the traditional management, the hay meadows are closed for grazing between the end of spring grazing in May and beginning of autumn grazing in August/September, so as not to disturb the growth of the sward during summer. However, several factors have led to the emergence since 1990 of the new phenomenon of grazing by sheep during early spring and summer.

One is a gradual abandonment of haymaking in the traditional meadows. It can most likely be assumed that the more the use of a traditional meadow for hay declines, the more it will be grazed, as the example of Lord's Meadow shows. In addition, dairy sheep farming has experienced an increase in recent decades (see Chapter 2.8), partly due to the temporary availability of additional grazing land, namely abandoned communal cattle pastures and new permanent grasslands on former arable. Often these grazing areas surround the traditional hay meadows, so that these are grazed ‘in passing’ at least at the edges, provided they are not actively used for hay making.

It can be assumed that the use of meadows as a source of fodder in spring and summer has become an important economic factor for sheep farmers nowadays. While the *utilised hay meadows* still are used for haymaking to some extent, however, and there are parts that remain ungrazed in the summer months, there are examples in the study area of places which have been converted completely into permanent sheep pastures, namely the *former hay meadows* Meadow Hill and Jacob’s Meadow (see Chapter 2.9). Other examples from the SCI ‘Eastern Hills of Cluj’ have been described by Paulini et al. (2012). Moreover, the conversion of traditional hay meadows into sheep pastures has been a general development in Transylvania since the 1990s (see for example Demeter and Kelemen 2011).

It should be mentioned that only grazing in the spring/summer resting period of the meadows is described here - but at the same time grazing in the winter months also is increasing strongly in the whole SCI ‘Eastern Hills of Cluj’, including the study meadows (personal communication Andrei Crişan, February 2023). The impact of grazing and trampling on the flora, fauna and vegetation of the studied meadows can only be evaluated by long-term studies. A first estimation of the impact on the meadow vegetation and phytodiversity is set out in Chapter 5 of this thesis.

It is also important to note that in the Lord's Meadow, flowering specimens of the *Phengaris* host plants *Sanguisorba officinalis* and *Gentiana cruciata* have decreased sharply in the 2020s (Natalia Timuş, personal communication, July 2022), most likely due to sheep grazing throughout the growing season.

4.3.3.2.5 Woody plants, burning in spring and other observations

Solitary shrubs, trees and clumps of shrubs scattered over the meadow surface are a typical element of the studied hay meadows nowadays. They do not disrupt mowing activities significantly and contribute to an attractive scenery with almost savannah-like character. They are also valuable from an ecological point of view, for example by providing habitats for birds and insects.

However, increasing scrub encroachment poses a threat to the hay meadows in the longer term, since typical grassland species are likely to disappear in the succession process and mowing is not possible anymore. For example, scrub encroachment has a detrimental effect on the host ants of *Phengaris alcon ‘cruciata’*, which, in addition to the decline in the number of *Gentiana cruciata* plants, has also contributed to the severe decline of the subpopulation of this butterfly taxon in the Lord's Meadow in recent years (Natalia Timuş, personal communication, June 2021).

The present-day occurrence of woody plants in the study hay meadows is a result of the partial abandonment of mowing and of maintenance works in the meadows since the 1990s. According to the local farmers, the meadows were almost free of woody plants before 1990).

The density of woody plants is distributed heterogeneously on the meadow surface, depending on the period of abandonment and other factors. According to the author's own observations and information obtained by the sheep holders and shepherds, it is assumed here that scrub encroachment is not prevented by the current form of ad hoc sheep grazing.

In the *utilised hay meadows*, the deliberate burning of biomass in spring is a new phenomenon; it is not remembered as a 'traditional' maintenance practice by the local farmers. This is also because, before the abandonment of hay making started in the 1990s, there was not enough woody material on the meadows to be burnt (Vasile Rus Sr., personal communication, February 2017).

However, in the more distant past, fires were a common tool to create and preserve open land in the region (Feurdean et al. 2015; Sunder-Plassmann 2016). While the sporadic recent fires may help to remove thick litter layers from the meadows, they might however be detrimental for parts of the ecosystem, especially the fauna (see for example Deák et al. 2014).

Finally, the increased occurrence of wild boar needs to be monitored further to ascertain if it was just a single event or if it will occur more often in the future, maybe related to the recent increase in maize fields in the landscape.

4.4 Discussion of the methodology

Some of the results obtained can be considered reliable for specific purposes, for example if they come from maps that leave little room for interpretation, such as the official ownership boundaries shown on the current map of the Great Meadow from the cadastral geoportal, the cadastral map of Lord's Meadow from 1921, or actual boundaries of the mown area as ascertained by first hand mapping.

Other results could be supplemented by furtherhistorical and anthropological research in particular. For example, analysis of the 19th century cadastral maps could be extended by more detailed historical research, e. g., to identify the large landowners of the Lord’s and Great Meadow and to explore the management of the meadows at that time. The land tenure structure could be placed in the context of the historical meadow tenure forms of the region.

Furthermore, the interviews on the traditional meadow use could potentially be enriched by extending it to a larger number of participants, at least for the Great Meadow, and open questions should be clarified, such as whether there is indeed a tendency towards a later mowing period in the meadows of Luna de Jos or why mowing was delayed in the communist period. Another open question is whether the shrubs and trees in the Great Meadow were also completely removed before 1990, as well as more details on the possible fertilisation period in the communist era.

For the recording of mown plots, mapping in the field is a relatively simple and accurate method, but could possibly be replaced or supplemented by drone surveys, which likely could be carried out more frequently and with less effort. In any case, the further monitoring of the meadow use and vegetation, for example of the grazing, mowing and scrub encroachment, could serve as a valuable information for both, ecological studies and the planning and evaluation of conservation measures. The data already available could be used for further studies on the impact of land use on natural resources, as done in Chapter 5.

4.5 Summary Chapter 4

This part of the thesis was aimed at gathering information about the land use and tenure history of the Lord’s Meadow (42 ha) and the Village Meadow (67 ha), both Dăbâca commune, and the Great Meadow (200 ha), Borşa commune, and thus to shed light on the continuity of use of the areas as meadows. The time period under consideration stretched back to the time of the first available cadastral maps (ca. 1880s). Furthermore, details of the historical meadow management (referring to the time before collectivisation), and land use changes which were encountered during the data collection period (2009-2014) were surveyed, to facilitate the design of appropriate conservation measures. To this end, interviews with local farmers and experts, observations and mapping in the field as well as the analysis of cadastral maps from different periods were carried out.

Land survey maps from the 18th and 19th century as well as cadastral maps from 1878/1883, 1921, the communist and post-communist period show that the hay meadows of this study have been open land continuously for minimum 250 years and, at least the Village and the Great Meadow, hay meadows for minimum 140 years. By contrast, in the Lord’s Meadow the continuous meadow use has been interrupted for around 40 years, when it was used as pasture for the steers and dairy cattle of the local communist collective farm. However, the use of the meadows since the 1990s has departed from the historical meadow management, as explained below.

The meadows all feature the same spatial tenure pattern nowadays: two to five rows, in most cases at right angles to the slope, with each row containing about two to several dozen elongated plots parallel to the slope. The size of the plots is in almost all cases much smaller than one hectare, usually 0.29 ha (a historical unit of area measurement in Transylvania) or its double or triple. This results in a large number of ownership parcels for each hay meadow, exceeding one hundred each in the Lord’s and Village Meadows, and even 300 in the Great Meadow.

The origin of this pattern goes back to different times: While in the Village Meadow it appears already in the map from 1878, in the Lord’s and presumably also in the Great Meadow it was created through the land reform of 1921, when ownership passed from a single noble to many peasant owners. In the 1950s, the multiple private ownership was dissolved in all meadows, in favour of the centralized ownership of the collective farms. Due to the land restitution starting 1990/1991, not only was private ownership restored in the hay meadows, but also the small-scale parcelling, and no large-scale land consolidation has taken place since then.

The process of land restitution, involving surveying of the plots and registration in the land registry, is at very different stages in the different hay meadows. While it is completed for the Great Meadow in Borșa commune through the National Cadastre and Land Registry Programme, the process is far from complete in the Village Meadow and even further in the Lord's Meadow (Dăbâca commune). This brings with it an increased risk of ownership rights no longer being enforceable, something which is already having an impact on management and protection options, at least in the Lord's Meadow.

Regarding the historical meadow management, structured and semi-structured interviews with local farmers carried out in 2011 and 2013 revealed that the traditional period of hay making usually started in July, sometimes also June, and lasted until July or August. Some farmers stated that the start or ending of the hay season was linked to certain events and Saint's Days. The hay making season in general lasted around one month, but several farmers also indicated a period of two weeks, given suitable weather.

The Lord's and Village Meadow were not fertilised either before, during or after the communist period, and neither with organic nor with mineral fertilisers. For the Great Meadow two farmers stated that during the communist era it had been fertilised with mineral nitrogen. Apart from this assumed exception, the meadows have traditionally been subject to nutrient removal by one, or rarely two, annual cuts and the only source of nutrient supply has been spring and autumn livestock grazing.

In addition to the hay production in summer, the meadows have traditionally been (and still are) grazed in spring and autumn by sheep, and in former times also by cattle. The grazing takes place before the field is 'shut-up', that is, protected for the growth of the sward in summer, and on the post-harvest aftermath respectively. For the Lord's and the Village Meadow it is known that the period of spring grazing with sheep traditionally lasted from around 20-22 April (linked to Saint George's Day on 23 April) to 10 May. After the 're-opening' of the meadows for grazing in August or September, they were traditionally first grazed by cattle until the 1990s, when cattle numbers declined sharply. Pre- and post-mowing grazing, a common practice in many traditional European hay meadows, has several economic advantages but presumably also has also contributed to the maintenance of meadow biodiversity.

Meadow management traditionally also included maintenance works, for example, the clearing of shrubs and molehill levelling, which were carried out every year in the spring. The statements of the farmers indicate that the physiognomy, at least of the Lord's and Village Meadow, differed from their present appearance, in that they were almost completely free of woody plants until 1990. Nowadays, they are characterised by solitary shrubs, trees and clumps of shrubs scattered over the meadow surface, giving the meadows almost a savannah-like character. Besides creating an attractive scenery, the woody species are also valuable from an ecological point of view, for example by providing habitats for birds and insects but maintaining the present level of cover will be challenging, given the trends in management.

To survey the extent of mown area and the mowing pattern, the mown plots were mapped with GPS devices in the field at the end of the mowing period in the years 2010 to 2014, in the Lord's and Village Meadow also in 2018 and 2019. It was found that the mown area was substantially smaller than the total area of the hay meadows and that the hay meadows differed in terms of the proportion of their area mown. The highest values were achieved in the Village Meadow, between 17 % in 2010 and 53 %

in 2012 and the second highest in the Great Meadow, between 19 % in 2010 and 42 % in 2012. The Lord's Meadow was almost completely unmown in 2010 (0.2 %) and with 13 % the largest proportion was mown in 2013. The areas that were not mown during the surveyed years comprise about 33% of the total area of the Village Meadow, about 37 % of the Great Meadow and about 70% of Lord's Meadow.

The proportion of the total area mown changed from year to year. The lowest values were found at the beginning of the period considered, then increased to maximum values in 2012 and 2013, followed by a decrease until the survey ended. The peak could be in relation to the introduction of subsidies for mown plots, which started in Dăbâca and Borșa communes in the year 2011 with a nature conservation project led by the thesis author and in the year 2012 with the introduction of the ‘Package for grasslands important for butterflies (*Maculinea* [=*Phengaris*] spp.)’ of the national agri-environment programme.

However, the weather during the single years could have had an influence on the proportion of mown area, too, since the annual precipitations in the year 2010 were significantly higher than the annual mean. Finally, decreasing numbers of cattle livestock on the small-scale farms could also have contributed to a decline in mown area in the course of the 2010s. The proportion of mown area and pattern of mown plots in the Lord's Meadow in the surveyed years depended almost entirely on mowing organised by third parties as nature conservation measures; the impact of national agri-environment measures has been very limited.

For the periods with the ‘traditional’ tenure pattern based on a large number of small ownership plots, a fine-grained, spatio-temporally heterogenous mowing pattern is assumed, considering also the duration of the traditional mowing period of at least two weeks. This pattern provides good conditions for high habitat and species diversity, as shown also by other examples from Romania.

The fine-grain mowing pattern of the study meadows was presumably altered to some extent in the communist period when the work tasks were centrally distributed within the agricultural cooperatives. After land restitution, which started in 1990, the ‘traditional’ pattern has gradually been replaced by a pattern of short- to long-term unmown and more or less regularly mown plots, plots which are often significantly larger than one hectare, determined less by tenure rights than by accessibility for mechanised mowing. These changes will most likely also affect the vegetation, flora and fauna of the hay meadows.

In the Village Meadow and the Lord’s Meadow (Dăbâca commune), mechanisation of the activities on the meadows (mowing, baling, transport) started not earlier than the end of the 2010s. In the Great Meadow (Borşa commune), at least a part of the haymaking work was apparently carried out with tractors in the communist period. In the 1990s, manual haymaking prevailed in all meadows, due to the low numbers of privately-owned tractors. During the last two decades, the number of tractors in the communes increased and manual haymaking was gradually replaced by mechanised work. In the period 2012-2014 motorised scythe mowers were provided for mowing of the meadows and still are used in the Lord’s Meadow for conservation measures (status: 2023).

In the year 2014, in the Village and Great Meadow 87 or 85 % of the mown surface were cut by tractor, the remaining area by motorised scythes or hand scythe. In the Lord’s Meadow scythe mowers prevailed (62 %), but there was also tractor mowing and hand scything. On the one hand, the increasing share of tractor mowing is likely to have a negative environmental impact, for example through a faster course of mowing compared to manual scything or through exerting heavy pressure on the surface. On the other hand, the meadows would remain almost completely unmown at present if no tractors were allowed for mowing, baling and transport, because only a few are still willing to do the work, especially the mowing, manually. Possible solutions would be the increased use of scythe mowers or tractors with low pressure tyres.

Since the 1990s, the novel land use practice of grazing sheep during the summer resting period has emerged in the study hay meadows. Reasons are the gradual abandonment of haymaking, but also an improvement of the general conditions for dairy sheep farming and the location of the traditional hay meadows, which are often surrounded by pastures and are therefore, especially at the margins, at risk of being grazed ‘in passing’.

The study hay meadows have been and remain affected to different degrees by this late spring/summer sheep grazing, with the most impacted being the Lord’s Meadow. But also in the Great Meadow, the year-round presence of sheep has continuously increased in recent years and several shepherd's huts and sheep pens have been installed (status: 2023). In general, the area of the meadows was and is irregularly affected by grazing, ranging from light grazing to intense browsing and heavy trampling on some areas. At the same time, grazing in the winter months also is increasing strongly. A first estimation of the impact of grazing on the meadow vegetation and phytodiversity is set out in Chapter 5 of this thesis.

Another threat to the hay meadows is the increasing scrub encroachment since typical grassland species are likely to disappear in the succession process and mowing is not possible anymore. The density of woody plants is distributed heterogeneously on the meadow surface, depending on the period of abandonment and other factors. It is estimated here that 15 % - 40 % of the surface of the studied meadows is covered by woody plants nowadays (2023). Connected to the increasing occurrence of woody species is the sporadic burning of the plant material in spring, observed in several years in the study meadows. While the sporadic fires may help to remove thick litter layers from the meadows, they might however be detrimental for parts of the ecosystem, especially the fauna.

It would be worth supplementing the historical land use and information on tenure and meadow management reported here with further land use historical research, and also by further monitoring of current land use. Both can serve as a basis for ecological studies, but also for the design of suitable management measures.

5 Impact of mowing abandonment and grazing on phytodiversity and vegetation

5.1 Introduction

Chapter 4 has shown how the *utilised hay meadows* have been farmed for at least 140 years in a way that, overall, involved many constant factors over time, like cutting once a year, absence of fertilization, division into multiple parcels of land, grazing in spring and autumn, etc. This consistency was disturbed after 1989 by increasing changes, the most important being the gradual and piecewise abandonment of mowing and the increase in year-round sheep grazing. Some meadows in the study area were abandoned completely and converted into permanent pastures. This situation led to the question of how the meadow vegetation, which was adapted to a long relatively constant use-pattern, would respond to mowing abandonment and increased grazing.

Traditional meadows are in general horizontally homogeneous stands with relatively tall vegetation. Due to mowing, they are characterized by a changing sward height (increasing sward, maximum, minimum after cutting) and regeneration (Dierschke and Briemle 2008). The cessation of mowing usually leads to various changes in grassland structure and species composition.

Examples are the disentanglement of homogenous stands into a more coarse-grained pattern, higher dominance of now more-competitive species, and the increase in proportion of either graminoids, tall forbs, or species of fringe communities (Dierschke and Briemle 2008). In general, the cessation of mowing also leads to an increased light shortage in the stands, which causes a suppression of small-growing species and weak competitors, and thus a decrease in species richness (Dierschke and Briemle 2008).

The conversion of mown grasslands into pasture often leads to a change in plant species composition. Dierschke and Briemle (2008) state that intensively grazed, former *Trisetum* meadows (*Polygono-Trisetion)* change into other vegetation types, like nutrient-rich pastures (*Cynosurion cristati*), red-fescue-pastures, *Nardus* grasslands, or pasture communities of the *Festuco-Brometea*.

For dry and nutrient-poor types of the *Arrhenatherion* meadows they specify that only very extensive grazing can conserve the species composition of former meadow stands (Dierschke and Briemle 2008). Mládek (2008) indicates that continous grazing is not suitable for the analyzed communities of the *Mesobromion* in the White Carpathians, as it leads to conversion into grasslands of the *Cynosurion cristati*-alliance.

Crofts and Jefferson (1999) write in the Lowland Grassland Management Handbook for the UK, that the conversion from meadow to permanent pasture leads to a decline or elimination of early flowering species that rely on seed production for the maintenance of populations, like *Rhinanthus minor* or *Fritillaria meleagris*.

Regarding changes in plant diversity induced by the conversion from mown to grazed grasslands, Bonari et al. (2017) state that the introduction of grazing in grasslands that were traditionally mown, or vice versa, can have detrimental effects on their biodiversity. However, in their study the overall richness of plants was not negatively affected by grazing, only that of plant species of regional conservation importance.

The preceding considerations lead to the formulation of the following hypotheses: The mown *Cirsio-Brachypodion* stands differ from the unmown or grazed stands regarding their plant diversity, vegetation structure and functional groups as well as floristic composition.

Many of the semi-dry grassland types in the Carpathian region farmed as hay meadows belong to the most species-rich grasslands in Europe (Dengler et al. 2014). As previously mentioned, the site of the world record for vascular plant species diversity on 0.1 m^2 and 10 m^2 is located at a distance of only 7-11 km from the study area in a (former) hay meadow (Dengler et al. 2012; Wilson et al. 2012; Roleček et al. 2019). Therefore, the assumption that the basiphilous semi-dry grasslands of the studied hay meadows show similar high vascular plant richness values as the grasslands with the highest species richness values in Europe shall be examined.

5.2 Methodology

5.2.1 Data collection

5.2.1.1 Sampling period, location, and selection criteria

The field sampling was carried out from 10.06.-18.08.2012 and 16.07.-18.08.2013 by different persons or teams. From a larger number of diversity relevés, 31 relevés were used for the analysis, of which 21 were carried out in two *utilised hay meadows*, the Village Meadow (see Figure 131) and the Great Meadow (see Figure 132).

In the *former hay meadows*, which were used as rough pastures at the time of data collection, 10 diversity relevés were carried out: five each in the upper part of the Meadow Hill and the Jacob's Meadow (see Figure 133). The relevés (plot size 10 m^2) are listed in Annex 4 while Annex 2 contains a part of the header data, including the geographical coordinates and names of the surveyors.

For the selection of the plots in the field three criteria were used:

- Land use
- Type of vegetation
- Structural homogeneity of the stand regarding vegetation and environment

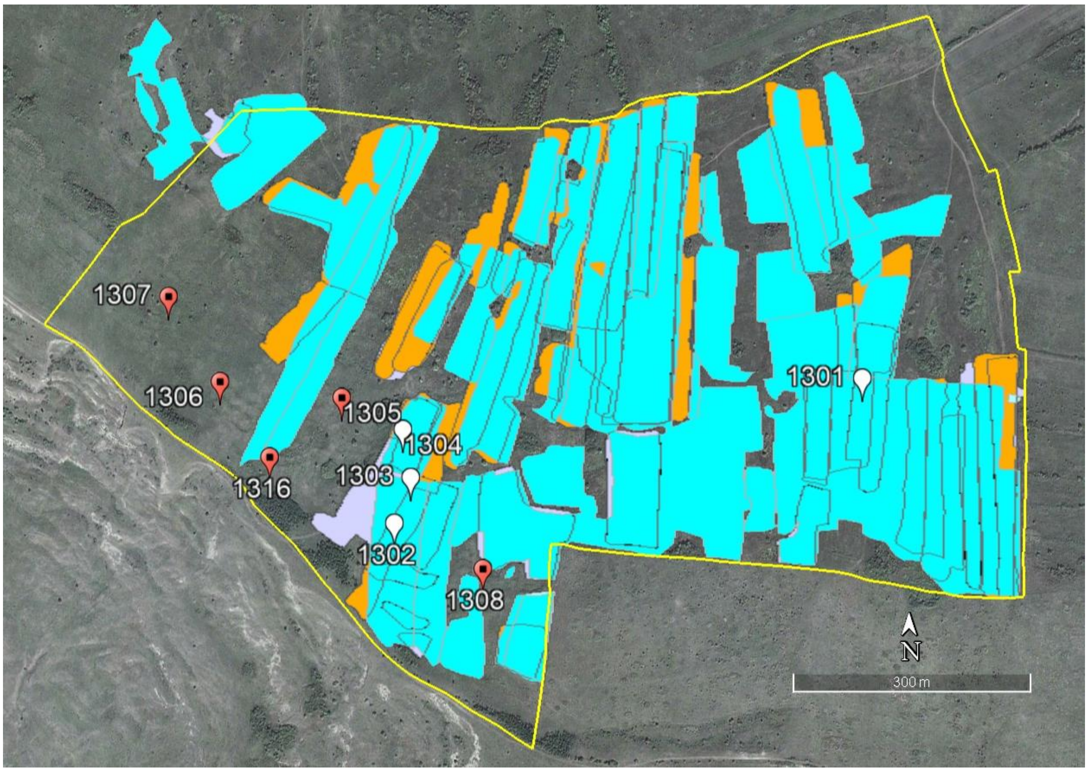

Figure 131: Location of the diversity relevés in the Village Meadow (yellow outline; Dăbâca commune) and display of the mown plots 2010 (light purple), 2011 (orange) and 2012 (blue)
White, empty symbols: relevés in mown stands; red symbols with squares: relevés in unmown stands; the numbers indicate the original relevé numbers. The Google Earth image is from September 2011 (Google, © 2023 Maxar Technologies)

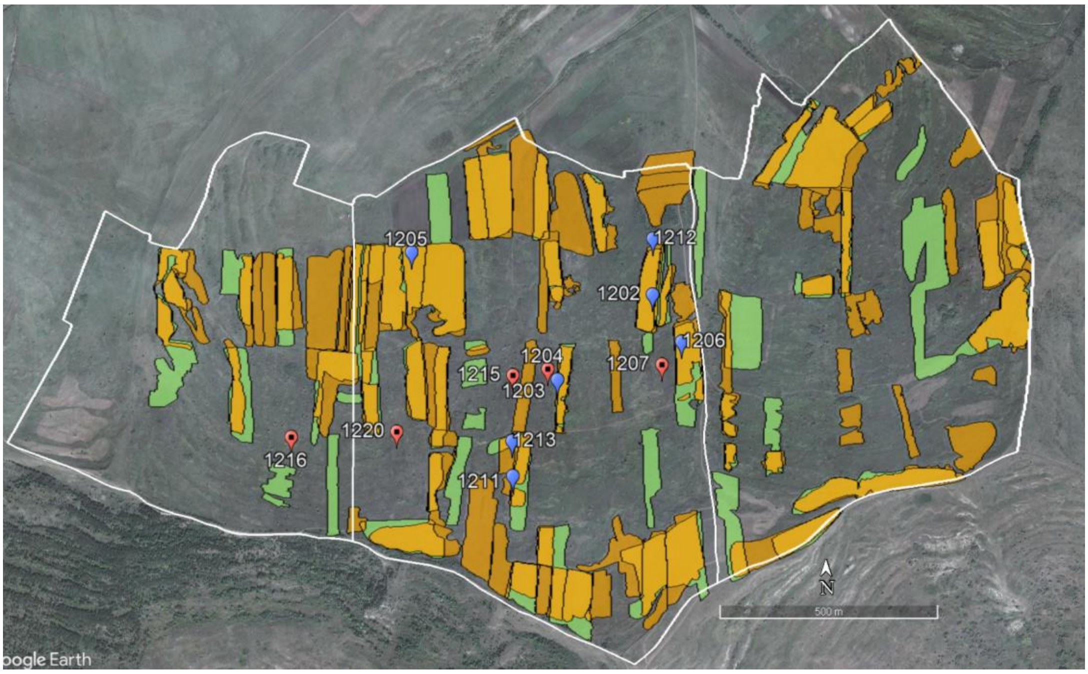

Figure 132: Location of the diversity relevés in the Great Meadow (white outline; Borşa commune) and display of the mown plots 2010 (green) and 2011 (orange)
Blue, empty symbols: relevés in mown stands; red symbols with squares: relevés in unmown stands; the numbers indicate the original relevé numbers. The Google Earth image is from September 2011 (Google, © 2023 Maxar Technologies).

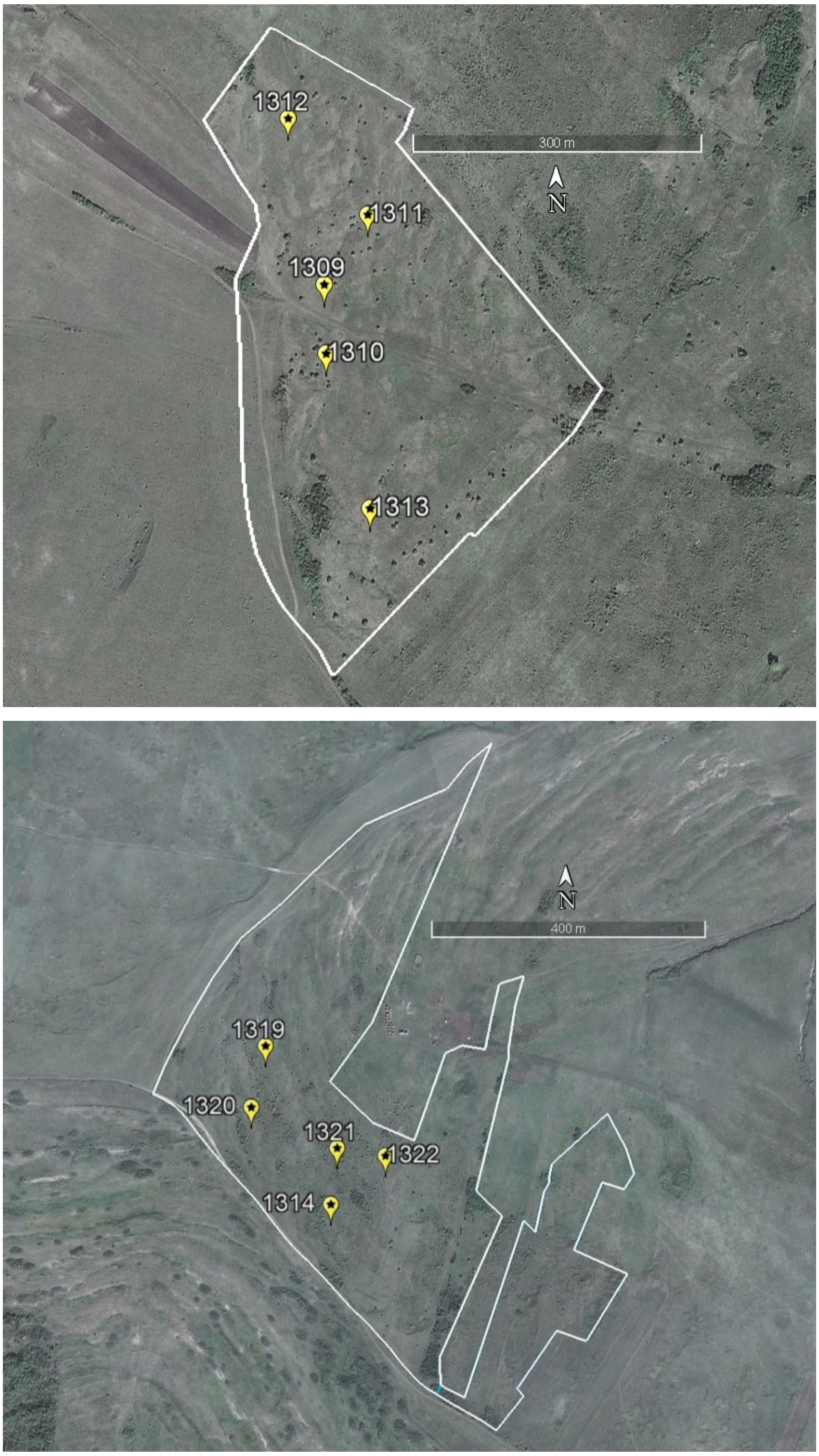

Figure 133: Location of the diversity relevés in the Meadow Hill (upper image, Dăbâca commune) and Jacob’s Meadow (lower image, Borşa commune)
Yellow symbols with stars: relevés in grazed stands; the numbers indicate the original relevé numbers. The Google Earth image is from September 2011 (Google, © 2023 Maxar Technologies).

5.2.1.2 Sampled land use variants

The diversity relevés were carried out on meadow areas assigned to three different land use variants: regular mowing, absence of mowing and grazing. The management types focused on the presence or absence of mowing were recorded in the *utilised hay meadows* (see Figure 131 and Figure 132). It is assumed that the areas not mown in the recorded period had regularly been mown at some point previously, so that they are formerly cut, now abandoned meadow areas. The possible occasional grazing of these areas was not considered.

The third management type, ‘grazing’, was recorded in the *former hay meadows* (see Figure 133). These areas had been mown regularly at some point before, therefore the variant includes, besides the current grazing, also the absence of mowing.

This sampling approach required the recording of mown and unmown areas during several years prior to collecting of the vegetation data (see Chapter 4.2.3). A discussion about the methodology can be found in Chapter 5.4.3. In the following, the management variants are described in more detail:

1. Variant ‘regularly mown’, recorded in areas <u>mown</u> in recent consecutive years (abbreviated ‘m’; n = 11), including these two options:
   - Data collection 2012: mown in the 2 years before sampling (2010, 2011; n = 7)
   - Data collection 2013: mown in the 3 years before sampling (2010-2012; n = 4)
2. Variant ‘unmown’, recorded in areas <u>not mown</u> in recent consecutive years (abbreviated ‘u’; n = 10), including these two options:
   - Data collection 2012: unmown in the 2 years before sampling (2010, 2011; n = 5)
   - Data collection 2013: unmown in the 3 years before sampling (2010-2012; n = 5)
3. Variant ‘grazed’, recorded in areas <u>used as rough permanent pasture</u> for sheep (abbreviated ‘g’; n = 10), including these two options:
   - Data collection 2013: not mown and grazed for ca. five years before sampling (Meadow Hill, n = 5)
   - Data collection 2013: not mown and grazed for ca. 15 years before sampling (Jacob’s Meadow, n = 5)

For every land use type, the two options were treated as one in the analysis; that is for example, the parcels mown in two consecutive years and those mown in three consecutive years both belong to the land use type ‘mown’.

Information regarding land use of the *former hay meadows* (abandonment of mowing, time since conversion) came from shepherds using the meadows at the time of data collection. The stocking rate of the *former hay meadows* could not be quantified exactly because the livestock were herded on large, unfenced areas of unknown extent, and for an unknown period per year.

For the *former hay meadow* Jacob's Meadow, the shepherd stated in the year 2013 that the sheep owner who used the meadow had 180 sheep and 85 goats grazing on the Jacob's Meadow (ca. 26 ha) and other adjacent areas. Furthermore, he specified that grazing on the meadow had started already before 1989 and that mowing stopped completely 15 years before 2013. The shepherd using the *former hay meadow* Meadow Hill stated that the upper part of the entire meadow had been used as a rough sheep pasture for five years.

Considering the large extent of the grazed area in both places (estimated 100 hectares and more), which also included fallow arable land, and the usual flock size of 100-300 sheep, it was assumed that the grazing intensity was extensive to highest semi-extensive, depending on the number of grazing days, and that the stocking rate was irregularly distributed over the area.

The *former* and *utilised hay meadows* had not been fertilized or manured since at least the year 1990 (information from local farmers, see also Chapter 4.3.2.1.3). The shepherds stated that in the *former hay meadows* they usually did not carry out maintenance work such as clearing or cutting of shrubs, and it was assumed that at least the *former hay meadows* are more or less regularly burnt in springtime.

5.2.1.3 Sampled vegetation types

When selecting the sites for the relevés, the aim was to sample semi-dry basiphilous grasslands of the alliance *Cirsio-Brachypodion pinnati*. Since the diversity relevés had also been part of the phytosociological survey (see Chapter 3), the selection of the diversity plots in the field was carried out prior to the phytosociological classification.

The assignment of the plots to semi-dry grasslands was thereby based on the presence of four species (*Brachypodium pinnatum, Ranunculus polyanthemos, Trifolium montanum, Centaurea scabiosa*), which were selected beforehand on the account of personal field observations and the following literature sources:

- Coldea et al. (2012), page 110: species assigned to the *Cirsio-Brachypodion pinnati* respectively *Brachypodietalia pinnati*
- Sanda et al. (2008), page 273: characteristic species for the *Cirsio-Brachypodion pinnati*

The selection criteria for plots in the field were the following: *Brachypodium pinnatum* had to be present, as well as at least two of the three species *Ranunculus polyanthemos*, *Trifolium montanum* and *Centaurea scabiosa*. There were exceptions in the *former hay meadow* Jacob's Meadow, where only one or two of the four mentioned species were present in three relevés; however, the relevés were subsequently classified as belonging to the *Cirsio-Brachypodion pinnati*.

Furthermore, six of the 31 relevés were placed randomly on the meadow surface. The suitability of these randomly placed relevés for the analysis was determined to be satisfactory in retrospect regarding the four diagnostic species of the *Cirsio-Brachypodion* / *Brachypodietalia pinnati* mentioned above.

The diversity relevés were classified afterwards as belonging to the *Polygalo-Brachypodietum pinnati* (19 relevés) and the *Cirsium furiens-Brachypodium pinnatum*-community (12 relevés). Stands of the *Brachypodio-Molinietum arundinacea* and the *Festuca pratensis*-community, which also belong to the *Cirsio-Brachypodion pinnati* grasslands in the meadows (see Chapter 3.3), were not covered. However, diversity relevés classified afterwards as belonging to the *Brachypodio-Molinietum arundinaceae* and *Molinietum caeruleae* were carried out separately (n = 8); this data is not included here.

5.2.1.4 Sampling routine and recorded parameters

The method chosen for the survey was the standardised sampling approach based on multi-scale nested-plot series described by Dengler (2009), which is based upon the methodology proposed by Whittaker (Shmida 1984) (see Figure 134). This approach has been used in numerous phytodiversity studies (e.g. Dengler et al. 2016) and also for the data included in the Database of Scale-Dependent Phytodiversity Patterns in Palaearctic Grasslands (GIVD-ID EU-00-003, Dengler et al. 2011). The results of the thesis can thus be compared with up-to-date findings about many other grasslands, and the effects of the land use change can also be examined on more than one spatial scale.

The largest of the nested plots was sized 10 m^2 and contained smaller sub-plots of 1 m^2, 0.1 m^2, 0.01 m^2 and 0.001 m^2, covering a range of five orders of magnitude as recommended by Dengler (2008) as a minimum number. For six relevés, the additional plot size 25 m^2 was also surveyed (marked with the letter E).

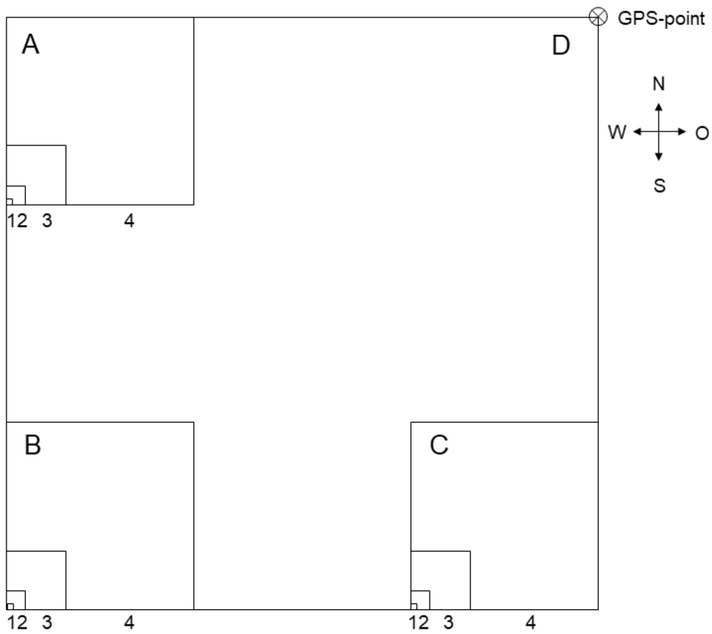

Figure 134: Scheme of the nested-plot series used in the survey
Plot sizes: D: 10 m^2 (316 cm x 316 cm); 4: 1 m^2 (100 cm x 100 cm); 3: 0.1 m^2 (31.6 cm x 31.6 cm); 2: 0.01 m^2 (10 cm x 10 cm); 1: 0.001 m^2 (3.16 cm x 3.16 cm); the illustration is true to scale.

The sub-plots were replicated 3-fold as suggested by Dengler (2009). They were evenly placed within the larger plot, always in the same outer corners, which rendered sampling easier and less destructive than placing them in the centre of the larger plot.

Figure 135: The dissertation author carrying out a phytodiversity relevé in Jacob's Meadow (Borşa commune, 13.08.2013)
Plot D (10 m^2, blue marking) and a sub-plot of 1 m^2 (white marking) can be seen.

In all the (sub-) plots a complete list of the vascular plant species was made. Additionally, species dominance (cover value in percentage) was estimated in the 0.01 m^2- and 10 m^2-plots, with the purpose of comparing several parameters on two different spatial scales. Here is an overview of the nested plot scheme replications and sizes:

- 1 x 10 m^2 (316 cm x 316 cm) species dominance (percent)
- 3 x 1 m^2 (100 cm x 100 cm) species presence
- 3 x 0.1 m^2 (31.6 cm x 31.6 cm) species presence
- 3 x 0.01 m^2 (10 cm x 10 cm) species dominance (percent)
- 3 x 0.001 m^2 (3.16 cm x 3.16 cm) species presence

Furthermore, the following parameters of vegetation structure have been recorded:

- Total cover of vegetation 10 m^2-plot and 0.01 m^2-plots
- Cover of bare ground 10 m^2-plot and 0.01 m^2-plots
- Cover of litter 10 m^2-plot and 0.01 m^2-plots
- Depth of litter 10 m^2-plot (median of 6 values)
  0.01 m^2-plots (one value measured per plot)
- Cover of bryophytes 10 m^2-plot and 0.01 m^2-plots

- Cover of lichens 10 m^2-plot (+ information about substrate)
- Cover of shrubs 10 m^2-plot
- Average height of shrub layer 10 m^2-plot
- Maximum height of shrub layer 10 m^2-plot
- Average height lower herbs & grasses layer 10 m^2-plot
- Average height upper herbs & grasses layer 10 m^2-plot

The cover values were estimated using the any-part-system (vertical projection). The litter depth was measured with a tape measure at different standardized points (towards the corners and in the centre) of the 10 m^2-plot and at one point of the 0.01 m^2-plot. The height of the herbs & grasses layer and the shrub layer was also measured with a tape measure (one value / plot). Several environmental parameters were also recorded, but were not included in the data analysis.

The taxonomy of vascular plants followed the Euro+Med PlantBase (Euro+Med 2006+). *Galium album* and *Galium mollugo* were treated as a species aggregate. In the following cases, subspecies which are considered species according to Săvulescu (1952-1976) were not considered separately:

- *Centaurea scabiosa* L. includes *Centaurea scabiosa* subsp. *spinulosa* (Spreng.) Arcang. (synonyms: *Centaurea spinulosa* Spreng., *Centaurea apiculata* subsp. *spinulosa* (Spreng.) Dostál).
- *Euphorbia esula* L. includes *Euphorbia esula* subsp. *tommasiniana* (Bertol.) Kuzmanov (synonym: *Euphorbia virgata* Waldst. & Kit.).

5.2.1.5 Data storage

The vegetation relevés were stored in databases using the programs EXCEL 2019 (Microsoft Corp. 2018) and TURBOVEG version 2.154 (Hennekens and Schaminée 2001).

5.2.2 Data analysis

5.2.2.1 Tests for differences between the land use variants

The hypotheses that the three land use variants mown (m), unmown (u) and grazed (g) differed in their recorded or calculated parameters of plant diversity, vegetation structure and functional groups were tested. For the analysis, usually the median value of the three replicates for each sub-plot size was used (for the life form the mean). The statistical analysis was carried out with the programme IBM SPSS Statistics for Windows, version 22 (IBM Corp. 2020).

For the tests, the following levels of significance (α) were used:

- $\alpha > 0.05$ (> 5 %) not significant
- $\alpha = 0.01 – 0.05$ (1 – 5 %) significant (*)
- $\alpha < 0.01$ (< 1 %) highly significant (**)

To test if the data followed a normal distribution, the Shapiro-Wilk-test was used. If the distribution was not normal, the data were checked for extreme outliers, which were deleted in cases in which they seemed to be real exceptions from the other data. The homogeneity of variance was checked by the Levene-Test. The following tests were carried out to affirm or reject the hypotheses:

- One-way analysis of variance (ANOVA) for independent samples (parametric)
  - Checked preconditions: homogeneity of variance
  - Post-hoc-test: Bonferroni correction
- H-Test (Kruskal-Wallis test) for independent samples (non parametric)
  - In case the preconditions for the ANOVA were not fulfilled
  - Post-hoc-test: pairwise comparisons

In the following, the tested parameters, that is, the dependent variables, will be listed.

5.2.2.2 Diversity of vascular plants

In addition to the species richness, which only indicates the presence of the taxa in a stand, the Shannon index and evenness show further components of diversity based on the variability in species quantities. In general, diversity is rated higher in a community where all species have the same population density than in a community where some species are frequent and others rare (Tremp 2005). The following indices for the diversity of vascular plants were used for the statistical tests:

- Species richness (species number per area) for all plot sizes
- Shannon index (H') for the 0.01 m^2-plots and 10 m^2-plots, calculated with the programme Diversitycalc (Möseler et al. 2009) according to the following formula (Tremp 2005; Möseler et al. 2009):

  $$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

  H' = Shannon index

  $p_i = n_i / N$ (relative proportion of species i between zero and 1)

  n_i = importance value of the species i

  N = sum of the importance values of all species

- Evenness (E) for the 0.01 m^2-plots and 10 m^2-plots, calculated with the programme EXCEL using the following formula (Tremp 2005):

  $$E = \frac{H'}{H_{max}}$$

  $H_{max} = \ln s$

  s = total number of species

5.2.2.3 Vegetation structure

The following vegetation structure parameters were used as dependent variables for the indicated plots sized:

- Total cover of vegetation 10 m^2 and 0.01 m^2
- Cover of bare ground 10 m^2 and 0.01 m^2
- Cover of bryophytes 10 m^2 and 0.01 m^2
- Cover of litter 10 m^2 and 0.01 m^2
- Depth of litter 10 m^2 and 0.01 m^2
- Cover of shrubs 10 m^2
- Average height of shrubs 10 m^2
- Maximum height of shrubs 10 m^2
- Average height of the lower herbs and grasses layer 10 m^2
- Average height of the upper herbs and grasses layer 10 m^2

5.2.2.4 Functional groups and life forms

The vascular plant species were divided into three functional groups:

- Graminoids: true grasses (*Poaceae*), sedges (*Cyperaceae*) and rushes (*Juncaceae*)
- Forbs: all species without graminoids, including woody plants and legumes *(Fabaceae)*
- Legumes (Fabaceae)

For each 0.01 m^2-plot and 10 m^2-plot, the proportion in the cumulated species cover was calculated for each group; this ratio was used as the dependent variable.

Furthermore, the effect of land use on the ratio of plant life form categories based on Raunkiaer's system (Raunkiaer 1937) was investigated. The allocation of the species to different life form categories was extracted from the BIOLFLOR database (Klotz et al. 2002). For the species not listed in BIOLFLOR the information was taken from the Flora of Romania by Ciocârlan (2000) (see Annex 4).

In the following, the 13 life form categories used in the analysis are listed. The high number of categories arises from the ‘mixed’ categories of the BIOLFLOR database, which contain species that can grow both as therophytes / geophytes / chamaephytes and hemicryptophytes:

- Therophytes
- Therophytes/hemicryptophytes, for example *Linum catharticum* or *Medicago lupulina*
- Therophytes s. l.: therophytes plus therophytes/hemicryptophytes
- Geophytes

- Geophytes/hemicryptophytes, for example *Thesium linophyllon*
- Geophytes s. l.: geophytes plus geophytes/hemicryptophytes
- Hemicryptophytes
- Chamaephytes (herbaceous)
- Chamaephytes/hemicryptophytes, for example *Glechoma hirsuta* or *Prunella grandiflora*
- Chamaephytes s. l.: chamaephytes plus chamaephytes/hemicryptophytes
- Phanerophytes
- Hemi-/pseudo-phanerophytes: hemi-phanerophytes (suffrutescent chamaephytes) like *Dorycnium pentaphyllum* subsp. *herbaceum*, *Thymus pulegioides* subsp. *pannonicus* or *Teucrium chamaedrys*; pseudo-phanerophytes like *Rubus caesius*
- Others: Taxa for which no life form can be specified, because they were not determined on the species level (e.g. *Potentilla* species)

For each 0.01 m^2-plot and 10 m^2-plot, the proportion in the cumulated species cover was calculated for each life form category and used as dependent variable for the statistical tests. The statistical analysis of these variables was carried out with the programme IBM SPSS Statistics for Windows, version 29 (IBM Corp. 2020).

5.2.2.5 Diagnostic species for the land use variants

For the identification of diagnostic species for the three land use variants, the program JUICE version 7.1 (Tichý 2002) was used. The relevé data for the 0.01 m^2- plots and the 10 m^2-plots, which are in percentage values, was imported from TURBOVEG. For the standardization of relevé data, occurrences of species in the different layers (shrub, herb and juvenile layer) were combined (Dengler et al. 2012). Two files were created divided by the plot size: a file containing the 0.01 m^2-plots with 93 relevés and 147 species, and a file containing the 10 m^2-plots with 31 relevés and 238 species.

Three groups were created in each file according to the land use type: mown, unmown, and grazed (see Chapter 5.2.1.2). For the identification of the diagnostic species for each group, the statistical fidelity measure phi-(Φ)-coefficient of association was used (see also Chapter 3.2.4.2). The phi-coefficient takes values from – 1 to + 1 (Chytrý et al. 2002); for convenience these values are multiplied with 100 in JUICE (Tichý et al. 2010). Positive values indicate that the species and the land use unit co-occur more frequently than would be expected by chance, with larger values indicating a greater degree of joint fidelity.

In this study, species with phi-coefficient values of at least 20 (0.20) were considered diagnostic, and species with phi-coefficient values of at least 45 (0.45) were considered highly diagnostic. Only significant phi-coefficient values were considered; the statistical significance was calculated by Fisher's exact test (level of significance $p > 0.05$) in JUICE (Chytrý et al. 2002; Tichý and Chytrý 2006); a standardisation of the relevé group size was also applied.

5.3 Results

5.3.1 Maximum species richness values

Table 40 shows the maximum vascular plant species richness values of the studied semi-dry grasslands for all five plot sizes separated by land use. The results indicate that, for all plot sizes, the maximum richness values are highest in the mown stands, compared to the unmown and grazed stands. For the grain sizes 0.01 m², 0.1 m² and 10 m² the maximum richness values of the unmown stands are also higher than of the grazed stands. For example, on 10 m² the maximum richness is 81 species in the mown, 68 in the unmown and 64 in the grazed stands. The mean richness value on 10 m² calculated for all 31 diversity relevés is 59 species.

Table 40: Maximum values of vascular plant species richness and comparison with world records

Plot size (m²)	**m** (n = 11)	**u** (n = 10)	**g** (n = 10)	Wilson et al. 2012 (world records)			Dengler et al. 2020 (Palaearctic realm records)		
				R	vegetation type	country	R	vegetation type	country
0.001	15	11	11	12	Limestone grassland	Sweden	19	Semi-dry grassland	Spain
0.01	26*	18	16	25	Wooded meadow	Estonia	25	Wooded meadow	Estonia
0.1	37	30	27	43	Semi-dry basiph. grassl.	Romania	43	Semi-dry grassland	Romania, Czech R.
1	56	44	46	89	Mountain grassland	Argentina	82	Semi-dry grassland	Czech Republic
10	81	68	64	98 (115**)	Semi-dry basiph. grassl.	Romania	98 (115**)	Semi-dry grassland	Romania

m: mown, **u**: unmown, **g**: grazed; * maximum is higher than published world / Palaearctic record; ** at the same location, Roleček et al. (2021) have found 115 vascular plant species per 10 m²; R: vascular plant species richness; relevé IDs for max. richness in mown plots: 0.001 m²: 1203A1; 0.01 m²: 1203A2; 0.1 m²: 1203A3, 1303C3; 1 m²: 1301A4; 10 m²: 1203D

It is important to consider that the richness values came from relevés in two different vegetation types (*Polygalo-Brachypodietum pinnati* and *Cirsium furiens*-community), and that the *Cirsium furiens*-community is possibly a management form of the *Polygalo-Brachypodietum pinnati*. In contrast, Chapter 3.3.1.4 provides mean, maximum and minimum richness values separated by vegetation type.

Table 40 shows the published records of maximum vascular plant richness for comparison, taken from the publication by Wilson et al. (2012) for worldwide maximum values and the publication by Dengler et al. (2020) for maximum values of the Palaearctic realm.

The maximum richness value found in the mown stands on 0.01 m² of 26 species is higher than the published world and Palaearctic record (25 species). The nested diversity plot series in which this new record occurs is shown in Annex 5; the series also includes the maximum richness values in the whole dataset for 0.001 m², 0.1 m² and 10 m² and was recorded in the year 2012 in a parcel of land mown for at least two previous years in the Great Meadow (see Figure 132, page 237).

The maximum richness value for the 1 m² size is proportionally further away from the Palaearctic record value (56 versus 82) than the values of the other plot sizes (see Table 40). However, the maximum richness values for all plot sizes are still high compared to most maximum richness values from other European regions (see Table 41). For instance, the aforementioned value for 1 m² (56 species) is higher than the maximum values for the other European regions (Western Europe: 53 species, Northern Europe and Baltic Seas: 49 species, Mediterranean Region: 48 species) (Dengler et al. 2020).

Table 41: Maximum richness of vascular plants across regions of the Palaearctic realm from Dengler et al. (2020)

Area (m²)	*Western Europe*	*Northern Europe and Baltic States*	*Eastern Europe*	*Mediterranean Region*	*Middle East and Caucasus*	*Russia*	*Kazakhstan and Middle Asia*	*Mongolia*	*China*	*Japan*	*Place and grassland type of Palaearctic maximum*
0.0001	9	5	**11**	8	3	5	5	–	–	–	Poland: wet grassland
0.001	**19**	12	13	12	4	9	15	–	–	–	Spain: meso-xeric grassland
0.01	23	**25**[a]	22	24	20	17	17	–	–	–	Estonia: meso-xeric grassland in a wooded meadow
0.1	34	35[b]	**43**[c]	37[b]	34	28	28	–	–	–	Romania (shoot; Fig. 3E) and Czech Republic (rooted)[c]: meso-xeric grassland
1	53	49	**82**[c]	48	48	52	37	11	59	58	Czech Republic: meso-xeric grassland
10	86	49[b]	**98**	71	65	76[d]	50	–	71[b]	–	Romania: meso-xeric grassland (Fig. 3E)
100	110	70	**133**[c]	99	85	109[d]	67	34	76	–	Czech Republic: meso-xeric grassland

Explanations from Dengler et al. (2020), page 11: in bold: Palaearctic maximum richness values; [a] Chytrý et al. (2015); [b] records are for 10 % smaller areas; [c] Wilson et al. (2012); [d] unpublished data provided by M. Chytrý

5.3.2 Differences regarding the plant species diversity

5.3.2.1 Differences regarding the plant species richness

Table 42 shows the mean vascular plant species richness of the studied semi-dry grasslands for the five plot sizes 0.001 m², 0.01 m², 0.1 m², 1 m² and 10 m² separated by land use and the results of the statistical tests. The results indicate that the mown stands have significantly higher mean richness values compared to the grazed stands for all plot sizes (0.001 m² – 10 m²) and significantly higher mean richness values compared to the unmown stands for the plot sizes 0.1 m², 1 m² and 10 m².

For example, on 10 m², the mown stands harbour on average 67 species, while both the unmown and grazed stands have on average 55 species; for 1 m² the numbers are

41 versus 32 (unmown) / 34 species (grazed) and for 0.1 m^2 the numbers are 27 versus 20 (unmown / grazed) (see Table 42 and Figure 136).

Table 42: Mean vascular plant species richness for the three land use variants

Plot size (m^2)	m (n = 11)	u (n = 10)	g (n = 10)	Type of test	Statistical values	p of the test	p of single cases
0.001	7.3 ± 1.5 ^{A}	6.8 ± 1.6	4.9 ± 1.5 ^{B}	H-Test	H (df 2, n = 31) = 10.29**	0.006	m>g**: 0.006 (pc)
0.01	14.6 ± 3.4 ^{A}	11.3 ± 3.1	10.2 ± 1.9 ^{B}	ANOVA	F (df 2, 28) = 5.80**	0.008	m>g**: 0.009 (B)
0.1	26.6 ± 4.8 ^{A}	19.5 ± 5.1 ^{B}	19.9 ± 3.1 ^{B}	ANOVA	F (df 2, 28) = 8.51**	0.001	m>u**: 0.003 (B); m>g**: 0.006 (B)
1	41.4 ± 5.1 ^{A}	31.8 ± 6.2 ^{B}	34.1 ± 4.8 ^{B}	ANOVA	F (df 2, 28) = 9.20**	0.001	m>u**: 0.001 (B); m>g*: 0.013 (B)
10	67.4 ± 7.2 ^{A}	54.7 ± 8.5 ^{B}	54.6 ± 5.5 ^{B}	ANOVA	F (df 2, 28) = 11.13**	<0.001	m>u**: 0.001 (B); m>g**: 0.001 (B)

m: mown, **u**: unmown, **g**: grazed; mean values of vascular plant species richness per plot with standard deviations are given; different letters (superscript A, B) and different variations of grey indicate significant differences between the land use variants; n: sample size; H: H-value; df: degrees of freedom; F: F-value; p: probability value; pc: pairwise comparisons, B: Bonferroni; the significance level α is indicated by the following symbols: α < 0.01: highly significant (**), α = 0.01 - 0.05: significant (*)

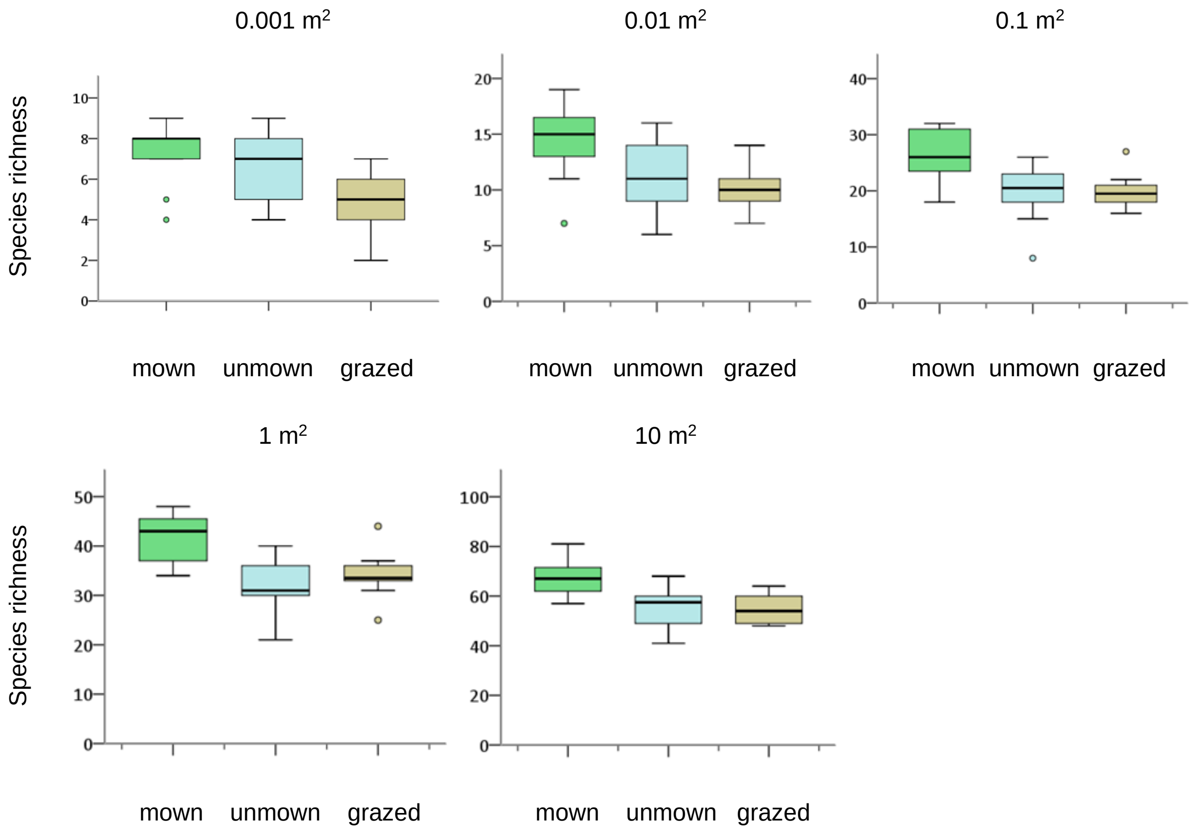

Figure 136: Boxplot diagrams of the mean vascular plant richness for the analysed five plot sizes and three land use variants

5.3.2.2 Differences regarding the Shannon index and evenness

Table 43 and Figure 137 show the mean values of the Shannon index and evenness of the studied semi-dry grasslands for the plot sizes 0.01 m^2 and 10 m^2 separated by land use and the results of the statistical tests.

Table 43: Mean Shannon index and evenness for the three land use variants

Diversity index	Plot size (m^2)	m (n = 11)	u (n = 10)	g (n = 9)[1]	Type of test	Statistical values	p of the test	p of single cases
Shannon index	0.01	1.99 ± 0.27	1.83 ± 0.36	1.83 ± 0.13	H-Test	H (df 2, n = 30) = 2.58	0.275	
	10	3.02 ± 0.29 ^{A}	2.80 ± 0.34 ^{A}	2.37 ± 0.30 ^{B}	ANOVA	F (df 2, 28) = 11.90**	<0.001	m>u**: <0.001 (B); u>g*: 0.013 (B)
Evenness	0.01	0.78 ± 0.05	0.78 ± 0.08	0.78 ± 0.04	H-Test	H (df 2, n = 30) = 0.14	0.932	
	10	0.72 ± 0.07 ^{A}	0.70 ± 0.08 ^{A}	0.59 ± 0.07 ^{B}	ANOVA	F (df 2, 28) = 9.05**	0.001	m>g**: 0.001 (B); u>g**: 0.007(B)

m: mown, **u**: unmown, **g**: grazed; mean values of the diversity indices per plot with standard deviations are given; different letters (superscript A, B) & different variations of grey indicate significant differences between the land use variants; n: sample size; H: H-value; df: degrees of freedom; F: F-value; p: probability value; B: Bonferroni; the significance level α is indicated by the following symbols: α < 0.01: highly significant (**), α = 0.01 - 0.05: significant (*)

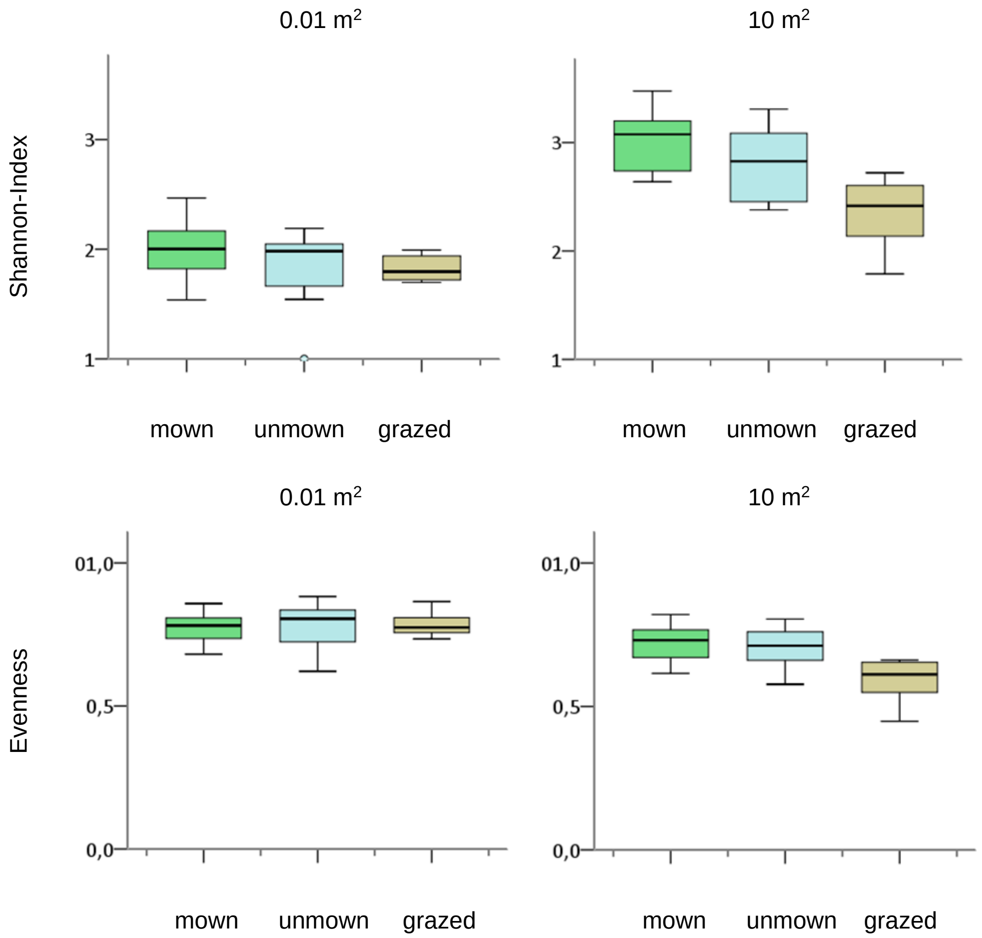

Figure 137: Boxplot diagrams of the mean Shannon-index and evenness for the plot sizes 0.01 m^2 and 10 m^2 and three land use variants

The results indicate that, for the plot size of 0.01 m^2, the mean Shannon index and evenness differ little between the mown, unmown and grazed variants, although the mown stands have higher mean richness values than the unmown and grazed on this spatial scale. That means the fewer species in the unmown or grazed stands have a similar equal distribution as the more numerous species of the mown stands. This could perhaps be due to the small plot size, which does not allow for much difference between the densities of the plants present (10-15 species on 10 cm x 10 cm).

A different pattern emerges at the plot size of 10 m^2 (see Table 43 and Figure 137): here, the grazed stands have significantly lower values of both diversity indices compared to the mown as well as to the unmown stands (e.g. evenness in the grazed stands: 0.59 versus mown stands: 0.72 and unmown stands: 0.70). This means that, on this spatial scale, the inequality of species cover (and abundance) is higher in the grazed areas.

5.3.3 Differences regarding the vegetation structure

Table 44 shows several vegetation structure parameters of the studied semi-dry grasslands separated by land use variant and the results of the statistical tests. Some of the parameters exist for two plot sizes, 0.01 m^2 and 10 m^2, while the information on the average height of the herbs and grasses layer and on the shrub layer was recorded only for the plot size 10 m^2.

The following (significant) differences between the mown, unmown and grazed stands were detected: The average height of the lower and higher herbs and grasses layer is significantly lower in the grazed stands than in the mown or unmown meadow stands (see Table 44).

While the total vegetation cover is approximately the same for all three land use types at the 10 m^2-scale (around 94 %), at the 0.01 m^2-scale it is significantly higher in the grazed stands than the abandoned stands. The values of the mown stands occupy a medium position and do not differ significantly from the values of the other land use variants. Thus, at the smaller spatial scale, the results show a greater heterogeneity of plant cover between the land use types which is not found at the larger spatial scale.

A significant difference found at the 10 m^2-scale is higher bare ground cover in the grazed stands compared to the mown and unmown stands; this is also found at the smaller spatial scale but is not significant (see Table 44). The last significant difference concerns the cover of bryophytes, which is lowest in the unmown stands as compared to the mown and grazed stands on the larger spatial scale; the same applies at the small spatial scale, but this difference is not significant.

Lichens were only found in the grazed stands, namely in four relevés of the *Cirsium furiens*-community on woody substrate, with cover values ranging between 0.01 % and 10 % per 10 m^2-plot and a median cover value of 0.06 % per 10 m^2-plot.

The mean cover and average / maximum height values of the shrub layer in the 10m^2-plots was calculated for all recorded relevés (n = 10 / 11), as well as for the plots with non-zero values (see Table 44). Only some of the relevés in the unmown and grazed stands had a shrub layer (four each), however, there was no significant difference between the three land use variants.

Table 44: Vegetation structure parameters for the three land use variants

Variable	Plot size (m^2)	m (n = 11)	u (n = 10)	g (n = 10)	Type of test	Statistical values	p of the test	p of single cases
Av. hight lower h&g layer (cm)	10	30.0 ± 12.7 ^{A}	34.8 ± 10.4 ^{A}	10.4 ± 8.3 ^{B}	H-Test	H (df 2, n = 31) = 14.19**	0.001	m > g*:0.011 (pc); u > g**:0.001 (pc)
Av. hight upper h&g layer (cm)	10	58.2 ± 14.7 ^{A}	69.0 ± 12.4 ^{A}	32.0 ± 17.2 ^{B}	H-Test	H (df 2, n = 31) = 14.35**	0.001	m > g*:0.03 (pc); u > g**:0.001 (pc)
Total cover vegetation (%)	0.01	76.5 ± 14.2	68.3 ± 20.5 ^{A}	87.6 ± 12.0 ^{B}	ANOVA	F (df 2, 27) = 3.69*	0.038	g > u*: 0.035 (B)
	10	92.7 ± 6.7	94.4 ± 6.2	94.4 ± 2.6	H-Test	H (df 2, n = 31) = 0.92	0.631	
Cover bare ground (%)	0.01	1.1 ± 1.7	0.1 ± 0.3	2.3 ± 3.4	H-Test	H (df 2, n = 27) = 4.80	0.091	
	10	0.7 ± 0.7 ^{A}	0.9 ± 0.6 ^{A}	4.0 ± 3.0 ^{B}	H-Test	H (df 2, n = 29) = 12.23**	0.002	g > m**: 0.003 (pc); g > u*: 0.025 (pc)
Cover bryophytes (%)	0.01	5.5 ± 7.1	0.7 ± 1.7	6.7 ± 9.6	H-Test	H (df 2, n = 30) = 4.02	0.134	
	10	2.7 ± 3.3 ^{A}	0.0 ± 0.0 ^{B}	4.4 ± 5.4 ^{A}	H-Test	H (df 2, n = 24) = 10.2**	0.006	m > u*: 0.011 (pc); g > u*: 0.02 (pc)
Cover litter (%)	0.01	81.3 ± 26.7	90.7 ± 11.7	75.5 ± 23.4	H-Test	H (df 2, n = 30) = 1.65	0.439	
	10	82.3 ± 13.4	88.5 ± 12.2	65.9 ± 32.0	H-Test	H (df 2, n = 31) = 3.88	0.144	
Depth litter (cm)	0.01	0.8 ± 0.5	2.0 ± 1.8	0.9 ± 0.5	H-Test	H (df 2, n = 30) = 3.76	0.153	
	10	0.7 ± 0.4	1.9 ± 1.4	0.7 ± 0.3	H-Test	H (df 2, n = 30) = 6.24*	0.044	
Cover shrubs (%)	10	0.0 ± 0.0	1.6 ± 2.6	1.9 ± 3.1	H-Test	H (df 2, n = 31) = 5.59	0.061	
Average hight shrubs (cm)	10	0.0 ± 0.0	21.5 ± 28.9	13.0 ± 18.3	H-Test	H (df 2, n = 31) = 5.72	0.057	
Max. hight shrubs (cm)	10	0.0 ± 0.1	30.0 ± 38.8	28.5 ± 41.5	H-Test	H (df 2, n = 31) = 5.64	0.059	
Cover shrubs (%)	10		4.0 ± 2.8	4.6 ± 3.4	T-Test	t (df 6) = -0.311	0.383	considering only relevés with non-zero values (4 each in unmown and grazed group)
Average hight shrubs (cm)	10		53.8 ± 13.8	32.5 ± 12.6	T-Test	t (df 6) = 2.279	0.063	
Max. hight shrubs (cm)	10		75.0 ± 4.1	71.3 ± 33.3	T-Test	t (df 6) = 0.224	0.830	

m: mown, **u**: unmown, **g**: grazed; mean values of vegetation structure parameters with standard deviations are given; different letters (superscript A, B) and different variations of grey indicate significant differences between the land use variants; av.: average; h&g: herbs and grasses; n: sample size; H: H-value; df: degrees of freedom; F: F-value; p: probability value; pc: pairwise comparisons, B: Bonferroni; t: t-value; the significance level α is indicated by the following symbols: α < 0.01: highly significant (**), α = 0.01 - 0.05: significant (*)

5.3.4 Differences regarding the proportion of guilds

Table 45 shows the mean proportion of the three functional groups graminoids, forbs (including woody plants and legumes) and legumes in the sum of the species cover values, separated by land use variant and the results of the statistical tests.

The results show that the grazed stands have a significantly higher mean proportion of graminoids (e.g. 62 % in 10 m^2-plots) and lower proportion of forbs (38 % in 10 m^2-plots) than the mown and unmown stands (in each case 47 % graminoids, 53 % forbs in 10 m^2-plots) in both plot sizes.

The comparison of the mown and unmown stands shows that, on the smaller spatial scale, the unmown stands have a higher proportion of forbs than the mown stands

(75 % versus 65 %, not significant). However, on the larger spatial scale the mown and unmown stands do not differ in their proportion of forbs (53 %) and graminoids (47 %) (see Table 45).

The proportion of legumes in the total plant cover is significantly lower in the grazed stands (3 %) compared to the unmown stands for both plot sizes (0.01 m^2: 13 %, 10 m^2: 11 %) and the mown stands for the 10 m^2-plot size (11 %) (see Table 45).

Table 45: Proportion of graminoids, forbs & legumes in the sum of species cover values

Functional group	Plot size (m^2)	m (n = 11)	u (n = 10)	g (n = 10)	Type of test	Statistical values	p of the test	p of single cases
Graminoids (%)	0.01	35 ± 15 ^{A}	25 ± 12 ^{A}	55 ± 17 ^{B}	ANOVA	F (df 2,27) = 9.95**	0.001	g>m*: 0.012 (B); g>u**: 0.001 (B)
	10	47 ± 12 ^{A}	47 ± 12 ^{A}	62 ± 10 ^{B}	ANOVA	F (df 2,28) = 6.49**	0.005	g>m*: 0.011 (B); g>u*: 0.013 (B)
Forbs (%)	0.01	65 ± 15 ^{A}	75 ± 12 ^{A}	45 ± 17 ^{B}	ANOVA	F (df 2,27) = 9.95**	0.001	m>g*: 0.012 (B); u>g**: 0.001 (B)
	10	53 ± 12 ^{A}	53 ± 12 ^{A}	38 ± 10 ^{B}	ANOVA	F (df 2,28) = 6.49**	0.005	m>g*: 0.011 (B); u>g*: 0.013 (B)
Legumes (%)	0.01	8 ± 7	13 ± 11 ^{A}	3 ± 3 ^{B}	H-Test	H (df 2, n = 29) = 6.16*	0.046	u>g*: 0.045 (pc)
	10	11 ± 6 ^{A}	11 ± 9 ^{A}	3 ± 2 ^{B}	H-Test	H (df 2, n = 30) = 11.36**	0.003	m>g**: 0.004 (pc); u>g*: 0.027 (pc)

m: mown, **u**: unmown, **g**: grazed; mean proportion in the sum of species cover values with standard deviations are given; different letters (superscript A, B) and different variations of grey indicate significant differences between the land use variants; graminoids: *Poaceae, Cyperaceae* and *Juncaceae;* forbs: all vascular plants except graminoids; legumes: *Fabaceae;* F: F-value; df: degrees of freedom; H: H-value; n: sample size; p: probability value; B: Bonferroni; pc: pairwise comparisons; the significance level α is indicated by the following symbols: α < 0.01: highly significant (**), α = 0.01 - 0.05: significant (*)

5.3.5 Differences regarding the proportion of plant life forms

Table 46 shows the mean proportion of 13 plant life form categories in the sum of the species cover values, separated by land use variant and the results of the statistical tests.

The hemicryptophytes have the largest proportion in all three land use variants (in the 10 m^2-plots around 79 % to 80 % of the total cover). The second highest ratio values on the 10 m^2-scale are reached in all land use variants by the geophytes/hemicryptophytes. The species included in this group in the BIOLFLOR database (Klotz et al. 2002) mostly have the attribution hemicryptophytes in the Romanian Flora by Ciocârlan (2000). In this study, the following species belong to this group: *Elytrigia intermedia, Elytrigia repens, Euphorbia esula, Glechoma hederacea,* and *Thesium linophyllon.* The relatively high proportion of the geophytes/hemicryptophytes is mainly due to the high average cover of *Elytrigia intermedia* in the plots.

Regarding differences between land use variants, the results indicate that the proportion of therophytes is significantly higher in the mown stands versus the unmown stands for both plot sizes (see Table 46). Furthermore, the proportion of the therophytes is significantly higher in the mown stands than in grazed stands for the 10 m^2 grain size (mown 1.24 %, unmown 0.19 %, grazed 0.14 %).

Table 46: Proportion of plant life form categories in the sum of species cover values

Life form (%)	Plot size (m^2)	m	u	g	Type of test	Statistical values	p of the test	p of single cases
Therophytes	0.01	0.69 ± 0.89^A	0.0 ± 0.0^B	0.45 ± 1.42	H-Test	H (df 2, n = 31) = 8.82*	0.012	m>u*: 0.015 (pc)
	10	1.24 ± 0.94^A	0.19 ± 0.25^B	0.14 ± 0.18^B	H-Test	H (df 2, n = 31) = 17.26**	<0.001	m>u**: 0.002 (pc); m>g**: 0.001 (pc)
Therophytes / Hemicryptophytes	0.01	0.18 ± 0.25	0.11 ± 0.33	0.49 ± 0.71	H-Test	H (df 2, n = 31) = 3.71	0.156	
	10	0.42 ± 1.09	0.00 ± 0.01	0.27 ± 0.26	ANOVA	F (df 2,28) = 1.05	0.362	
Therophytes s. l.	0.01	0.87 ± 0.87^A	0.11 ± 0.33^B	0.94 ± 1.87	H-Test	H (df 2, n = 31) = 7.20*	0.027	m>u*: 0.023 (pc)
	10	1.66 ± 1.29^A	0.20 ± 0.24^B	0.41 ± 0.37^B	H-Test	H (df 2, n = 31) = 14.44**	<0.001	m>u**: 0.001 (pc); m>g*: 0.042 (pc)
Geophytes	0.01	11.77 ± 7.57^A	7.58 ± 6.82	4.46 ± 4.76^B	ANOVA	F (df 2,28) = 3.32*	0.051[a]	m>g*: 0.048 (B)
	10	4.54 ± 4.38	4.92 ± 4.05^A	1.97 ± 1.41^B	H-Test	H (df 2, n = 31) = 6.05*	0.048	u>g*: 0.048 (pc)
Geophytes / Hemi-cryptophytes	0.01	2.33 ± 3.22	7.65 ± 13.89	4.44 ± 9.34	ANOVA	F (df 2,28) = 0.85	0.438	
	10	7.40 ± 7.68	9.88 ± 13.60	9.38 ± 16.98	ANOVA	F (df 2,28) = 0.11	0.901	
Geophytes s. l.	0.01	14.09 ± 8.99	15.23 ± 13.08	8.90 ± 8.81	ANOVA	F (df 2,28) = 1.06	0.361	
	10	11.94 ± 6.42	14.80 ± 13.44	11.34 ± 16.56	ANOVA	F (df 2,28) = 0.21	0.808	
Hemicryptophytes	0.01	80.05 ± 7.33	78.23 ± 12.62	81.75 ± 11.61	ANOVA	F (df 2,28) = 0.27	0.763	
	10	78.85 ± 5.77	79.84 ± 12.64	79.82 ± 14.73	ANOVA	F (df 2,28) = 0.03	0.975	
Chamaephytes	0.01	0.24 ± 0.52	0.11 ± 0.34	0.47 ± 0.80	ANOVA	F (df 2,28) = 0.98	0.388	
	10	0.43 ± 0.71	0.05 ± 0.10	0.39 ± 0.44	H-Test	H (df 2, n = 31) = 6.08*	0.048	*[g>u: 0.083 (pc); m>u: 0.113 (pc)]*
Chamaephytes / Hemicryptophytes	0.01	3.00 ± 4.31	2.95 ± 6.20	0.97 ± 2.35	ANOVA	F (df 2,28) = 0.66	0.526	
	10	4.05 ± 3.34^A	1.91 ± 1.84	0.73 ± 1.12^B	H-Test	H (df 2, n = 31) = 9.99**	0.007	m>g**: 0.005 (pc)
Chamaephytes s. l.	0.01	3.25 ± 4.21	3.05 ± 6.15	1.44 ± 2.29	ANOVA	F (df 2,28) = 0.50	0.612	
	10	4.48 ± 3.14^A	1.96 ± 1.81	1.11 ± 1.10^B	H-Test	H (df 2, n = 31) = 9.01*	0.011	m>g**: 0.009 (pc)
Hemi- / Pseudo-Phanerophytes	0.01	1.25 ± 3.75	1.24 ± 3.92^A	6.72 ± 9.45^B	H-Test	H (df 2, n = 31) = 7.67*	0.022	g>u*: 0.025 (pc)
	10	2.07 ± 4.85	0.92 ± 1.82	5.47 ± 5.59	ANOVA	F (df 2,28) = 2.89	0.072	
Phanerophytes	0.01	0.17 ± 0.48	1.06 ± 1.88	0.00 ± 0.00	H-Test	H (df 2, n = 31) = 3.61	0.164	
	10	0.67 ± 0.82	2.18 ± 1.86	1.67 ± 2.19	ANOVA	F (df 2,28) = 2.15	0.135	
Others	0.01	0.31 ± 0.52	1.08 ± 2.66	0.24 ± 0.48	H-Test	H (df 2, n = 31) = 0.36	0.833	
	10	0.33 ± 0.46	0.11 ± 0.17	0.17 ± 0.38	ANOVA	F (df 2,28) = 1.01	0.376	

m: mown, **u**: unmown, **g**: grazed; mean proportion in the sum of species cover values with standard deviations are given (in %); different letters (superscript A, B) and different variations of grey indicate significant differences between the land use groups; F: F-value; df: degrees of freedom; H: H-value; n: sample size; p: probability value; B: Bonferroni; pc: pairwise comparisons; the significance level α is indicated by the following symbols: α < 0.01: highly significant (**), α = 0.01 - 0.05: significant (*); a: the probability value of the ANOVA is > 0.05, however, the p-value of the single case is < 0.05

Regarding geophytes, there are two significant differences in the mean cover proportion between the land use variants. At the 0.01 m^2 grain size, there is a significantly higher proportion of geophytes in the mown stands (11.77 %) compared to the grazed stands (4.46 %). The unmown stands have an intermediate position (7.58 %). On the larger spatial scale, the proportion of geophytes is highest in the unmown stands (4.92 %, mown: 4.54 %) and differs significantly from the grazed stands (1.97 %).

The cover proportion of the chamaephytes/hemicryptophytes is significantly higher in the mown than in the grazed stands (10 m^2-plot size, see Table 46). A contributing factor to this result is the high cover values of *Prunella grandiflora* in the mown stands. This species is an indicator species for regularly mown stands (see next chapter).

For both plot sizes, the hemi-/pseudo-phanerophytes have the highest cover proportion in the grazed stands and the smallest in the unmown stands (see Table 46). The difference between grazed and unmown stands is significant for the 0.01 m^2-plot size. For phanerophytes, the results show no significant differences between the land use variants. On the larger spatial scale, the highest cover proportion values occur in the unmown stands (2.18 %) followed by the grazed (1.67 %) and the mown stands (0.67 %, see Table 46).

5.3.6 Indicator species for land use types

The floristic composition was investigated only with regard to the occurrence of diagnostic species for the three land use variants (mown, unmown, grazed). The results shown in Table 47 indicate that there are between 11 and 21 indicator species for each land use type fulfilling the criteria of a phi-coefficient of association value ≥ 20.

Additional information shown in the table are the assignment of the species to phytosociological groups like dry grasslands, semi-dry grasslands, ruderal communities etc., the assignment as diagnostic species of three communities identified in the phytosociological study (*Brachypodio-Molinietum arundinaceae*, *Polygalo-Brachypodietum pinnati* and *Cirsium furiens-Brachypodium pinnatum*-community), and the life form.

Furthermore, species which are listed by Kuhn et al. (2021) as indicator species for mown (manually or mechanically) or grazed (extensively or intensively) *Cirsio-Brachypodion* grasslands in the SCI ‘Eastern Hills of Cluj’ are marked with (K), some of the plots being located in the three *utilised hay meadows* surveyed in this thesis.

The diagnostic species differ between the two studied spatial scales and there are only a few overlaps. The species identified as diagnostic for both plot sizes for the mown stands are *Rhinanthus rumelicus, Prunella grandiflora, Agrostis capillaris* and *Leucanthemum vulgare.* For the unmown stands *Dichoropetalum carvifolia* and for the grazed stands *Agrimonia eupatoria* are identified as diagnostic.

Species that are highly diagnostic (fidelity value ≥ 45) for regular mowing are *Rhinanthus rumelicus, Prunella grandiflora, Ferulago sylvatica, Tragopogon pratensis* subsp. *orientalis* and *Crepis biennis*. Three species are highly diagnostic for the abandonment of mowing: *Dichoropetalum carvifolia, Cirsium pannonicum* and *Carex michelii.* Finally, the highly diagnostic indicator species for grazing are *Daucus carota, Carex distans, Cirsium furiens, Agrimonia eupatoria, Xeranthemum cylindraceum* and *Carlina vulgaris* (see Table 47). The specifications for highly diagnostic species all refer to the 10 m^2 plot size, as the phi-coefficient values in the small plots only range between 21 and 39.

Table 47: Indicator species for land use types

	Fidelity value		**Assignment to phytosociological groups**						**Diagnostic for communities**			**Life form**
	0.01 m^2	10 m^2	dry grasslands	semi-dry grasslands	C *Mol.-Arrh.* / Ord. *Mol.*	Ord. *Arrh.* / All. *Arrh.*	C *Trifolio-Geranietea*	ruderal communities	*Brachypodio.-Molinietum*	*Polygalo-Brachyp.*	*Cirs. furiens.*-community	
mown												
Trifolium montanum (K)	37			x					x	x		H
Viola hirta	35			x						x	x	H
Carex montana	29			x						x		H
Salvia pratensis (K)	29			x		x				x		H
Leontodon hispidus	25			x		x						H
Ranunculus polyanthemos (K)	25			x					x	x	x	H
Luzula campestris	25			x		x						H
Origanum vulgare	25						x			x		H
Onobrychis viciifolia (K)	22			x							x	H
Cruciata glabra (K)	21			x						x		H
Rhinanthus rumelicus	33	67		x						x[C]		Th
Prunella grandiflora	32	58		x						x		Ch/H
Agrostis capillaris	39	41		x		x						H
Leucanthemum vulgare (K)	22	36		x		x			x			H
Ferulago sylvatica		53					x			x		H
Tragopogon pratensis subsp. *orientalis*		49				x				x		H
Crepis biennis		45				x						H
Tristeum flavescens		44		x		x				x		H
Campanula glomerata		41		x						x		H
Dianthus carthusianorum		41		x						x		H
Scabiosa ochroleuca (K)		40		x						x		H
Number (21 total)	14	11		17		8	2		3	15	3	
Percent (multiple assignments possible)				*81*		*38*	*10*		*14*	*71*	*14*	
unmown												
Securigera varia	36						x			x	x	H
Filipendula vulgaris	31			x			x					H
Peucedanum oreoselinum	26						x					H
Ononis spinosa subsp. hircina	22			x								H
Dichoropetalum carvifolia	26	56					x		x			H
Cirsium pannonicum		54		x						x[C]		H
Carex michelii		45		x						x[C]		H
Salvia pratensis		42		x		x				x		H
Geranium sanguineum		41					x			x		H
Centaurea scabiosa		39		x						x		H
Centaurea phrygia		39				x	x			x		H
Number (11 total)	5	7		6		2	6		1	7	1	
Percent (multiple assignments possible)				*55*		*18*	*55*		*9*	*64*	*9*	
grazed												
Thymus pulegioides subsp. *pannonicus*	35		x									Hemi-Ph.
Achillea millefolium (K: *A. collina*)	32					x		x				H
Plantago lanceolata (K)	30				x						x	H
Veronica austriaca	28						x			x	x	Ch
Fragaria viridis (K)	26			x					x		x	H
Agrimonia eupatoria (K)	26	50		x			x				x[C]	H
Daucus carota		73						x			x	H
Carex distans		62			x							H
Cirsium furiens		56						x			x[C]	H
Xeranthemum cylindraceum (K)		47	x					x				Th
Carlina vulgaris (K)		47						x			x	H
Linum perenne		44		x							x	H
Medicago lupulina		41		x							x	Th/H
Euphorbia esula		39						x	x		x	G/H
Number (14 total)	4	9	1	4	2	0	2	5	2	1	10	
Percent (multiple assignments possible)			*7*	*29*	*14*	*0*	*14*	*36*	*14*	*7*	*71*	

Fidelity measure: phi-coefficient of association (presence/absence); only significant phi-coefficient values were considered (Fisher's exact test, $p > 0.05$); (K): concordant indication as mowing / grazing indicator species by Kuhn et al. (2021); C: class; *Mol.-Arrh.: Molinio-Arrhenatheretea;* O: order; *Mol.: Molinietalia; Arrh.: Arrhenatheretalia;* All.: alliance; *Arrh.: Arrhenatherion;* x[C] = association character species; H: hemicryptophyte; Th: therophyte; Ch/H: chamaephyte / hemicryptophyte; Ch: herbaceous chamaephyte; Hemi-Ph.: hemi-phanerophyte; Th/H: therophyte / hemicryptophyte; G/H: geophyte / hemicryptophyte

A comparison of the indicator species identified here with the indicator species listed by Kuhn et al. (2021) shows the following similarities and differences: From the 25 indicator species for mown grasslands identified by Kuhn et al. (2021), seven correspond to indicator species for mown stands found in this study (indicated in Table 47).

One of the indicator species listed by Kuhn et al. (2021) for mown grasslands is an indicator for the unmown stands here (*Ononis spinosa*), and another species characteristic for mown grasslands in the study of Kuhn et al. (2021) is found to be an indicator for grazed stands here (*Medicago lupulina*). From the 15 indicator species for grazed grasslands identified by Kuhn et al. (2021), six correspond to indicator species for grazing found in this study.

The assignment to phytosociological groups based on the diagnostic species for both spatial scales is described in the following. The diagnostic species for the mown and unmown stands belong in either case to three groups:

- Semi-dry basiphilous grasslands of the order *Brachypodietalia pinnati* or alliance *Cirsio-Brachypodion pinnati*
- Mesic grasslands of the order *Arrhenatheretalia elatioris* or alliance *Arrhenatherion elatioris*
- Thermophilic herb fringe communities of the class *Trifolio-Geranietea*

The mown and unmown stands differ in the proportion of species in the respective sociological groups. In the mown stands, 81 % of the 21 diagnostic species belong to the group of semi-dry basiphilous grasslands, 38 % to the mesic meadows and 10 % to the fringe communities (multiple assignments possible; see Table 47).

In the unmown stands, only 55 % of the 11 diagnostic species belong to the group of semi-dry basiphilous grasslands, and the amount of thermophilic fringe species has increased also to 55 % (multiple assignments possible). The proportion of diagnostic species of mesic meadows amounts to 18 %.

The stands which had been grazed for at least five and up to 15 years contain diagnostic species not only of three, but six sociological groups. The spectrum is expanded by dry grasslands (*Thymus pulegioides* subsp. *pannonicus*, *Xeranthemum cylindraceum*), the class *Molinio-Arrhenatheretea* (*Plantago lanceolata*) as well as ruderal communities (e.g. *Daucus carota, Cirsium furiens*, see Table 47). The diagnostic species *Carex distans* was assigned to the order *Molinietalia*; it often grows on saline soils (Ciocârlan 2000).

The species of basiphilous semi-dry grasslands account for only 29 % of the diagnostic species in the grazed stands. The largest sociological group is formed by the species of ruderal communities with 43 %. The other groups contain between 7 and 14 % of the diagnostic species (multiple assignments possible; see Table 47).

Some of the diagnostic species for the grazed stands have properties which render them unpalatable for livestock, like spiny or thistle-like growth forms (e.g. *Cirsium* *furiens, Carlina vulgaris*), toxicity (*Euphorbia esula*) or high content of essential oils (*Thymus pulegioides* subsp. *pannonicus*). Furthermore, there are also epizoochorous diagnostic species like *Daucus carota* and *Agrimonia eupatoria*.

Most of the diagnostic species of the three land use variants are hemicryptophytes, except for *Rhinanthus rumelicus* and *Prunella grandiflora* in the mown stands and five species in the grazed stands (see Table 47), which thus show the greatest life form diversity of the diagnostic species.

Regarding the correspondence between diagnostic species for land use types and the diagnostic species for three plant communities identified in the phytosociological study, there is a clear pattern. Both the mown and unmown stands show a significantly higher percentage of diagnostic species for the *Polygalo-Brachypodietum pinnati* (mown: 71, unmown: 64) than for the *Brachypodio-Molinietum arundinaceae* (mown: 14, unmown: 9) or the *Cirsium furiens*-community (mown: 14, unmown: 9). Among the diagnostic species there are also three association character species of the *Polygalo-Brachypodietum pinnati* (*Rhinanthus rumelicus* in the mown stands and *Cirsium pannonicum* and *Carex michelii* in the unmown stands).

In contrast, in the grazed stands 71 % of the diagnostic species are also diagnostic for the *Cirsium furiens*-community, and only 14 % for the *Brachypodio-Molinietum arundinaceae* and 7 % for the *Polygalo-Brachypodietum pinnati*. Among the species diagnostic for the grazed stands there are two species named by Dengler et al. (2012) as diagnostic for the informal *Cirsium furiens*-community, namely *Agrimonia eupatoria* and *Cirsium furiens*.

5.4 Discussion and outlook

5.4.1 Reasons for extremely high species richness

The hypothesis that the grasslands of the study meadows reach similar vascular plant richness values as the extremely species-rich semi-dry grasslands in several regions at the foothills of the Carpathians and some wooded meadows in Estonia (Dengler et al. 2014) was confirmed. This is exemplified by one of the worldwide highest values of small-scale vascular plant species richness on 0.01 m^2 (26 species).

The mean richness values on 10 m^2 of 59 species considering all relevés, and 67 species considering only the mown stands, are comparable with the mean values of the very species-rich *Cirsio-Brachypodion* grasslands from the foothills of the Ukrainian Eastern Carpathians (54-57 species / 10 m^2) and the White Carpathians in the Czech Republic (62 species / 10 m^2) (Roleček et al. 2014). However, they are slightly lower than the highest mean values indicated for Transylvania (74-85 species / 10 m^2) (Dengler et al. 2012; Roleček et al. 2014).

The species richness findings complement the results from Chapter 3, which confirm the occurrence of the *Brachypodio-Molinietum arundinacea* and related communities like the *Polygalo-Brachypodietum pinnati* in the meadows. These communities are closely linked to the occurrence of the highest species richness values in the peri-Carpathian region (Roleček et al. 2014) and also have many species in common with the extremely species-rich *Laelatu* wooded meadows in Estonia, for example *Campanula glomerata, Filipendula vulgaris, Leucanthemum vulgare* agg., *Molinia caerulea* agg., *Primula veris* and *Serratula tinctoria* (Roleček et al. 2014). This similarity supports concepts of species coexistence based on species pool theories (Roleček et al. 2014).

Furthermore, a long continuity of regular extensive mowing management seems to play an important role at all sites with the highest richness values. In general, temporal continuity of grassland management seems to be linked to a higher biodiversity and to a higher number of grassland specialists (see e.g. Feurdean et al. 2018, Kuhn et al. 2021). Aavik et al. (2008) for example could show for wooded meadows in Estonia that the positive effects of mowing on plant species diversity are additionally enhanced by the continuity of the constant extensive mowing regime.

More detailed considerations on several concepts of species coexistence, which may be important in the studied hay meadows to achieve high richness values, are presented in the following. They are partly based on the information provided by the authors mentioned below about the other sites of extremely high species richness, and supplemented with personal observations:

- Presumed large size of the species pool for the following reasons (compare Zobel 1992; Dengler et al. 2014; Roleček et al. 2014):
  - Evolutionary factors

    The climatic conditions of the study area, such as the relatively cold and humid meso-climate compared to other sites with *Festuco-Brometea* grasslands (Roleček et al. 2014), intermediate levels of soil moisture (compare Fajmonová et al. 2020 for the White Carpathians) and other site conditions like deep, clayey soils (Roleček et al. 2014) enable the occurrence of species with a relatively wide ecological range, from drought-adapted to more moisture demanding species (Roleček et al. 2014). The transitional biogeographical position between the Central European Floristic Region and the Pontic-South Siberian Floristic Region also contributes to the existence of a large species pool (see Chapter 3.3.11.2).
  - Historical factors

    The presumed long existence of open land vegetation (see Chapter 4.3.1.2.3) may have led to the 'accumulation of suitable species that migrated through the region in consequence of changing climate', and a lower risk of local extinction (Dengler et al. 2014). Similarly, a large pool of species adapted to regular cutting may have accumulated due to at least 140 years of use as hay meadows.
- Concepts of landscape and land use heterogeneity:
  - Edge effect

    The study hay meadows are in large part characterized by a small-scale mosaic of different interlocking vegetation types, so that many transition areas arise. Each transition from one vegetation type to another creates an edge effect through the overlapping of species on both sides, and there is often a particularly high species diversity in the transition areas (Dierschke 1994). If and to what extent the edge effect actually contributes to the extremely high vascular plant species richness remains to be determined.
  - Vicinism

    The vegetation mosaic of the hay meadows caused by morphological heterogeneity, differences in soil moisture etc., but also landscape heterogeneity on a larger scale, where the meadows are (still) surrounded by other types of grasslands, shrubberies, forest edges, etc., can increase the grassland species density through the effect of vicinism (Dengler et al. 2014). Vicinism, sometimes also called mass effect, is defined as the 'occurrence of plant species in a less favourable environment […] as a result of the continuous supply of propagules from neighbouring areas' (Zonnefeld 1995).

    Therefore, the mosaic of mown, not-yet-mown and temporarily fallow patches in the large meadows which has characterized the traditional meadows during long periods, could also have an important positive effect on plant species richness through the effect of vicinism.

- Reduction of asymmetric competition:

  One of the most important factors of mowing is the reduction of asymmetric competition for light and soil resources through the removal of biomass and litter. This supports low-growing, shade-intolerant and other poorly competitive species (Zobel 1992; Dengler et al. 2014), for example by reducing the likelihood of their local extinction (Lepš 1999), leading to a higher species richness.

  Dengler et al. (2014) provide a further explanation for the higher plant species richness of meadows compared to pastures; the 'equalizing effects' of mowing, where 'all species experience a similar biomass reduction', whereas grazing affects the plant species to different extents. They also assume that mowing could lead to negative frequency dependence as a stabilizing mechanism of species diversity (Fox 2013), since 'dominant species lose proportionally more of their superficial biomass through a cut than small, low-grown ones'.

  Secondly, the resources nutrients and water are also limited, for example through the absence of fertilisation and the particular soil conditions in the meadows. This can prevent the dominance of highly competitive species and allow the coexistence of slower-growing, less competitive species (Leuschner and Ellenberg 2017).

- Other management-related factors:

  The tradition of spring and autumn grazing by cattle or sheep has likely also contributed to the high species richness in the study meadows (see e.g. Janišová et al. 2023). For instance, the hooves of livestock can create gaps and therefore regeneration niches for seeds in the sward (Gamble and St. Pierre 2010; Pinches et al. 2013), while grazing can prevent competitive and tussocky grass species from dominating (Crofts and Jefferson 1999; Gamble and St. Pierre 2010).

  Another traditional management aspect which could have contributed to the high plant diversity is the strewing and turning of the hay in the field, through which the seeds could fall to the ground again (Gamble and St. Pierre 2010).

5.4.2 Impact of land use change

The research hypotheses could be confirmed; there are differences between the mown, unmown, and grazed basiphilous semi-dry grasslands regarding vascular plant diversity, vegetation structure and functional groups as well as the floristic composition.

The finding that mown stands have higher plant richness values than the formerly mown, now abandoned, or grazed stands is consistent with several findings from literature. Kuhn et al. (2021) for instance found for *Cirsio-Brachypodion* grasslands in the SCI 'Eastern Hills of Cluj' that the highest plant richness values were recorded in mown stands. Furthermore, the grasslands *intensively* grazed by sheep had significantly lower species richness values than abandoned, mown or *extensively* grazed grasslands.

Similar results are shown by Turtureanu et al. (2014) for plant species richness on 10 m^2 in basiphilous dry and semi-dry grasslands in different parts of the Transylvanian

Plateau, mostly in protected areas, where the mown stands showed the highest richness values compared to the grazed and unused stands.

In contrast, Roleček et al. (2021) report that the switch of management from mowing to medium-intensity sheep grazing of the meadow steppes in the ‚Hay Meadows of Cluj' nature reserve had increased the species richness of the world-record plot from 98 to 115 vascular plant species between the years 2009 and 2021. However, the reason for this increase was mainly a higher number of ruderal species like *Capsella bursa-pastoris*, *Daucus carota*, *Equisetum palustre, Carduus acanthoides,* and *Xeranthemum cylindraceum* (Roleček et al. 2019; Roleček et al. 2021), and a decrease in species richness was expected over time due to the decline of grazing-sensitive species (Roleček et al. 2021).

The lower mean Shannon index and mean evenness of the grazed stands compared to the mown and unmown stands at the grain size 10 m^2 also finds correspondences in literature. Kuhn et al. (2021) for example observed that grazed stands had significantly lower Shannon index values than traditionally mown stands and *intensively* grazed stands had significantly lower evenness values than traditionally mown stands (plot size 16 m2).

Fischer and Wipf (2002) detected that the evenness of the meadow stands decreased with time since conversion to pastures for non-lactating cows by the value of -0.11 for subalpine hay meadows called Mähder near Davos (Switzerland); however, this finding was for a period of 50 years (plot size 16 m^2). Csergö and Demeter (2011a) obtained lower evenness values in grazed grasslands versus mown or abandoned (but previously mown) grasslands in the Romanian Eastern Carpathians, yet the difference was not significant (plot size 1 m^2).

The results obtained in this study are interpreted such that it is indeed mainly the land use change that has led to a decrease in species richness and evenness, at least for grain sizes 0.1 m^2 and above. This is supported by the results from Turtureanu et al. (2014) who found that for grain sizes of 0.1 m^2 to 100 m^2 land use was one of the best predictors for plant species richness. Interestingly, 0.1 m^2 is the plot size above which the differences in richness values between mown and unmown stands are significant in this study as well.

Other important predictors of plant species richness found by Turtureanu et al. (2014) were humus content at the grain sizes 0.0001 m^2 to 0.1 m^2, litter cover (0.01 m^2 to 10 m^2), heat load index (1 m^2 and 10 m^2) and microrelief (0.1 m^2 to 100 m^2).

In the following, conclusions will be drawn from the results about which factors might have led to the changes in plant species richness and evenness in the meadows affected by abandonment and grazing, and which changes in vegetation structure and floristic composition are taking place.

To provide an overview, the most important results of the hypothesis tests as well as the diagnostic species are summarized in Table 48. The arrows in the table indicate differences of the unmown and grazed stands compared to the mown stands, in each case for the 0.01 m² and 10 m² plot size. Bold yellow arrows indicate significantly smaller and bold blue arrows signficantly higher values compared to the mown stands.

Table 48: Summary of the most important differences between mown and abandoned / grazed meadow stands

		Mowing abandonment		Grazing		
		0.01 m²	10 m²	0.01 m²	10 m²	
Diversity	Species richness	↘	**↘**	**↘**	**↘**	Species richness
	Evenness	—	—	—	**↘**	Evenness
Vegetation structure	Total cover vegetation	↘	—	↗	—	Total cover vegetation
	Cover of bryophytes	↘	**↘**	↗	↗	Cover of bryophytes
	Cover of bare ground	↘	↗	↗	**↗**	Cover of bare ground
	Cover of litter	↗	—	—	↘	Cover of litter
	Depth of litter	↗	↗	↗	—	Depth of litter
	Height upper h&g layer		↗		**↘**	Height upper h&g layer
	Height lower h&g layer		↗		**↘**	Height lower h&g layer
Guilds and life forms	Share of graminoids	↘	—	**↗**	**↗**	Share of graminoids
	Share of forbs	↗	—	**↘**	**↘**	Share of forbs
	Share of therophytes	**↘**	**↘**	↘	**↘**	Share of therophytes
	Share of geophytes	↘	—	**↘**	↘	Share of geophytes
	Share of chamaephytes / hemicryptophytes	—	↘	↘	**↘**	Share of chamaephytes / hemicryptophytes
	Share of hemi-phanerophytes	—	↘	↗	↗	Share of hemi-phanerophytes
Floristic composition	Diagnostic species	*Securigera varia, Filipendula vulgaris, Dichoropetalum carvifolia, Peucedanum oreoselinum, Ononis spinosa* subsp. *hircina*	*Dichoropetalum carvifolia, Cirsium pannonicum, Carex michelii, Salvia pratensis, Geranium sanguineum, Centaurea scabiosa, Centaurea phrygia*	*Thymus pulegioides* subsp. *pannonicus, Achillea millefolium, Plantago lanceolata, Veronica austriaca, Fragaria viridis, Agrimonia eupatoria*	*Agrimonia eupatoria, Daucus carota, Carex distans, Cirsium furiens, Xeranthemum cylindraceum, Carlina vulgaris, Linum perenne, Medicago lupulina, Euphorbia esula*	Diagnostic species

The arrows refer to differences compared to the mown stands: the arrows point up or down if the values differ more than 10 % from the values in the mown plots, a smaller difference is indicated by a horizontal line. Bold arrows indicate statistically significant differences compared to the mown stands (yellow: smaller values, blue: higher values). Empty cells stand for values not surveyed. The parameters mentioned refer to mean values; the diversity parameters refer to vascular plant species diversity. h&g = herbs and grasses

The cessation of mowing automatically results in a lack of periodic exposure to light during the summer period, which was previously ensured by regular cutting. This increases competition for light, which in turn allows species that can compete better for light to become more dominant. These are, for example, tall species, such as the indicator species for the unmown stands *Dichoropetalum carvifolia* and *Peucedanum oreoselinum* (see Table 48).

By changing the availability of limiting resources and thus shifting the competition towards species with high growth rate and effective vegetative reproduction (Dierschke and Briemle 2008), one would also expect a decrease in evenness to follow. A possible explanation for the constant evenness in the examined dataset is that the recorded period of abandonment is too short.

The fact that some species of the original species assemblage of the mown meadows are absent in the unmown stands, i.e. the plant species richness is lower, could be explained by the failing colonization of light-demanding species and other weak competitors due to the absence of suitable microsites, for example. This is supported by the measured increase in litter layer thickness and cover as well as the greater height of the vegetation (neither significant, see Table 48).

One group of species possibly affected by these changes are the therophytes. In total, 10 therophyte species occur in the recorded diversity relevés (5 % of the 102 species found), some of them only in one or two relevés, like *Camelina microcarpa* or *Euphrasia pectinata*. The low proportion of therophytes in the studied stands is common for semi-dry grasslands, where therophytes are rarely able to establish (Leuschner and Ellenberg 2017).

Mowing abandonment and grazing of the traditional study hay meadows reduces the already low proportion of therophyte cover even further, especially for the species *Rhinanthus rumelicus*, which is one of the best indicator species for the mown stands. In the unmown stands the species is less common, and it is absent from the grazed stands. Interestingly, five of the six therophyte species found in the mown or unmown (but not in the grazed) stands are holoparasites (*Cuscuta epithymum*) or hemiparasites (*Rhinanthus rumelicus, Rh. minor, Melampyrum cristatum and Euphrasia pectinata*).

In the unmown stands, the lower proportion of therophytes may be explained by the already mentioned higher cover and greater thickness of the litter layer, and furthermore by a lack of gaps created by mowing, allowing seeds to germinate and seedlings to establish. The increase in litter layer depth and height of the vegetation could also play a role in the significantly lower bryophyte layer cover in the unmown stands versus mown stands. Similarly, Peintinger & Bergamini (2006) show that bryophyte biomass is negatively correlated with litter mass and vascular plant biomass in mown and abandoned pre-alpine calcareous fens.

In summary, it can be deduced that vascular plant species richness seems to decrease more rapidly after mowing abandonment than the evenness, that is, species disappear from the stands before disentanglement takes place and higher dominance ratios of individual species eventually occur.

Regarding the diagnostic species, in the unmown stands a decrease in the *Arrhenatherion / Arrhenatheretalia* species, which are generally more tolerant to mowing, and a clear increase in the generally more mowing-sensitive *Trifolio-*

Geranietea species can be observed. Many of these fringe species belong to the characteristic species composition of the semi-dry grassland communities a priori (Chytrý et al. 2007; Coldea et al. 2012). The number of *Cirsio-Brachypodion* species is declining. However, the diagnostic species continue to belong to the same three sociological groups, like in the mown stands.

Sheep grazing during a period of at least five years with simultanous abandonment of mowing resulted in a significant increase in bare ground cover in the grazed stands (see Table 48). This can most likely be explained by livestock trampling leading to gaps in the vegetation cover, for instance by removal of dead biomass or erosion (Csergö & Demeter 2011a). Browsing can additionally lead to gaps by damaging the plants.

The higher occurrence of bare ground in the *former hay meadows* apparently did not lead to an increased cover of therophytes, as one could expect (see also Briemle et al. 2002). The lower cover proportion of therophytes in the unmown and grazed stands may also be influenced by the possible changed conditions for the host species of the many parasitic therophytes found therein. In contrast, the proportion of semi-woody dwarf shrubs increased in the grazed stands. According to Briemle et al. (2002), these usually have elastic branches that do not break so easily when exposed to trampling, what could give them an advantage over the more sensitive species.

The proportion of graminoids has increased in the grazed stands compared to the mown stands, at the expense of forbs, probably mainly species sensitive to grazing and trampling. Similar results were found by Fischer and Wipf (2002) for subalpine meadows in Davos (Switzerland), where the cover of graminoids increased by 14 % in grazed stands compared to mown stands (after a period of 50 years). The higher vegetation cover in the grazed stands at the 0.01 m^2-scale could also be explained by the higher cover of graminoids, which can form dense swards.

The highest cover of the bryophyte layer in grazed stands is consistent with findings from literature. For instance, Boch et al. (2018) found that in mesic grasslands in three different regions in Germany the bryophyte cover was about twice as high in pastures than in meadows and mown pastures. Explanations for this pattern are manifold; for example, higher light availability at the soil surface, open patches suitable for bryophyte colonization, or more suitable substrates like stones and deadwood in pastures, etc. (Boch et al. 2018). Similar factors probably led to the fact that lichens were only found in the grazed stands.

The observed decrease in species richness is probably mainly due to the absence of species present in the originally mown stands, which are sensitive to grazing and trampling. This also applies to highly palatable species, for example species of mesic meadows like *Arrhenatherum elatius* or *Trisetum flavescens*, whose group has the lowest proportion of diagnostic species here. Possible explanations for the reduction of evenness through grazing could be uneven nutrient depositions followed by exclusion processes (Csergö and Demeter 2011a), or a proliferation of unpalatable species.

It seems that, with the start of grazing, the semi-dry grasslands of the traditional meadows will progress from a clear profile of three sociological groups (semi-dry grasslands, mesic grasslands, fringe communities) to a melange of multiple sociological groups, as far as one can tell from the list of diagnostic species. This is accompanied by a loss of typical species of basiphilous semi-dry grasslands and an increase in common species such as *Plantago lanceolata* or *Achillea millefolium,* as well as species of ruderal communities. The results suggest that the plant community *Polygalo-Brachypodietum pinnati*, which presumably originally had the largest proportion in area of the semi-dry meadow vegetation, is transformed by grazing into other communities like the *Cirsium furiens-Brachypodium pinnatum*-community.

The results of this part of the thesis indicate that in the long term only regular mowing can preserve the extremely high species richness and typical species composition which characterize the semi-dry grassland vegetation of the traditional hay meadows in the study area. Short-term abandonment of mowing results in a decrease of vascular plant species richness and a shift in species composition within the typical species inventory of the *Polygalo-Brachypodietum pinnati*. This suggests that stands that have not been mown for short periods can possibly be transformed back into stands with the typical structure and species composition of the regularly mown *Polygalo-Brachypodietum pinnati*.

5.4.3 Discussion of the methodology

The impact of different land use types on the vegetation can be examined through an experimental approach or by recording the actual management in the field. During an experiment, one has control over the main influence factors and thus a more secure data basis.

However, it is challenging to apply the experimental approach in the study meadows, especially protecting plots against grazing (in the mowing / abandonment of mowing-land use variant), but also to determine the exact grazing pressure. This is because grazing is often still carried out as unregulated shepherding without enclosure of the land, and because large parts of the semi-abandoned meadows are grazed without explicit permission of the owners.

The data collection in this thesis was flanked by many discussions with the land users about the current and former management of the meadows (see also Chapter 4). The knowledge gathered in the process helped to assess which options for collecting land use data would be possible.

The approach that was finally chosen in this thesis was to use the maps of the mown areas surveyed for the land use study (see Chapter 4.3.3.1.1), a data source, which is very accurate regarding the presence or absence of mowing. An unknown factor is the extent to which these stands were also grazed for short periods, but this factor is likely distributed evenly across both mown and unmown stands.

A limitation to the data collection arose from the fact that the information on presence or absence of mowing was only available for two or three years prior to the data collection, and these variants were compared with a longer period of grazing (5-15 years). Furthermore, the variants mown / not mown during two or three years and grazing since five or 15 years were analysed together to obtain enough data.

If the study were to be repeated, it would be desirable to have a higher number of replicates per land use variant and hay meadow, and more precise data on the grazing management. Furthermore, it would be important to obtain land use data over a longer period, especially a longer period of mowing abandonment.

5.4.4 Outlook

This study design used in this thesis could be complemented with the following aspects: The survey of data on non-vascular plant species would provide information about a further component of biodiversity. Additionally, data about the humus content could be recorded, which is important for plant species diversity at the finest scales (Turtureanu et al. 2014).

Regarding the nested-plot series, it would be interesting (but more time-consuming) to collect species cover data for the 0.1 m^2 or 1 m^2 plot sizes to investigate how the evenness and other quantity-dependent parameters vary across these spatial scales.

The data analysis presented here is limited, apart from determining the diagnostic species and the maximum values of diversity, to testing whether there are differences regarding several parameters between mown, unmown, and grazed meadow stands. A further step would be to carry out regression analyses to find models between dependent variables (e.g. species richness) and independent variables (e.g. land use, environmental parameters).

An example of such an analysis can be found in the publication by Turtureanu et al. (2014), who calculated the relationship between plant species richness and land use / environmental parameters with a dataset of nested plots using generalised linear models.

Further analysis options for the available data are the determination of species-area relationships and of z-values as a measure of beta-diversity (see for example Dengler 2009 and Dembicz et al. 2021). With vegetation data containing several replicates of smaller plot sizes the spatial heterogeneity of floristic, structural and abiotic parameters can be assessed too (Dengler 2009).

In addition to the examined differences regarding functional groups (graminoids, forbs, legumes) and species traits (life form), the differences concerning numerous other traits can be examined (e.g. type of vegetative propagation, strategy type, etc.). The traits can also be analysed as components of diversity (Dengler 2009). Furthermore, the mean Ellenberg indicator values and grassland utilisation indicator values of the mown, unmown, and grazed grasslands could be compared with each other.

With the collection of further data, the impact of land use change on vegetation and diversity of other plant communities could be assessed. Another interesting aspect would be to compare the vegetation and plant diversity of the ‘new’ pastures, that is, grazed *former hay meadows*, with those of the old sheep pastures, that is, areas that were traditionally used as pasture in the study area, mostly as (former) common pastures.

As land use changes have persisted since the 2012-2013 data collection, and sheep grazing has expanded and intensified, it would be important to examine the current status of the vegetation of the *utilised* and *former hay meadows* and compare it with the data presented here. The longer-reaching influence of mowing abandonment and grazing on the traditional hay meadows could be assessed in this way.

Finally, the diagnostic species for the mown, unmown, or grazed meadows can be taken as indicator species to assess the condition of individual parts of the meadow vegetation and thus be used, for example, in monitoring.

5.5 Summary Chapter 5

In this survey the hypothesis that mown *Cirsio-Brachypodion pinnati* stands differ from unmown or grazed stands regarding their plant diversity, vegetation structure and selected functional groups as well as floristic composition was examined. Furthermore, the suspicion that the basiphilous semi-dry grasslands of the study hay meadows have vascular plant richness values similar to those with the highest species richness values in Europe was confirmed.

The data was collected in summer 2012 and 2013 in the Village Meadow (Dăbâca commune, 9 plots) and the Great Meadow (Borşa commune, 12 plots) as well as one former hay meadow per commune, which were used as rough pastures at the time of data collection (10 plots). The diversity relevés were carried out on meadow areas assigned to three different land use variants: In the Village and Great Meadow regular mowing and absence of mowing was surveyed, while in the former meadows the recorded variant was grazing. The mown plots had previously been mapped over several years.

More exactly, the variant ‘regularly mown’ meant mown in the two or three years before sampling, and the variant ‘unmown’ accordingly meant not mown in the two or three years before sampling. The variant ‘grazed’ was applied to areas not mown and grazed by sheep for around five or 15 years before sampling. The grazing intensity was assumed to be extensive to highest semi-extensive and the stocking rate was irregularly distributed over the area.

The assignment of the plots to basiphilous semi-dry grasslands was based on the presence of the four species *Brachypodium pinnatum, Ranunculus polyanthemos, Trifolium montanum* and *Centaurea scabiosa*. The diversity relevés were classified afterwards as belonging to the *Polygalo-Brachypodietum pinnati* (19 relevés) and the *Cirsium furiens-Brachypodium pinnatum*-community (12 relevés).

The survey method was a standardised sampling approach based on nested-plot series described by Dengler (2009). The largest of the nested plots was sized 10 m^2 and contained smaller sub-plots of 1 m^2, 0.1 m^2, 0.01 m^2 and 0.001 m^2, which were replicated 3-fold and evenly placed in the outer corners of the larger plot. In all the (sub-)plots a complete list of the vascular plant species was recorded and in the 0.01 m^2-plots and 10 m^2-plots species dominance (cover value in percentage, vertical projection) was estimated. Furthermore, parameters of vegetation structure were recorded in the 10 m^2-plots, in part also in the 0.01 m^2-plots.

For the analysis, usually the median value of the three replicates for each sub-plot size was used. Parametric and non-parametric statistical tests were applied to check the hypotheses. The dependent variables were species richness, Shannon index, evenness, several vegetation structure parameters and the proportion in the cumulated species cover for the three functional groups graminoids, forbs and legumes as well as for life form categories based on Raunkiaer's system. For the identification of diagnostic species for the three land use variants, the statistical fidelity measure phi-coefficient of association was used.

These methods confirmed that the grasslands of the study meadows reach similar vascular plant richness values to the extremely species-rich semi-dry grasslands in several regions at the foothills of the Carpathians and some wooded meadows in Estonia, for example a mean richness value at the 10 m^2 scale of 59 species when all relevés are taken into account, and 67 species if only the mown stands are considered. Furthermore, one of the worldwide highest values of small-scale vascular plant species richness on 0.01 m^2 (26 species) was found in one of the mown *Polygalo-Brachypodietum pinnati* stands.

This finding confirms the close link of the *Brachypodio-Molinietum arundinacea* and related communities like the *Polygalo-Brachypodietum pinnati* as well as of certain species like *Filipendula vulgaris, Molinia caerulea* agg., *Primula veris* and *Serratula tinctoria* to the occurrence of the highest species richness values in the peri-Carpathian region, supporting concepts of species coexistence based on species pool theories. Furthermore, a long continuity of regular extensive mowing management seems to play an important role at all of the sites with the highest richness values.

Extensive mowing can enhance species coexistence, especially by reduction of asymmetric competition for light and soil resources through the removal of biomass and litter, which supports low-growing, shade-intolerant and other poorly competitive species, for example by reducing the likelihood of their local extinction. The presumed long existence of open land vegetation may have led to the accumulation of suitable species and a lower risk of local extinction. Similarly, a large pool of species adapted to regular cutting may have accumulated due to the long use as hay meadows.

Other factors which could have contributed to the high species richness are the transitional biogeographical position of the study area and the climatic and soil conditions, which enable the occurrence of species with a relatively wide ecological range. Furthermore, the landscape and land use heterogeneity could play a role, as well as the tradition of spring and autumn grazing of the meadows.

Secondly, the research hypotheses that there are differences between the mown, unmown, and grazed basiphilous semi-dry grasslands regarding vascular plant diversity, vegetation structure and functional groups, as well as the floristic composition, could also be confirmed.

The results indicate that the mown stands have significantly higher mean richness values compared to the grazed stands for all plot sizes (0.001 m^2 – 10 m^2) and significantly higher mean richness values compared to the unmown stands for the plot sizes 0.1 m^2, 1 m^2 and 10 m^2. For example, on 10 m^2, the mown stands harbour on average 67 species, while both the unmown and grazed stands have on average 55 species; for 1 m^2 the numbers are 41 versus 32 (unmown) / 34 species (grazed) and for 0.1 m^2 the numbers are 27 versus 20 (unmown / grazed). The results obtained in this study are interpreted such that it is indeed mainly the land use change that has led to a decrease in species richness, at least for plot sizes of 0.1 m^2 and above, as supported by other studies.

The fact that the plant species richness is lower in unmown versus mown stands could be explained by the failing colonization of light-demanding species and other weak competitors due to the absence of suitable microsites, for example. This is supported by the measured increase in litter layer thickness and cover, as well as the greater height of the vegetation (neither significant).

Mowing abandonment and grazing of the studied traditional hay meadows reduces the already low proportion of therophyte cover even further, especially for the species *Rhinanthus rumelicus*, which is one of the best indicator species for the mown stands. Interestingly, five of the six therophyte species found in the mown or unmown (but not in the grazed) stands are holoparasites (*Cuscuta epithymum*) or hemiparasites (*Rhinanthus rumelicus, Rh. minor, Melampyrum cristatum and Euphrasia pectinata*).

The observed decrease in species richness through grazing is probably mainly due to the absence of species present in the originally mown stands, which are sensitive to grazing and trampling. This also applies to highly palatable species, for example species of mesic meadows like *Arrhenatherum elatius* or *Trisetum flavescens*, whose group has the lowest proportion of diagnostic species in the grazed stands.

The results of the survey regarding the equal distribution of species indicate that, for the plot size of 0.01 m^2, the mean Shannon index and evenness differ little between the mown, unmown and grazed variants, which could perhaps be due to the small plot size. At the plot size of 10 m^2, the grazed stands have significantly lower values of both diversity indices compared to the mown as well as to the unmown stands. Possible explanations for the reduction of evenness through grazing could be uneven nutrient depositions followed by exclusion processes or a proliferation of unpalatable species. The similar evenness values in mown and unmown plots could be explained by too short a recorded period of abandonment. The results indicate that vascular plant species richness decreases more rapidly after mowing abandonment than does evenness.

Regarding the vegetation structure, the average height of the herbs and grasses layer is significantly lower in the grazed stands than in the mown or unmown meadow stands. At the 10 m^2-scale, the bare ground cover in the grazed stands is significantly higher than in the mown and unmown stands. The cover of bryophytes is significantly lower in the unmown stands as compared to the mown and grazed stands at the 10 m^2-scale. Finally, the grazed stands have a significantly higher mean proportion of graminoids and lower proportion of forbs and legumes than the mown and unmown stands in both plot sizes.

The floristic composition was investigated only with regard to the occurrence of diagnostic (indicator) species for the three land use variants (mown, unmown, grazed). The results indicate that there are between 11 and 21 indicator species for each land use type fulfilling the criteria of a phi-coefficient of association value ≥ 20. The diagnostic species differ between the two studied spatial scales and there are only a few overlaps. The species identified as diagnostic for both plot sizes for the mown stands are *Rhinanthus rumelicus, Prunella grandiflora, Agrostis capillaris* and

Leucanthemum vulgare, for the unmown stands *Dichoropetalum carvifolia* and for the grazed stands *Agrimonia eupatoria*.

The diagnostic species for the mown and unmown stands belong in either case to three sociological groups: semi-dry basiphilous grasslands of the order *Brachypodietalia pinnati*, mesic grasslands of the order *Arrhenatheretalia elatioris*, and thermophilic herb fringe communities of the class *Trifolio-Geranietea.* In the mown plots, the proportions of species of the semi-dry basiphilous grasslands and mesic grasslands are higher than in the umown plots, where the proportion of thermophilic fringe species is highest. The grazed stands contain diagnostic species of a wider range of sociological groups. The largest sociological group is formed by the species of ruderal communities, while diagnostic species of mesic grasslands are absent.

Both the mown and unmown stands show a significantly higher percentage of diagnostic species for the *Polygalo-Brachypodietum pinnati* than for the *Brachypodio-Molinietum arundinaceae* or the *Cirsium furiens-Brachypodium pinnatum*-community. In the grazed stands, more than two third of the diagnostic species are also diagnostic for the *Cirsium furiens-Brachypodium pinnatum*-community, and only a small share for the *Brachypodio-Molinietum arundinaceae* and the *Polygalo-Brachypodietum pinnati*.

The results regarding the floristic composition indicate that with grazing, the species composition changes clearly and the plant community *Polygalo-Brachypodietum pinnati* is transformed into other communities like the *Cirsium furiens-Brachypodium pinnatum*-community. Short-term abandonment of mowing results in a decrease of vascular plant species richness and a shift in species composition within the typical species inventory of the *Polygalo-Brachypodietum pinnati*. This suggests that stands that have not been mown for short periods can possibly be transformed back into stands with the typical structure and species composition of the regularly mown *Polygalo-Brachypodietum pinnati*.

6 Conclusions and outlook

6.1 Species-rich and rare grassland communities

The three surveyed hay meadows from Dăbâca and Borșa communes share many similarities in terms of abiotic site conditions, plant communities, syntopic occurrence of several *Phengaris* taxa, historical and current tenure structure as well as land use history and current land use change. Thus, they can be considered as three examples of one meadow type, which could for instance be referred to as old hay meadows. Other adjectives describing the meadows would be semi-natural, semi-dry, highly biodiverse, traditional, extensively farmed, large, (semi-)open or strip-fielded. The expansion of the thesis focus from single vegetation types to a holistic view on the wider habitat of the *Phengaris* butterflies helped expose a common pattern, which has not so far been considered from an interdisciplinary point of view in the region.

The initial assumption that the hay meadows harbour very species-rich meadow steppes was confirmed; the *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939 was documented. This is a meadow steppe community of the Carpathian fringes often associated with the highest values of plant species richness on a small scale, for example by Illyés et al. (2007), Roleček et al. (2014) or Roleček et al. (2019). The fact that in the study meadows, however, the closely related association *Polygalo majoris-Brachypodietum pinnati* Wagner 1941 had even higher mean species richness values (61 versus 56 species / 10 m^2) could be an interesting starting point for further comparative studies of the plant diversity and syntaxonomical relationship between these communities. In the meadows surveyed these two vegetation types often occur adjacent to each other and are distinguished by the presence of indicator species for fluctuating soil moisture.

The high plant diversity, exemplified through one of the worldwide highest known values of small-scale vascular plant species richness on 0.01 m^2, and the occurrence of the named plant communities show the high importance of the study meadows in the European context as part of a type of particularly species-rich semi-dry grasslands. The development of these grasslands depends on multiple factors, as summarised by Roleček et al. (2014) in a general model. Management continuity as a crucially relevant factor, which Aavik et al. (2008) also highlighted, could be confirmed for the last 140 years in the case of two of the study meadows. Whether the 40-year interruption of this continuity in the third meadow resulted in the plant diversity and species composition of this meadow being different from those of the other two meadows is an interesting question for future research.

The other factors mentioned by Roleček et al. (2014) increasing grassland diversity are also observed in the study meadows, for example abiotic factors like calcium-rich bedrock, or slope movements creating a complex relief and thus allowing for the occurrence of dry, mesic and wet vegetation types that are closely interlocked with each other. Site position at the transition between prevailingly mesophilous vegetation vs. prevailingly thermophilous vegetation (e.g., forest-steppe communities) also contributes to species richness. Continuous and long-lasting human presence in the area can be documented for the region, a crucially important factor for the persistence of ancient grasslands (see also Feurdean et al. 2017). This fact may contribute to the occurrence of species representative of early-Holocene heliophilous communities such as *Veratrum nigrum*, *Serratula coronata*, *Danthonia alpina* and *Dichoropetalum carvifolia* (Hájková et al. 2011; Roleček et al. 2014).

In this context, Feurdean et al. (2018) even speak of a third type of biodiversity-rich grasslands in Central Eastern Europe, besides the primary grasslands on poor soils (primary grasslands I) and the semi-natural grasslands developed as a result of human activities replacing forests. They call this third type primary grasslands II, that is, ‘ancient grasslands on deeper soils, maintained by climate and disturbances during the early Holocene and then predominantly by disturbances until the present’. Assuming that this view is correct, the studied hay meadows could indeed be examples of this primary grassland II.

Further phytosociological research in the hay meadows could address the relationship between the *Brachypodio-Molinietum arundinaceae* and the *Molinietum caeruleae* with the species *Molinia arundinacea*. This would be particularly important since both communities have so far rarely been reported from Romania, which suggests at least rarity and is even more astonishing as they occur close to the Hay Meadows of Cluj, a protected area widely known among botanists. The hay meadows are therefore a potentially important site for further phytosociological research.

6.2 *Phengaris* spp. occurrence in the hay meadows

A feature shared by the *Brachypodio-Molinietum arundinaceae* and the *Molinietum caeruleae* is the correlation with *Gentiana pneumonanthe*, the host plant species of *Phengaris alcon 'pneumonanthe'*, which is mainly related to these two plant communities in the study meadows. The host plant species for *Phengaris nausithous* and *Phengaris teleius*, *Sanguisorba officinalis*, occurs in these two communities as well, but also in a wider range of moist to semi-dry grasslands. However, this greater sociological amplitude did not prevent the sharp decline of *Sanguisorba officinalis* in the Lord’s Meadow during recent years (state: 2023), most probably due to intensive grazing (Natalia Timuş, personal communication, July 2022). *Gentiana pneumonanthe* on the other hand, was apparently protected physically to some extent by the high and dense *Molinia arundinacea* stands and shows a less severe decline (Natalia Timuş, personal communication, May 2023).

Generally, it can be assumed that an important prerequisite for the syntopic occurrence of several *Phengaris* taxa is the close interlocking of semi-dry grasslands (including the *Brachypodio-Molinietum arundinacea*) with *Molinietum caeruleae* meadows, which in turn is based on the abiotic factors, especially soil and relief properties. Interesting is also the coincidence of the occurrence of very species-rich steppe meadows with the unique occurrence of all European *Phengaris* taxa, which raises the question of whether the other areas with extremely species-rich meadow steppes are also characterised by particularly diverse insect communities.

Based on the results of this thesis, the *Phengaris* spp. occurrence can now be considered in the context of the land tenure structure and history of land use. What is striking is the traditional mowing date in July to August, which should be unfavourable for the species *Phengaris nausithous*, *Ph. teleius* and *Ph. alcon 'pneumonanthe'*, all of which occur as adult butterflies from about the 10^{th} of July to the 10^{th} of August (*Ph. alcon 'pneumonanthe')* or the end of August (the other two species) (Timuş et al. 2013b; Timuş 2014). A possible explanation for this is that the unfavourable effect of mowing in the flight period may have been reversed by the traditional heterogeneous mowing pattern. On the other hand, it may be that larger populations of these *Phengaris* taxa only developed from the 1990s onwards, when the unmown areas increased.

6.3 Mowing abandonment and grazing: impacts and aspects of methodology

The vegetatin survey carried out in the period 2009-2013 already demonstrated an influence of mowing abandonment in parts of the meadows, as can be seen from the phytodiversity data (lower species richness in unmown stands), structural features (lower cover of bryophytes in unmown stands), and species composition (higher share of fringe species in unmown stands). It is also evidenced by the mapping of mown areas, indicating completely abandoned sections of the hay meadows (33 % – 70 % of the surface, site dependent).

Furthermore, parts of the hay meadows were, even by that time, affected by year-round sheep grazing, indicated, e.g., by the presence of the *Cirsium furiens-Brachypodium pinnatum*-community. This means that the structure, species composition and diversity values of the vegetation described here likely already reflect shifts from the original state with traditional land management characterised by annual mowing and no grazing in summer. On the other hand, the results reflect a condition of the vegetation that was still closer to the original condition as compared to today, because mowing abandonment and grazing have increased since then. As a result, the vegetation and biodiversity data collected from ten to fourteen years ago (as of 2023) have an important documentary value.

The study demonstrates that the absence of mowing leads to a decrease in plant species richness and year-round grazing leads to a decrease in species richness and evenness (related to 10 m^2). We can assume a further loss of plant diversity since 2013 across the study area. Without management measures, the result of this development will most probably be the loss of species, especially rare species and grassland or meadow specialists, at a local and ultimately regional level. For example, Wilsey and Polley (2004) indicate that grasslands with lower plant species evenness could carry a greater risk of local extinction events of rare species or species with reduced above-ground growth rate. But dominant plant species can also become extinct in a fragmented habitat, often with a time delay in the sense of an extinction debt (Tilman et al. 1994).

These processes may be buffered to a certain extent by the high habitat heterogeneity within the meadows, as has probably happened in the past when conditions became unfavourable for certain species. However, in the study meadows the land use change has already caused considerable negative effects, for example on the flagship species of the meadows, the *Phengaris* butterflies: In the Lord's Meadow, the populations of *Phengaris alcon 'cruciata', Ph. alcon 'pneumonanthe', Ph. teleius* and *Ph. nausithous*, as well as their host plants and host ants have severely been reduced since the beginning of the 2010s. In fact, *Phengaris alcon 'cruciata'* was not found in that meadow in 2021 and 2022 (Natalia Timuş, personal communication, August 2022).

The recording of land use changes is important in order to explore or monitor the impact of such changes on the natural resources of the surveyed meadows. The most important changes - the absence of mowing and associated maintenance works and the increase in year-round sheep grazing - vary in ease of recording unless an experimental approach is chosen. While the mown areas can be mapped in the field or through aerial photographs, grazing is more difficult to record. This is because it is carried out in an *ad hoc* manner, e.g. without fences, and is thus distributed unevenly over the area, depending on the individual decisions of several sheep keepers and the shepherds they employ.

In this thesis, for the reasons mentioned above, it was decided on the one hand not to record the factor grazing in the land use variants 'mown' / 'unmown', on the assumption that, if present, it would have a statistically similar effect on all plots. On the other hand, the land use variant 'grazed' was not surveyed in the same three *utilised hay meadows* as the variants 'mown' / 'unmown', but in two *former hay meadows* transformed into permanent pastures, assuming due to several indications that they had the same vegetation types and site conditions before transformation. This is based on the space-for-time substitution approach, in this case the assumption that permanent grazing would have a similar effect in the *utilised hay meadows* after the corresponding time.

With the development of a reliable recording method for the stocking rate it may also be possible to survey the land use variant 'grazed' in the *utilised hay meadows*. Finally, it should be noted that despite the downsides of the non-experimental approach, the difficulty of an experimental approach was considered even higher when planning the survey, as it seemed impossible, from the experience of several years, to protect certain plots in the meadows against grazing.

6.4 Other changes in meadow management

In addition to mowing abandonment and grazing, several developments were observed in the hay meadows for which some general effects are suspected, effects which should be verified by further studies:

- Allowing the occurrence of scattered woody plants on the meadows, which has been practised in Lord's and Village Meadow since the 1990s; before which these meadows were almost free of shrubs or trees. Up to a certain proportion of woody plants, this could have a positive effect on biodiversity, especially that of birds and insects. The effect on the meadow vegetation would need to be researched. For instance Aavik et al. (2008) found for a wooded meadow in Estonia that the plant species richness decreased in parts of the meadow where, due to the woody plants, 50% or less of direct irradiation reached the herbaceous layer.

- Scrub encroachment in parts of the hay meadows. A decrease in open land plant species and plant diversity is assumed.
- Increase in monodominant *Calamagrostis epigejos*-stands, which can also lead to a decline in typical meadow species and plant diversity (see e.g. Pruchniewicz and Żołnierz 2017).
- Change in size of mown plots from around 0.3 to 0.9 ha to sizes of several hectares. This is assumed to have a negative impact on biodiversity, as it eliminates escape areas which, in the event of unfavourable use on one plot, can buffer the negative impact on the neighbouring plot (see e.g. Schumacher et al. 1995).
- Tractor mowing, implying a faster mowing process, which might have negative effects on the meadow fauna. Furthermore, heavy machines could negatively affect the soil structure and water balance due to compaction. Another effect of tractor mowing could be larger areas of fringe vegetation through omitting steeper and wetter parts of the meadows that used to be cut when manual scything dominated.

These changes are modifying the flora, fauna, vegetation, and biodiversity of the meadows gradually, while grave impositions like transformation into arable or fertilisation have stayed away so far in the *utilised hay meadows*. However, there is increasing evidence in Dăbâca commune that a conversion of at least parts of the hay meadows into arable could be imminent in the near future.

6.5 Proposed conservation objectives and measures

Due to their numerous natural and agro-historical values, there can be no doubt that the surveyed hay meadows must be protected. Not least, as there is also a legal obligation to maintain the species for which the Site of Community Importance (SCI) has been designated (in this case for example *Phengaris nausithous* and *Phengaris teleius*) and to avoid the deterioration of protected habitats (article 6(2) of the Habitats Directive, Council of the European Communities 2013).

It is not the aim of this thesis to propose a specific management plan for the surveyed hay meadows. However, in the following, some aspects important for management planning shall be highlighted on the basis of the results of this thesis. In this context, it is important to first define the conservation objectives in order to use the resources in a well-targeted manner and to identify possible conflicts of objectives (see e.g. the grassland management decision making model by Crofts and Jefferson 1999). Based on the results of this thesis and other studies in the meadows, the following priority conservation assets are proposed, whose conservation in good condition are defined as conservation objectives:

1. The populations of *Phengaris nausithous*, *Phengaris teleius, Phengaris alcon ‘pneumonanthe’, Phengaris alcon ‘cruciata’* and *Phengaris arion* as flagship species, which includes the protection of their specific host plants and host ants.
2. The plant community *Molinietum caeruleae* (with *Molinia arundinacea*), for several reasons: The community is correlated with the host plant species for *Ph. nausithous*, *Phengaris teleius* and *Phengaris alcon ‘pneumonanthe’*, belongs to the habitat type 6410 of Annex I of the Habitats Directive, and is not described so far for Romania with this *Molinia* species.
3. Basiphilous semi-dry grasslands, especially stands of the *Polygalo-Brachypodietum pinnati* and the *Brachypodio-Molinietum arundinaceae*, due to their high plant species diversity and the affiliation to an extremely species-rich steppe meadow type. In addition, these grasslands also belong to a protected habitat type of the Habitats Directive (6210).
4. The soils of the meadows (chernozems, phaeozems, vertisols), especially their high humus content and rich soil biology, since their specific characteristics form the basis for the site-specific plant communities and since they are a huge carbon reservoir (Sunder-Plassmann 2016).
5. The characteristic historical tenure structure and / or a similar small-scale mowing pattern, which represents its own value as a cultural heritage and whose origins go back more than a hundred years into the past. The small-scale mowing pattern is also a likely factor playing a role in the high plant diversity and can be a key to resolving conflicts of objectives in nature conservation (e.g. the requirement for different mowing dates).
6. A limited number of individual trees, shrubs and clumps of shrubs on the meadow surface, as they are likely to have a positive effect on faunal diversity and create an attractive scenery. However, negative effects on the meadow species must be taken into account and the woody plants must be in accordance with the subsidy regulations.
7. The meadows in their entire extent as a component of the cultural landscape. The large size of the meadows also has a positive effect on the maintenance of biodiversity, due to offering a high diversity of different habitats.

Since there are several potential conservation objectives with different needs, which is due to the fact that the hay meadows harbour many natural values worth protecting, the management should be planned on the level of the whole meadows. From this viewpoint, the basic management approach should be to maintain a high land use and habitat heterogeneity, which ensures that favourable conditions for the different objectives are created intrinsically in parts of the meadows. Furthermore, the principle should be applied that the area-specific historical management should be maintained, reintroduced or substituted by land use forms close to it in its effect (Schumacher et al.

1995). But also changes in traditional agriculture could be integrated if their ecological effect is positive, e.g. more woody plants in the meadows or more areas not mown in the short term.

The following measures are recommended as important components of the meadow management:

- Regular mowing, allowing, however, for longer mowing intervals to be tested that are sufficient for the conservation of overall biodiversity and/or specific high priority species or habitats.
- Mowing dates that correspond to the historical mowing dates, except for the *Molinietum caeruleae*-stands and the core areas of the populations of *Phengaris nausithous, Phengaris teleius* and *Phengaris alcon 'pneumonanthe',* which need mowing dates starting no earlier than late August.
- Create a heterogenous mowing pattern, e.g., through small plot sizes (less than 1 ha), temporally staggered mowing and/or leaving small areas unmown. For instance, Jongepierová et al. (2008) recommend for sites with *Phengaris nausithous* and *Ph. teleius* mowing before mid-June or after late August, to leave at least 10 % of the area unmown until the following year (each year different parts) and to avoid cutting parts with late-developing plants such as *Gentiana pneumonanthe*.
- Spring and autumn grazing as well as a grazing rest from the beginning of May until after the hay harvest.
- Leave a limited number of shrubs and trees on the meadow surface.
- Notwithstanding the above, the initial (restorative) management measures for meadow parts overgrown by shrubs or monodominant stands of grasses have to be designed differently.

6.6 Economic aspects, agri-envrionment payments and legal regulations

Important for the planning of protection measures are constraints and development scenarios based on the economic, legal, and socio-economic framework conditions. The following considerations take into account the results of this thesis, but also knowledge and experiences of the thesis author gained during the 'Mozaic Projects' (Paulini 2012, 2015), and the work for the Mozaic Association.

The tenure structure of numerous individually owned parcels in the study meadows is intrinsically connected to an economy of many small agricultural holdings, each owning a small number of different livestock requiring hay as winter fodder (dairy cows, sheep, formerly also water buffaloes). The decline of subsistence farming and especially in the numbers of dairy cattle in the villages of the study area leads to a situation in which the historical tenure structure is hardly reflected in the mowing structure; that relates to other factors nowadays.

It is to be expected that the tenure structure will itself disappear in the near future, since the comprehensive land survey that has already been carried out for the Great Meadow (Borșa community) can serve as the basis for land consolidation. A tendency towards land consolidation can also be expected for the Lord's and Village Meadow (Dăbâca commune) without a comprehensive land survey, here more likely driven by large farmers from outside, who have already obtained a considerable share of the commune's agricultural land. In this process, many owners who could not complete the land restitution process are in risk of losing their land property in the meadows, especially in the Lord's Meadow.

The decreasing demand for hay by a shrinking small-scale dairy cattle farming sector during the last decades was not compensated by the increase in either the dairy sheep sector or in the demand from commercial dairy cattle farms (who rather cultivate fodder plants on arable land). In any case, it would be important to find out who the current users of the hay meadows are, apart from the few remaining active small-scale farmers, and who could be potential customers for species-rich hay in the region (e.g. horse keepers). If more of the meadows are to be mown, even for nature conservation purposes, there would have to be a use for the hay.

Some of the areas that are still regularly mown are subject to management that is detrimental to the priority conservation assets, for example in the eastern part of the Village Meadow, where in recent years annual mowing of a large *Molinietum caeruleae* stand in July has caused a sharp decline in the populations of several *Phengaris* taxa. If extensive, contiguous parts of the hay meadows become the property of large commercial farmers, the use of fertilisers on the meadows is also imaginable, unless the agri-environment payments are more attractive economically (which however allow the use of manure with maximum 40 kg N / ha, Direcţia Generală Dezvoltare Rurală 2022).

At the same time, part of the permanent grassland newly created since the 1990s on former cultivated land is being converted back into arable, at least in Dăbâca commune, which forces sheep holders to move to other areas, such as the semi-abandoned traditional hay meadows like the Lord's Meadow. Therefore, time is an important factor in conservation efforts, also because the restoration of areas affected by land-use change is getting more and more difficult, for example due to increasing scrub encroachment, spreading of monodominant *Calamagrostis epigejos* stands, or the increase of impoverished or overgrazed meadows.

Regarding subsidies for environmental-friendly agriculture, the 'Package for grasslands important for butterflies (*Maculinea* [=*Phengaris*] spp.)' of the Romanian Agri-Environment and Climate Scheme (AECS), which is available for the communities Borșa und Dăbâca since 2012, has a suitable mowing date for *Phengaris nausithous, Ph. teleius* and *Ph. alcon 'pneumonanthe'* (after 25 August) (Direcţia Generală Dezvoltare Rurală 2022).

However, due to the design of the AECS in Romania, only one package out of five is available in any particular commune. This means that in Borșa and Dăbâca commune the semi-natural grasslands are not eligible for the main package targeted at High Nature Value (HNV) grasslands, even though they belong to this category (see Paulini et al. 2011). It also means that all grasslands in these communes, for which agri-environment payments are obtained, have to be mown or grazed after the 25 August (Direcţia Generală Dezvoltare Rurală 2022), which does not make sense for grasslands that do not require a late mowing date due to their species composition.

For the still active dairy farmers, the late mowing date may even be a reason not to claim the subsidies, which ultimately means a lack of protection for the High Nature Value grasslands present in the communes. The recording of mown surface in the Village Meadow until 2019 shows, that at least until that year the availability of the agri-environment payments does not lead to the maintenance of a higher proportion of mown area in the long term, after the peak following their introduction in 2012. However, the impact of the subsidies would have to be studied in detail.

For a better protection of the surveyed meadows (and in general the semi-natural grasslands of the study area and many other communes) through the Agri-Environment and Climate Scheme, the measures would have to be changed. The basic agri-environment package for HNV grasslands, which allows mowing dates from 15 June / 1 July, depending on the altitude, should be available for this type of grassland everywhere in Romania. Furthermore, an economically attractive package specifically for hay meadow protection that excludes grazing during summer would be needed (see also Sólyom et al. 2011), as well as top-ups for plots that require a late mowing date. A further approach would be to design agri-environment payments especially for the protection of old grasslands. In any case there should be local advisory services for farmers to make full use of the chances of compensation for low-intensity farming.

The fact that the surveyed meadows are in a Site of Community Importance (SCI) of the Natura 2000 Network offers several conservation opportunities. There is a management plan and site regulation (Ministerul Mediului, Apelor si Padurilor (MMAP) 2016a, 2016b), which stipulates for example in Art. 7. (5) that hay meadows are to be managed by mowing and pastures by grazing (Ministerul Mediului, Apelor si Padurilor (MMAP) 2016b). Mowing is allowed after 15 June (Art. 7. (9) b), except for plots receiving agri-environment payments (*Maculinea* package), which must be mown after 25 August. This means, the site regulation does not mandatorily impose a late mowing date for grasslands harbouring *Phengaris* species with a late flight period.

It is also worth mentioning that there are still no Natura 2000 payments in Romania in the Common Agricultural Policy period 2023-2027 (Romanian Ministry of Environment 2019; Direcţia Generală Dezvoltare Rurală 2022), which could compensate farmers for losses or additional costs incurred as a result of not carrying out management activities with a negative impact on the protected species and habitats.

Another drawback is that the habitat type 6210, which includes the extremely species-rich semi-dry grasslands of the hay meadows, is not mentioned in the Standard Data Form of the SCI (European Environment Agency 2020), and the habitat type 6410, which includes the *Molinia* meadows, is listed with the cover zero. Overall, it can be concluded that the implementation of appropriate management measures to protect habitats and species included in the Habitats Directive is difficult to enforce by agri-environment payments and Natura 2000 regulations under the current conditions, like meadow plots abandoned by owners, unclear ownership, illegal grazing during summer and lack of consulting for farmers.

In the future management of the surveyed hay meadows the so-called Grassland Law (*Legea pajiştilor*) will play a role, which regulates various aspects around the management, administration and organisation of all grassland areas at the municipal level (Guvernul României 2013; Parlamentul României 2022). Among others, the law prescribes management plans (*amenajament pastoral*) that must be drawn up for each municipality and will come into force from 2024 onwards, defining a specific management for each permanent grassland patch (Parlamentul României 2022).

Experience with the management plans of the communes of Borșa and Dăbâca shows that they tend to be drawn up according to agro-economic concerns and that nature conservation plays no, or a subordinate role; also, too little attention is paid to the actual plant communities of the grassland patches. Furthermore there is a tendency to list traditional hay meadows, for example the Great Meadow, as permanent pastures in the management plans, which would be fatal for their long-term protection as hay meadows.

6.7 Proposed approach and resources

Considering the above said, especially the currently still insufficient protection by laws or incentives for environmentally friendly agriculture, the following double-track approach is proposed as a possible way forward to a successful protection of the surveyed meadows: On the one hand, as a potentially quicker solution, purchasing and leasing of a large, relatively contiguous part of the hay meadows should be promoted, through entities dedicated to nature conservation, as it is commonly practised, for example, in Germany. In this way, management can be set on the basis of nature conservation objectives, the chance of stopping illegal grazing increases and the historic landform can be protected. This approach replaces the original agricultural use with a maintenance use that depends on self-financing of the nature conservation entities, subsidies, donations, and volunteer work.

On the other hand, however, efforts should also be made to maintain the still existing agricultural use of the hay meadows by supporting the farmers to carry out and advance low-intensity practices. One reason is that the support of the existing farming in systems, which contain high levels of biodiversity, is the most (cost-)effective option, as Kleijn et al. (2009) indicate. Possible ways would be, for example, to support the transformation of small family holdings to middle-sized dairy farms, but also to promote the low-intensity use of the traditional hay meadows amongst the commercial dairy farms, for example through consulting about the agri-environment payments.

For the development of a viable small-scale agricultural sector a comprehensive support of the farmer communities is furthermore needed, e.g. through small-scale processing facilities, machines and technologies adapted to the low-intensity practices and the support of entrepreneurial skills (Jitea et al. 2021). A further advantage of this approach is that it supports acceptance for the conservation of the traditional hay meadows by the locals. In any case all conservation measures should be complemented by awareness-raising, education, and participation of the local population. Furthermore, it is important to find ways to involve sheep farmers in the protection of the traditional hay meadows.

The conservation efforts for these meadows will be most sustainable if their exceptional value in several respects is recognised by the local population, the local economy and decision-makers. First steps in this direction have already been taken since the *Phengaris* butterflies have given the name to the micro-region and project '*Ținutul Fluturelui Albastru'* (Land of the Blue Butterfly) which includes ten other communes besides Borșa and Dăbâca and promotes sustainable local development.

Thus, the many complex constraints for the protection of the traditional hay meadows might eventually be counterbalanced by some advantages and resources: The long-standing interdisciplinary research of the meadows, involving among others the nearby Babeş-Bolyai University of Cluj-Napoca, the location in a Natura 2000 site as well as the commitment of several local NGOs (Mozaic Association, Romanian Lepidopterological Society, Asociația Plaiuri Noi), which have gained long-time experience in the practical protection of the surveyed meadows or, in the case of latter NGO, have launched the micro-region named above.

6.8 Outlook and importance of the study hay meadows

Finally, the importance of further research on the surveyed hay meadows should be mentioned (see also Chapter 3.4.3 and 5.4.4). This can include, for example, the following topics: Further phytosociological studies, examination of the current state of vegetation and plant diversity and comparison with the data from 2009-2013, as well as research of the faunistic diversity of the meadows. Furthermore, regular monitoring of vegetation, target species and diversity should also be carried out, as well as monitoring of land use. An important issue would be furthermore the examination of the meadow soils as a carbon sink and the impact of climate change to the meadow ecosystem.

Furthermore, the occurrence of the priority plant communities (*Molinietum caeruleae*, *Brachypodio-Molinietum arundinaceae* and *Polygalo-Brachypodietum pinnati*) and *Phengaris* taxa should be investigated in the whole Natura 2000 area and beyond. A comparison with similar old semi-natural hay meadows in the region could supplement the knowledge about the meadows with further information.

In summary, the surveyed meadows deserve further research and protection for several reasons: Their high richness of vascular plant species makes them important from a conservation perspective since their proper management can ensure the protection of an important part of regional biodiversity. They are significant from a scientific perspective, e.g. as a study object for the mechanisms of species coexistence, and harbour several plant species of conservation interest, such as *Pontechium maculatum, Iris aphylla, Serratula coronata* as well as several orchid species, and of course as flagship species, all European *Phengaris* taxa. Furthermore, the traditional hay meadows provide important public goods and ecosystem services, for example as home for many pollinators important for the adjacent agricultural land, as a large carbon sink or as a recreation area for the growing urban centre of Cluj-Napoca.

The meadows may be the remnants of a once widespread type of traditional hay meadows in the region, that can still be preserved for the future. They are included in a network of semi-natural grasslands covering the hill slopes of the landscape and thus important for the overall biodiversity of the study area. At the same time, as High Nature Value farmland, they are a typical element of the Transylvanian cultural landscape and an important part of the European natural and cultural heritage. This thesis serves as a detailed and interdisciplinary study that shows which aspects are important to consider for the successful conservation of the traditional hay meadows in the Hills of Cluj.

Summary of the thesis

In the peri-Carpathian region, Western Estonia, and Southern Öland (Sweden) some basiphilous semi-dry grasslands feature exceptionally high values of vascular plant species richness, especially when managed as traditional hay meadows. The overall goal of this thesis was to survey traditional hay meadows in the Hills of Cluj (Transylvania, Romania), which were suspected to contain these very species-rich type of semi-dry grasslands as well. In addition to vegetation and phytodiversity data, the survey included aspects of land tenure, meadow management and land use change. This detailed and interdisciplinary approach aimed to show, by way of example, which aspects are important to consider for the successful conservation of Transylvania's cultural landscapes and their biodiversity.

The study was carried out in three traditional hay meadows of 42 ha, 67 ha and 200 ha, situated in the communes of Dăbâca and Borșa, which are located in the north-western part of the Transylvanian Plateau. The surveyed meadows stand out due to the syntopic occurrence of five taxa of the butterfly genus *Phengaris* (syn.: *Maculinea*), unique in Europe. The meadows are located on north-facing slopes and characterised by a complex relief and a small-scale vegetation pattern of different grassland types and of shrubs and trees scattered over the meadow surface. The main soil types of the meadows are chernozems, phaeozems and vertisols, developed from carbonate-rich marls and characterised by an exceptionally high humus content, a high clay content and intensive bioturbation.

The dissertation uses three methodological approaches: first, in a phytosociological survey with focussing on the basiphilous semi-dry grasslands and *Molinia* meadows, 102 Braun-Blanquet-relevés were carried out in the years 2009-2013 on either 25 m^2 or 10 m^2. Second, in a socio-historical study, the land use and tenure from 1880 onwards was determined with the help of cadastral maps. In addition, information on traditional meadow management and land use changes in the post-communist era was collected in interviews with farmers and local experts, and the mown areas were mapped in the field.

Third, a diversity survey compared regularly mown basiphilous semi-dry grassland stands with unmown or permanently grazed stands with regard to their plant species diversity, structure, functional groups and floristic composition. For this purpose, 31 nested-plot series were recorded in 2012 and 2013, using the plot size 10 m^2 and three replicates each of 1 m^2, 0.1 m^2, 0.01 m^2 and 0.001 m^2.

The results of the phytosociological part show that four of nine identified plant communities belong to the alliance of subcontinental semi-dry basiphilous grasslands *Cirsio-Brachypodion pinnati*, also called meadow steppes. This includes the *Polygalo majoris-Brachypodietum pinnati* Wagner 1941 with the highest mean vascular plant species richness (61 species / 10 m^2) and the *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939, which is often associated with the highest values of plant species richness on a small scale. Both associations are closely related to the *Cirsium*

furiens-Brachypodium pinnatum-[Cirsio-Brachypodion]-community Dengler et al. (2012), which was found in the meadows as well.

Furthermore, for the first time for Romania, the *Molinietum caeruleae* Koch 1926 with the explicit mentioning of *Molinia arundinacea,* which often is considered a subspecies of *Molinia caerulea,* is described. The association covered around 2-3 % of the meadow area, manifested as numerous isolated stands. It has similarities to the *Gentiano pneumonanthis-Molinietum litoralis* Ilijanić 1968, which was firstly described from Croatia and is also characterised by the occurrence of *Molinia arundinacea*.

In the meadows, the *Molinietum caeruleae* with *Molinia arundinacea* was part of a vegetation complex along a gradient of humidity: The *Molinietum caerulaea* on moderately moist sites with alternating soil moisture was followed by the *Brachypodio-Molinietum arundinaceae* on more mesic sites with alternating soil moisture and this by the *Polygalo-Brachypodietum pinnati* on meso-xeric sites.

The other plant communities identified were the *Danthonio-Stipetum stenophyllae* Ghişa 1941, the *Mentho longifoliae-Juncetum inflexi* Lohmeyer ex Oberdorfer 1957 nom. invers., the *Caricetum vesicariae* Chouard 1924, and two preliminarily-described informal plant communities: the *Calamagrostis epigejos*-[Molinietalia caeruleae]-community and the *Festuca pratensis*-[Cirsio-Brachypodion pinnati]-community.

Sanguisorba officinalis, the host plant species of *Phengaris teleius* and *Ph. nausithous,* occurred in several plant communities in the study meadows, including communities of moist sites and semi-dry grasslands with alternating soil moisture. *Gentiana pneumonanthe,* the host plant species of *Phengaris alcon 'pneumonanthe',* was related mainly to the *Molinietum caeruleae* and the *Brachypodio-Molinietum.*

Almost all the plant communities identified are considered vulnerable or endangered according to the European Red List of Habitats. Six of the nine plant communities are protected by the Habitats Directive as habitat types 6210, 6240, and 6410. 335 vascular plant species have been identified, of which 22 are of national conservation concern, two species are endemic to Romania, and one species is protected by the Habitats Directive, namely *Pontechium maculatum*.

The land use and tenure study revealed that two of the study meadows have been managed continuously as hay meadows for a minimum of 140 years, while in the third meadow the continuity of use was interrupted for around 40 years, during which time it was used as cattle pasture. The meadows all have the same tenure pattern characterised by hundreds of small and narrow plots which has its origin at least 100 years ago. Many of the plots are not entered in the land register, which brings with it an increased risk of ownership rights no longer being enforceable, something which is already having an impact on management and protection options.

The meadows were traditionally mown once a year between June to August, were not fertilised and were grazed in spring and autumn by cattle and sheep. The hay making season in general lasted several weeks. The physiognomy of the meadows differed from their present appearance; in that they were almost completely free of woody plants until 1990.

The mown area recorded annually in the period 2010-2014 was substantially smaller than the total area of the hay meadows and ranged between 0.2 % and 53 %. The hay meadows differed in terms of the proportion of area mown which furthermore changed from year to year with a peak in 2012 and 2013. This could be in relation to the introduction of agri-environment payments in the area. For the periods in which the traditional small-scale tenure pattern was respected, a fine-grained, spatio-temporally heterogenous mowing pattern is assumed - something which in general provides good conditions for high habitat and species diversity. Year-round sheep grazing, abandonment of mowing, and the resulting encroachment of scrub are the most important land use changes in the post-communist era.

The meadow steppes featured, as suspected, very high plant richness values, also exemplified by one of the worldwide highest values of small-scale vascular plant species richness on 0.01 m^2 (26 species). Short-term abandonment of mowing in the steppe meadows resulted in a decrease of vascular plant species richness and a shift in species composition within the typical species inventory of the *Polygalo-Brachypodietum pinnati*. Conversion of the traditional meadows to permanent sheep pastures led to a decrease in vascular plant species richness and evenness and a replacement of typical meadow species through species of other communities, including ruderal vegetation.

The grazed stands had a significantly higher mean proportion of graminoids and lower proportion of forbs and legumes compared to the mown and unmown stands. The species identified as highly diagnostic for the mown stands were *Rhinanthus rumelicus, Prunella grandiflora, Ferulago sylvatica,* and *Crepis biennis*, for the unmown stands *Dichoropetalum carvifolia, Cirsium pannonicum,* and *Carex michelii,* and for the grazed stands *Daucus carota, Carex distans, Cirsium furiens, Agrimonia eupatoria, Xeranthemum cylindraceum,* and *Carlina vulgaris.*

This dissertation provides a holistic view on the traditional hay meadows of the study area and reveals possible factors contributing to the high plant diversity of the steppe meadows as well as to the unique co-occurrence of all European *Phengaris* taxa: a heterogenous vegetation pattern caused by abiotic conditions; a small-scale tenure structure resulting in a mosaic-like land use pattern and the long continuity of low-input meadow management.

The existing laws on grassland protection, the protection status as part of a Natura 2000 site as well as the available agri-environment payments seem not to be able to conserve the valuable grasslands in the face of delayed land restitution, illegal sheep grazing and decline of small family farming. Therefore, this dissertation recommends suitable management measures and strategies for a successful protection of the surveyed hay meadows. These include the purchasing or leasing of meadow plots through entities dedicated to nature conservation, as well as maintaining the agricultural use of the hay meadows that still exists by supporting the farmers to carry out low-intensity management practices.

Zusammenfassung der Dissertation

Im Karpatenvorland, westlichen Estland und Süden von Öland (Schweden) weisen einige basenreiche Halbtrockenrasen einen außergewöhnlich hohen Artenreichtum an Gefäßpflanzen auf, insbesondere wenn sie als traditionelle Heuwiesen bewirtschaftet werden. Das Ziel dieser Arbeit war es, traditionelle Heuwiesen im Klausenburger Hügelland (Siebenbürgen, Rumänien) zu untersuchen, von denen vermutet wurde, dass sie ebenfalls diese sehr artenreichen Halbtrockenrasen enthielten. Außer Daten zu Vegetation und Pflanzendiversität erfasste die Untersuchung auch Aspekte der Landbesitzverhältnisse, der Wiesennutzung und des Landnutzungswandels. Mit diesem detaillierten und interdisziplinären Ansatz soll beispielhaft aufgezeigt werden, welche Gesichtspunkte für eine erfolgreiche Erhaltung der Kulturlandschaften Siebenbürgens und ihrer Biodiversität wichtig sind.

Die Untersuchung wurde in drei traditionellen Heuwiesen von 42 ha, 67 ha und 200 ha Größe in den Gemeinden Dăbâca und Borșa im nordwestlichen Teil des Siebenbürgischen Beckens durchgeführt. Die untersuchten Wiesen zeichnen sich durch ein europaweit einzigartiges syntopes Vorkommen von fünf Taxa der Schmetterlingsgattung *Phengaris* (Syn.: *Maculinea*) aus. Die Heuwiesen befinden sich an nordexponierten Hügelhängen und weisen ein komplexes Relief sowie ein kleinräumiges Vegetationsmuster verschiedener Grünlandtypen auf. Die Wiesenflächen sind mit vereinzelten Sträuchern und Bäumen bzw. Strauchgruppen durchsetzt. Bei den Hauptbodentypen der Wiesen handelt es sich um Tschernoseme, Phaeozeme und Vertisole aus karbonatreichen Mergeln, die durch einen außergewöhnlich hohen Humusgehalt, einen hohen Tongehalt und eine intensive Bioturbation gekennzeichnet sind.

Die Dissertation bedient sich dreier methodischer Ansätze: Erstens wurden im Rahmen einer pflanzensoziologischen Erhebung mit Schwerpunkt auf basenreichen Halbtrockenrasen und Pfeifengras-Wiesen in den Jahren 2009 bis 2013 102 Braun-Blanquet-Aufnahmen auf 25 m^2 oder 10 m^2 durchgeführt. Zweitens wurden in einer sozio-historischen Studie die historische Landnutzung und die Besitzverhältnisse ab 1880 mit Hilfe von Katasterkarten ermittelt. Zusätzlich wurden Informationen über die traditionelle Wiesenbewirtschaftung und Landnutzungsänderungen in der postkommunistischen Ära in Interviews mit Landwirten und lokalen Experten erhoben und die Mahdnutzung in den Wiesen kartiert.

Drittens erfolgte im Rahmen einer Diversitätsuntersuchung ein Vergleich regelmäßig gemähter Halbtrockenrasenbestände mit ungemähten oder dauerhaft beweideten Beständen hinsichtlich ihrer Pflanzenartenvielfalt, Struktur, funktionellen Gruppen und floristischen Zusammensetzung. Zu diesem Zweck wurden in den Jahren 2012 und 2013 31 *nested-plot*-Serien mit einer Plotgröße von 10 m^2 und jeweils drei Wiederholungen von 1 m^2, 0,1 m^2, 0,01 m^2 und 0,001 m^2 durchgeführt.

Die Ergebnisse des pflanzensoziologischen Teils zeigen, dass vier der neun identifizierten Gesellschaften zum Verband subkontinentaler basenreicher

Halbtrockenrasen *Cirsio-Brachypodion pinnati* gehören, die auch als Wiesensteppen bezeichnet werden. Dazu zählt die Assoziation *Polygalo majoris-Brachypodietum pinnati* Wagner 1941 mit dem höchsten durchschnittlichen Artenreichtum (61 Arten / 10 m^2) und die Assoziation *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939, die oft mit den höchsten Werten des Pflanzenartenreichtums auf kleinen Flächen in Zusammenhang gebracht wird. Beide Assoziationen sind eng verwandt mit der *Cirsium furiens-Brachypodium pinnatum*-[Cirsio-Brachypodion pinnati]-Gesellschaft Dengler et al. (2012), die ebenfalls in den Wiesen gefunden wurde.

Außerdem wird erstmalig für Rumänien das *Molinietum caeruleae* Koch 1926 unter expliziter Nennung der Art *Molinia arundinacea* beschrieben, die oft als Unterart von *Molinia caerulea* angesehen wird. Die Assoziation trat in zahlreichen vereinzelten Beständen auf und nahm etwa 2 % bis 3 % der Wiesenfläche ein. Sie weist Ähnlichkeiten mit dem *Gentiano pneumonanthis-Molinietum litoralis* Ilijanić 1968 auf, das erstmals für Kroatien beschrieben wurde und ebenfalls durch das Vorkommen von *Molinia arundinacea* gekennzeichnet ist.

In den Wiesen war das *Molinietum caeruleae* mit *Molinia arundinacea* Teil eines Vegetationskomplexes entlang eines Feuchtegradienten: Auf das *Molinietum caeruleae* an mäßig wechselfeuchten Stellen folgte das *Brachypodio-Molinietum arundinaceae* an frischen, wechseltrockenen Abschnitten sowie das *Polygalo-Brachypodietum pinnati* an halbtrockenen Stellen.

Die anderen identifizierten Gesellschaften waren das *Danthonio-Stipetum stenophyllae* Ghişa 1941, das *Mentho longifoliae-Juncetum inflexi* Lohmeyer ex Oberdorfer 1957 nom. invers. und das *Caricetum vesicariae* Chouard 1924 sowie zwei provisorisch beschriebene informelle Gesellschaften: die *Calamagrostis epigejos*-[Molinietalia caeruleae]-Gesellschaft und die *Festuca pratensis*-[Cirsio-Brachypodion pinnati]-Gesellschaft.

Sanguisorba officinalis, die Wirtspflanzenart von *Phengaris teleius* und *Ph. nausithous*, kam in den untersuchten Wiesen in mehreren Pflanzengesellschaften vor, darunter in Gesellschaften feuchter Standorte sowie Halbtrockenrasen mit wechselnder Bodenfeuchte. *Gentiana pneumonanthe*, die Wirtspflanzenart von *Phengaris alcon ‚pneumonanthe'*, war hauptsächlich im *Molinietum caeruleae* und *Brachypodio-Molinietum arundinaceae* zu finden.

Fast alle identifizierten Pflanzengesellschaften gelten nach der Roten Liste gefährdeter Lebensräume Europas als gefährdet (*vulnerable*) oder stark gefährdet (*endangered*). Sechs der neun Pflanzengesellschaften sind durch die FFH-Richtlinie als Lebensraumtypen 6210, 6240 und 6410 geschützt. Es wurden 335 Gefäßpflanzenarten identifiziert, von denen 22 nach nationalem Recht geschützt und zwei Arten in Rumänien endemisch sind. Eine Art ist durch die FFH-Richtlinie geschützt, nämlich *Pontechium maculatum.*

Die Untersuchung der Wiesennutzung und der Besitzverhältnisse ergab, dass zwei der Wiesen seit mindestens 140 Jahren kontinuierlich als Heuwiesen bewirtschaftet wurden, während bei der dritten Wiese die kontinuierliche Nutzung für etwa 40 Jahre unterbrochen wurde, als sie als Weide für Milchkühe diente. Die Wiesen weisen alle die gleiche Flurform auf, die durch Hunderte kleiner und schmaler Parzellen gekennzeichnet ist und deren Ursprung mindestens 100 Jahre zurückreicht. Viele der Parzellen sind nicht im Grundbuch eingetragen, was ein erhöhtes Risiko des Verlustes der Eigentumsrechte mit sich bringt und sich bereits jetzt auf die Bewirtschaftungs- und Schutzmöglichkeiten auswirkt.

Die Wiesen wurden traditionell einmal im Jahr von Juni bis August gemäht, nicht gedüngt und im Frühjahr und Herbst von Rindern und Schafen beweidet. Die Mahdperiode dauerte im Allgemeinen mehrere Wochen. Die Wiesen waren bis in die 90er Jahre des letzten Jahrhunderts nahezu gehölzfrei und unterschieden sich dadurch von ihrem heutigen, fast savannenartigen Erscheinungsbild.

Die im Zeitraum 2010 bis 2014 jährlich erfasste gemähte Fläche war wesentlich kleiner als die Gesamtfläche der Heuwiesen und lag zwischen 0,2 % und 53 %. Die Heuwiesen unterschieden sich hinsichtlich des Anteils an gemähter Fläche, die darüber hinaus von Jahr zu Jahr variierte und in den Jahren 2012 und 2013 am größten war. Dies könnte mit der Einführung von Vertragsnaturschutzprogrammen im Untersuchungsgebiet zusammenhängen. Für die Zeiträume, in denen die traditionelle kleinteilige Flurform respektiert wurde, wird ein mosaikartiges, räumlich und zeitlich heterogenes Mahdmuster angenommen, welches im Allgemeinen gute Voraussetzungen für eine hohe Lebensraum- und Artenvielfalt schafft. Die wichtigsten Landnutzungsänderungen in der postkommunistischen Ära waren ganzjährige Schafbeweidung, Mahdaufgabe und daraus resultierende Verbuschung.

Die Wiesensteppen zeichneten sich - wie vermutet - durch sehr hohe Alpha-Diversitätswerte aus, was auch durch einen der weltweit höchsten Werte für den Artenreichtum von Gefäßpflanzen auf 0,01 m^2 belegt werden konnte (26 Arten). Die kurzfristige Einstellung der Mahd in den Wiesensteppen führte zu einem Rückgang des Gefäßpflanzenartenreichtums und zu einer Verschiebung der Artenzusammensetzung innerhalb des typischen Arteninventars des *Polygalo-Brachypodietum pinnati*. Die Umwandlung der traditionellen Wiesen in Schafweiden führte zu einem Rückgang des Artenreichtums und der Evenness der Gefäßpflanzen und zu einer Verdrängung der typischen Wiesenarten durch Arten anderer Gesellschaften, einschließlich Ruderalvegetation.

Die beweideten Bestände wiesen einen signifikant höheren durchschnittlichen Anteil an Graminoiden und einen geringeren Anteil an Kräutern und Leguminosen auf als die gemähten und ungemähten Bestände. In den gemähten Beständen hatten folgende Arten einen hohen diagnostischen Wert: *Rhinanthus rumelicus, Prunella grandiflora, Ferulago sylvatica, Tragopogon pratensis* subsp. *orientalis* und *Crepis biennis*. In den ungemähten Beständen waren dies *Dichoropetalum carvifolia, Cirsium pannonicum* und *Carex michelii* und in den beweideten Beständen *Daucus carota, Carex distans, Cirsium furiens, Agrimonia eupatoria, Xeranthemum cylindraceum* und *Carlina vulgaris.*

Diese Dissertation bietet einen ganzheitlichen Blick auf die traditionellen Heuwiesen des Untersuchungsgebietes und zeigt mögliche Faktoren auf, die zu der hohen Pflanzenartenvielfalt der Wiesensteppen sowie dem einzigartigen gemeinsamen Vorkommen aller europäischen *Phengaris*-Taxa geführt haben könnten: ein abiotisch bedingtes heterogenes Vegetationsmuster, eine kleinteilige Flurform und daraus hervorgehend ein mosaikartiges Nutzungsmuster sowie die lange Kontinuität der extensiven Bewirtschaftung.

Die bestehenden Gesetze zum Grünlandschutz, der Schutzstatus innerhalb eines FFH-Gebietes und die verfügbaren Vertragsnaturschutzprogramme scheinen die wertvollen Grünlandflächen angesichts der verzögerten Landrückgabe, illegalen Schafbeweidung und des Rückgangs der kleinbäuerlichen Landwirtschaft jedoch nicht in ausreichendem Maße schützen zu können. Die vorliegende Dissertation diskutiert daher geeignete Managementmaßnahmen sowie Strategien für einen erfolgreichen Schutz der untersuchten Heuwiesen. Diese umfassen den Erwerb von Wiesenflächen durch Naturschutzorganisationen sowie die Aufrechterhaltung der noch bestehenden landwirtschaftlichen Nutzung durch die Förderung und Weiterentwicklung nachhaltiger Bewirtschaftungsarten.

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The greatest support, finally, has come from my husband Jan Dirk Schierloh - my greatest thanks also go to him. The fact that this journey has come to a happy end is also due to him, the best travelling companion imaginable.

Annexes

Annex 1: Sorted phytosociological table

The table is inserted as an attachment.

Annex 2: Additional header data of the phytosociological table

The following table shows selected header data for the 102 relevés analysed in the phytosociological study, including information about the surveyors, environmental parameters (aspect, inclination, altitude), as well as the date and coordinates of the relevés. The parameters total vegetation cover, relevé area and species number are included into the sorted phytosociological table shown in Annex 1.

Original relevé number	Comm.	Hay mead.	Sur-veyor	Apect (°)	Incli-nation (°)	Alti-tude (m)	Year	Month	Day	Latitude	Longitude
30	5	L	1	360	2	457	2009	8	4	46.921687	23.734305
34	9	G	6	-	-	461	2009	7	-	46.887343	23.712593
35	9	G	6	-	-	463	2009	7	-	46.887228	23.712477
36	3	V	1	360	1	411	2009	8	4	46.926199	23.728315
37	2	V	1	360	3	390	2009	8	4	46.928131	23.728458
38	3	L	6	-	-	441	2009	7	-	46.922506	23.735649
38	7	V	1	360	0	383	2009	8	4	46.929430	23.726437
39	3	L	6	-	-	447	2009	7	-	46.922211	23.734636
39	8	V	1	360	1	390	2009	8	4	46.928131	23.728458
40	3	L	6	-	-	450	2009	7	-	46.921853	23.735228
41	3	L	6	-	-	451	2009	7	-	46.921943	23.735004
41	5	V	1	360	3	404	2009	8	4	46.928683	23.719545
45	3	V	6	-	-	409	2009	7	-	46.928018	23.718496
46	3	V	6	-	-	429	2009	7	-	46.925462	23.722763
131	7	J	6	-	-	437	2009	7	-	46.891213	23.674442
132	8	J	6	-	-	450	2009	7	-	46.893410	23.671313
530	7	V	4	360	0	438	2009	8	3	46.925232	23.721442
531	7	V	4	360	0	438	2009	8	3	46.925283	23.720802
532	7	V	4	360	0	431	2009	8	3	46.926033	23.719552
533	7	V	4	360	0	429	2009	8	3	46.926213	23.720292
534	7	V	4	360	0	440	2009	8	3	46.926310	23.720910
535	5	V	4	360	0	436	2009	8	3	46.925573	23.719852
536	2	V	4	360	0	409	2009	8	3	46.927162	23.721642
1001	6	L	2	360	2	416	2009	7	22	46.924486	23.735049
1002	7	L	2	360	4	419	2009	7	22	46.924476	23.734848
1003	6	L	2	360	5	419	2009	7	22	46.924452	23.734860
1004	6	L	2	360	1	428	2009	7	22	46.923746	23.734319
1005	7	L	2	360	5	429	2009	7	22	46.923729	23.734409
1006	6	L	2	360	3	430	2009	7	22	46.923748	23.733989
1007	7	L	2	360	2	428	2009	7	22	46.923943	23.733638
1008	2	L	2	360	0	-	2009	7	22	46.923943	23.733638
1010	7	L	2	360	5	438	2009	7	22	46.923819	23.732646
1011	6	L	2	360	3	452	2009	7	22	46.922613	23.734217
1012	3	L	2	360	0	468	2009	7	23	46.920976	23.734092

Original relevé number	Comm.	Hay mead.	Sur-veyor	Apect (°)	Incli-nation (°)	Alti-tude (m)	Year	Month	Day	Latitude	Longitude
1013	3	L	2	360	2	457	2009	7	23	46.922312	23.734595
1014	3	L	2	360	2	-	2009	7	23	46.921728	23.734889
1015	3	L	2	360	3	457	2009	7	23	46.922312	23.734595
1016	6	L	2	360	1	456	2009	7	23	46.922289	23.734938
1017	3	L	2	360	2	453	2009	7	23	46.922388	23.735735
1018	6	L	2	360	0	-	2009	7	23	-	-
1019	7	L	2	360	5	-	2009	7	23	-	-
1020	4	L	2	360	0	402	2009	7	23	46.925210	23.737925
1031	4	G	2	338	2	413	2009	7	24	46.888481	23.707830
1032	4	G	2	338	3	421	2009	7	24	46.888694	23.707840
1033	4	G	2	338	2	422	2009	7	24	46.888499	23.707444
1034	4	G	2	315	0	408	2009	7	24	46.889799	23.709054
1035	7	G	2	338	15	422	2009	7	24	46.888085	23.706728
1036	7	G	2	360	5	435	2009	7	24	46.887703	23.708290
1053	4	G	3	-	0	364	2009	7	30	46.891838	23.706351
1054	3	G	3	-	0	370	2009	7	30	46.891352	23.706403
1055	1	G	3	-	0	395	2009	7	30	46.889797	23.706357
1056	4	G	3	-	0	431	2009	7	30	46.887147	23.701828
1057	6	G	3	-	0	430	2009	7	30	46.887142	23.701327
1058	3	G	3	-	0	430	2009	7	30	46.887238	23.700976
1059	7	G	3	360	5	423	2009	7	30	46.887849	23.699763
1060	4	G	3	-	0	431	2009	7	30	46.886594	23.699728
1061	4	G	3	-	0	443	2009	7	30	46.885950	23.698931
1062	4	G	3	-	0	445	2009	7	30	46.886455	23.689990
1202E	8	G	9	315	9	397	2012	6	27	46.889650	23.701590
1203E	7	G	8	360	12	419	2012	6	28	46.887900	23.698730
1204E	7	G	8	360	10	414	2012	6	28	46.888120	23.698440
1205E	7	G	7	315	5	377	2012	7	4	46.890520	23.694350
1206E	8	G	7	360	5	416	2012	7	8	46.888680	23.702460
1207E	8	G	7	360	10	418	2012	7	8	46.888210	23.701870
1208D	8	G	1	360	12	374	2012	7	11	46.890310	23.693610
1209D	7	G	1	45	15	396	2012	7	11	46.890230	23.689350
1210D	8	G	1	360	6	403	2012	7	11	46.889560	23.690360
1211D	7	G	10	45	10	450	2012	7	13	46.885920	23.697390
1212D	8	G	7	270	8	397	2012	7	14	46.890800	23.701600
1213D	7	G	7	23	8	436	2012	7	15	46.886640	23.697370
1215D	8	G	12	270	8	425	2012	7	26	46.887990	23.697390
1216D	7	G	1	360	5	439	2012	8	16	46.886720	23.690730
1217D	5	G	1	315	10	384	2012	8	17	46.890240	23.700720
1220D	7	G	1	68	5	441	2012	8	18	46.886830	23.693900
1301D	7	V	7	45	9	416	2013	7	16	46.926638	23.726336
1302D	7	V	7	45	4	453	2013	7	18	46.925003	23.718610
1303D	7	V	7	45	10	430	2013	7	23	46.926420	23.717740
1304D	7	V	7	45	12	434	2013	7	23	46.926060	23.718750
1305D	7	V	7	360	10	430	2013	7	23	46.926420	23.717740

Original relevé number	Comm.	Hay mead.	Sur-veyor	Apect (°)	Incli-nation (°)	Alti-tude (m)	Year	Month	Day	Latitude	Longitude
1306D	7	V	7	315	3	457	2013	7	24	46.926600	23.715730
1307D	7	V	7	45	1	442	2013	7	25	46.927560	23.714880
1308D	7	V	7	45	12	451	2013	8	2	46.924490	23.720070
1309D	8	H	4	45	8	437	2013	8	4	46.936570	23.700850
1310D	7	H	7	45	5	443	2013	8	4	46.935930	23.700890
1311D	7	H	4	90	10	436	2013	8	4	46.937230	23.701420
1312D	8	H	7	90	6	447	2013	8	4	46.938160	23.700320
1313D	7	H	7	90	1	424	2013	8	5	46.934540	23.701490
1314D	8	J	7	360	7	443	2013	8	6	46.891840	23.673260
1315D	7	V	5	23	14	431	2013	8	10	46.926250	23.718760
1316D	7	V	5	45	10	461	2013	8	11	46.925750	23.716550
1317D	5	H	5	360	1	432	2013	8	11	46.934870	23.703020
1318D	5	H	5	90	1	427	2013	8	11	46.936940	23.702290
1319D	8	J	4	45	8	445	2013	8	12	46.893900	23.671990
1320D	8	J	5	45	3	445	2013	8	12	46.893100	23.671730
1321D	8	J	4	45	1	429	2013	8	12	46.892570	23.673370
1322D	8	J	5	45	3	429	2013	8	12	46.892470	23.674290
1323D	5	L	5	360	3	452	2013	8	13	46.922560	23.735640
1324D	5	L	5	360	2	443	2013	8	13	46.922500	23.735360
1325D	3	H	5	315	2	420	2013	8	16	46.936630	23.702710
1326D	5	H	5	23	2	429	2013	8	16	46.936320	23.702640
1327D	3	L	5	23	1	458	2013	8	16	46.922160	23.734340
1328D	5	L	4	23	5	457	2013	8	18	46.921810	23.735480

Comm: plant community: 1: *Caricetum vesicariae*, 2: *Mentho longifoliae-Juncetum inflexi*, 3: *Molinietum caeruleae*, 4: *Calamagrostis epigejos*-[Molinietalia caeruleae]-community, 5: *Brachypodio pinnati-Molinietum arundinaceae*, 6: *Festuca pratensis*-[Cirsio-Brachypodion pinnati]-community, 7: *Polygalo majoris-Brachypodietum pinnati*, 8: *Cirsium furiens-Brachypodium pinnatum*-[Cirsio-Brachypodion pinnati]-community, 9: *Danthonio-Stipetum stenophyllae*

Hay mead.: surveyed hay meadow: L: Lord’s Meadow, G: Great Meadow, V: Village Meadow, J: Jacob’s Meadow, H: Meadow Hill

Surveyors: 1: Inge Paulini & Monica Beldean, 2: Inge Paulini & Dr. Sabin Bădărău, 3: Dr. Sabin Bădărău & Dr. Cristian Maloş, 4: Monica Beldean, 5: Inge Paulini, 6: Dr. Marius Bărbos, 7: Inge Paulini & Beatrice Biro, 8: Inge Paulini, Monica Beldean & Beatrice Biro, 9: Inge Paulini, Monica Beldean, Beatrice Biro & Emilia Stoianov, 10: Monica Beldean & Beatrice Biro, 12: Beatrice Biro & Emilia Stoianov

Quantification of contribution to relevés for each person: Inge Paulini (n = 71), Dr. Sabin Bădărău (n = 36), Monica Beldean (n = 30), Beatrice Biro (n = 22), Dr. Marius Bărbos (n = 10), Dr. Cristian Maloș (n = 10), Emilia Stoianov (n = 2)

Annex 3: List of vascular plant species

The following species list includes 320 vascular plant species found in the 102 analysed relevés made in the *utilised* and *former hay meadows*, complemented by 15 species observed in the meadows outside the relevés in the years 2008-2013 (see also Chapter 3.3.11).

Species name	Species name with author	Selected synonyms	Family	No.	Diver-sity	Cons.
Achillea millefolium	Achillea millefolium L.		Asteraceae	90	x	
Achillea setacea	Achillea setacea Waldst. & Kit.		Asteraceae	1		
Adonis vernalis	Adonis vernalis L.		Ranunculaceae	26	x	v (D)
Agrimonia eupatoria	Agrimonia eupatoria L.		Rosaceae	34	x	
Agrostis canina	Agrostis canina L.		Poaceae	3	x	
Agrostis capillaris	Agrostis capillaris L.	Agrostis tenuis Sibth.	Poaceae	29	x	
Agrostis stolonifera	Agrostis stolonifera L.		Poaceae	33	x	
Allium fuscum	Allium fuscum Waldst. & Kit.	Allium paniculatum subsp. fuscum (Waldst. & Kit.) Arcang.	Amaryllidaceae	1	x	
Allium oleraceum	Allium oleraceum L.		Amaryllidaceae	10	x	
Allium scorodoprasum	Allium scorodoprasum L.		Amaryllidaceae	1	x	
Alopecurus pratensis	Alopecurus pratensis L.		Poaceae	7		
Anacamptis coriophora	Anacamptis coriophora (L.) R. M. Bateman, Pridgeon & M. W. Chase	Orchis coriophora L.	Orchidaceae			r (O)
Anacamptis morio	Anacamptis morio (L.) R. M. Bateman, Pridgeon & M. W. Chase	Orchis morio L.	Orchidaceae			r (O)
Anacamptis palustris subsp. elegans	Anacamptis palustris subsp. elegans (Heuff.) R. M. Bateman, Pridgeon & M. W. Chase	Orchis palustris subsp. elegans (Heuff.) Soó, Orchis laxiflora subsp. elegans (Heuff.) Soó	Orchidaceae			r (O)
Anagallis arvensis	Anagallis arvensis L.		Primulaceae	1		
Anemone sylvestris	Anemone sylvestris L.		Ranunculaceae			
Anthericum ramosum	Anthericum ramosum L.		Asparagaceae	34	x	
Anthoxanthum odoratum	Anthoxanthum odoratum L.		Poaceae	23	x	
Anthyllis vulneraria	Anthyllis vulneraria L.		Fabaceae	1		
Arabis hirsuta	Arabis hirsuta (L.) Scop.		Brassicaceae	1	x	
Arenaria serpyllifolia	Arenaria serpyllifolia L.		Caryophyllaceae	8	x	
Aristolochia clematitis	Aristolochia clematitis L.		Aristolochiaceae	1	x	
Arrhenatherum elatius	Arrhenatherum elatius (L.) J. Presl & C. Presl		Poaceae	5		
Artemisia absinthium	Artemisia absinthium L.		Asteraceae	1		
Asparagus officinalis	Asparagus officinalis L.		Asparagaceae	3		
Asperula cynanchica	Asperula cynanchica L.		Rubiaceae	55	x	

Species name	Species name with author	Selected synonyms	Family	No.	Diver-sity	Cons.
Astragalus monspessulanus	Astragalus monspessulanus L.		Fabaceae	1	x	
Avenula pubescens	Avenula pubescens (Huds.) Dumort.		Poaceae	3		
Bothriochloa ischaemum	Bothriochloa ischaemum (L.) Keng	Dichanthium ischaemum (L.) Roberty, Andropogon ischaemum L.	Poaceae	2	x	
Brachypodium pinnatum	Brachypodium pinnatum (L.) P. Beauv.		Poaceae	59	x	
Briza media	Briza media L.		Poaceae	49	x	
Bromopsis erecta	Bromopsis erecta (Huds.) Fourr.	Bromus erectus Huds.	Poaceae	11	x	
Bromopsis inermis	Bromopsis inermis (Leyss.) Holub	Bromus inermis Leyss.	Poaceae	1	x	
Bupleurum falcatum	Bupleurum falcatum L.		Apiaceae	16	x	
Calamagrostis epigejos	Calamagrostis epigejos (L.) Roth		Poaceae	21	x	
Calystegia sepium	Calystegia sepium (L.) R. Br.		Convolvulaceae	3		
Camelina microcarpa	Camelina microcarpa Andrz. ex DC.		Brassicaceae	1	x	
Campanula bononiensis	Campanula bononiensis L.		Campanulaceae	1	x	
Campanula glomerata	Campanula glomerata L.		Campanulaceae	29	x	
Campanula patula	Campanula patula L.		Campanulaceae	2	x	
Campanula persicifolia	Campanula persicifolia L.		Campanulaceae	1		
Campanula sibirica	Campanula sibirica L.		Campanulaceae	1	x	
Cardamine hirsuta	Cardamine hirsuta L.		Brassicaceae	2	x	
Carduus acanthoides	Carduus acanthoides L.		Asteraceae	1	x	
Carex caryophyllea	Carex caryophyllea Latourr.	Carex praecox Jacq., nom. illeg.	Cyperaceae	28	x	
Carex distans	Carex distans L.		Cyperaceae	24	x	
Carex filiformis	Carex filiformis L.	Carex tomentosa L.	Cyperaceae	59	x	
Carex hirta	Carex hirta L.		Cyperaceae	15	x	
Carex humilis	Carex humilis Leyss.		Cyperaceae			
Carex michelii	Carex michelii Host		Cyperaceae	15	x	
Carex montana	Carex montana L.		Cyperaceae	13	x	
Carex riparia	Carex riparia Curtis		Cyperaceae	1		
Carex vesicaria	Carex vesicaria L.		Cyperaceae	1		
Carex vulpina	Carex vulpina L.		Cyperaceae	1		
Carlina vulgaris	Carlina vulgaris L.		Asteraceae	6	x	
Carum carvi	Carum carvi L.		Apiaceae	8		
Caucalis platycarpos	Caucalis platycarpos L.		Apiaceae	1	x	
Centaurea jacea	Centaurea jacea L.		Asteraceae	18	x	
Centaurea nigrescens	Centaurea nigrescens Willd.		Asteraceae	1		
Centaurea phrygia	Centaurea phrygia L.		Asteraceae	83	x	
Centaurea scabiosa	Centaurea scabiosa L.		Asteraceae	46	x	

Species name	Species name with author	Selected synonyms	Family	No.	Diver-sity	Cons.
Centaurium pulchellum	Centaurium pulchellum (Sw.) Druce		Gentianaceae	1	x	
Cerastium fontanum subsp. vulgare	Cerastium fontanum subsp. vulgare (Hartm.) Greuter & Burdet	Cerastium holosteoides Fr.	Caryophyllaceae	1	x	
Cerastium pumilum subsp. glutinosum	Cerastium pumilum subsp. glutinosum (Fr.) Jalas	Cerastium glutinosum Fr.	Caryophyllaceae	9	x	
Cerinthe minor	Cerinthe minor L.		Boraginaceae	4	x	
Cichorium intybus	Cichorium intybus L.		Asteraceae	19	x	
Cirsium arvense	Cirsium arvense (L.) Scop.		Asteraceae	4	x	
Cirsium canum	Cirsium canum (L.) All.		Asteraceae	28	x	
Cirsium furiens	Cirsium furiens Griseb. & Schenk		Asteraceae	4	x	e, k (D)
Cirsium oleraceum	Cirsium oleraceum (L.) Scop.		Asteraceae	1		
Cirsium pannonicum	Cirsium pannonicum (L.f.) Link	Cirsium canum subsp. pannonicum (L. f.) Stoj. & Stef.	Asteraceae	12	x	
Cirsium vulgare	Cirsium vulgare (Savi) Ten.		Asteraceae	10	x	
Clematis integrifolia	Clematis integrifolia L.		Ranunculaceae	20	x	
Clematis recta	Clematis recta L.		Ranunculaceae	19	x	
Clinopodium vulgare	Clinopodium vulgare L.	Calamintha vulgaris (L.) Druce	Lamiaceae	8	x	
Colchicum autumnale	Colchicum autumnale L.		Colchicaceae	19	x	
Convolvulus arvensis	Convolvulus arvensis L.		Convolvulaceae	50	x	
Cornus sanguinea	Cornus sanguinea L.		Cornaceae	1	x	
Crataegus monogyna	Crataegus monogyna Jacq.		Rosaceae	47	x	
Crepis biennis	Crepis biennis L.		Poaceae	5	x	
Crepis setosa	Crepis setosa Haller f.		Poaceae	9		
Cruciata glabra	Cruciata glabra (L.) Ehrend.	Galium vernum Scop.	Rubiaceae	25	x	
Cruciata laevipes	Cruciata laevipes Opiz	Galium cruciata (L.) Scop.	Rubiaceae	22	x	
Cuscuta epithymum	Cuscuta epithymum (L.) L.		Convolvulaceae	3	x	
Cyanus triumfettii	Cyanus triumfettii (All.) Á. Löve & D. Löve	Centaurea triumfetti All.	Asteraceae	3	x	
Cynosurus cristatus	Cynosurus cristatus L.		Poaceae	6	x	
Cytisus albus	Cytisus albus Hacq.	Chamaecytisus albus (Hacq.) Rothm.	Fabaceae	18	x	
Dactylis glomerata	Dactylis glomerata L.		Poaceae	67	x	
Dactylorhiza incarnata subsp. incarnata	Dactylorhiza incarnata subsp. incarnata (L.) Soó	Dactylorhiza latifolia (L.) Soó	Orchidaceae			r (O) / v (B)
Danthonia alpina	Danthonia alpina Vest	Danthonia calycina (Vill.) Rchb., Danthonia provincialis DC.	Poaceae	32	x	

Species name	Species name with author	Selected synonyms	Family	No.	Diver-sity	Cons.
Daucus carota	Daucus carota L.		Apiaceae	43	x	
Deschampsia cespitosa	Deschampsia cespitosa (L.) P.Beauv.		Poaceae	12	x	
Dianthus carthusianorum	Dianthus carthusianorum L.		Caryophyllaceae	10	x	
Dichoropetalum carvifolia	Dichoropetalum carvifolia (Vill.) Pimenov & Kljuykov	Peucedanum carvifolia Vill.	Apiaceae	25		
Dictamnus albus	Dictamnus albus L.		Rutaceae			v / r (O)
Dipsacus laciniatus	Dipsacus laciniatus L.		Dipsacaceae	3		
Dorycnium pentaphyllum subsp. herbaceum	Dorycnium pentaphyllum subsp. herbaceum (Vill.) Bonnier & Layens	Dorycnium herbaceum Vill.	Fabaceae	18	x	
Echium vulgare	Echium vulgare L.		Boraginaceae	6	x	
Elytrigia intermedia	Elytrigia intermedia (Host) Nevski	Elymus hispidus (Opiz) Melderis, Agropyron intermedium (Host) P. Beauv.	Poaceae	52	x	
Elytrigia repens	Elytrigia repens (L.) Nevski	Elymus repens (L.) Gould	Poaceae	4	x	
Epilobium hirsutum	Epilobium hirsutum L.		Onagraceae	1		
Epilobium palustre	Epilobium palustre L.		Onagraceae	1		
Equisetum arvense	Equisetum arvense L.		Equisetaceae	32	x	
Equisetum ramosissimum	Equisetum ramosissimum Desf.		Equisetaceae	1	x	
Equisetum telmateia	Equisetum telmateia Ehrh.		Equisetaceae	3		
Erigeron acris	Erigeron acris L.		Asteraceae	2	x	
Erigeron annuus	Erigeron annuus (L.) Desf.		Asteraceae	3	x	
Erigeron canadensis	Erigeron canadensis L.	Conyza canadensis (L.) Cronquist	Asteraceae	3		
Eryngium campestre	Eryngium campestre L.		Apiaceae	11	x	
Eryngium planum	Eryngium planum L.		Apiaceae	2		
Euphorbia cyparissias	Euphorbia cyparissias L.		Euphorbiaceae	1		
Euphorbia epithymoides	Euphorbia epithymoides L.	Euphorbia polychroma A. Kern.	Euphorbiaceae	4		
Euphorbia esula	Euphorbia esula L.		Euphorbiaceae	51	x	
Euphorbia illirica	Euphorbia illirica Lam.	Euphorbia villosa Waldst. & Kit. ex Willd.	Euphorbiaceae	3	x	
Euphorbia platyphyllos	Euphorbia platyphyllos L.		Euphorbiaceae	1		
Euphrasia pectinata	Euphrasia pectinata Ten.	Euphrasia tatarica Spreng.	Orobanchaceae	2	x	
Falcaria vulgaris	Falcaria vulgaris Bernh.		Apiaceae	5	x	
Fallopia convolvulus	Fallopia convolvulus (L.) Á. Löve		Polygonaceae	1		
Ferulago sylvatica	Ferulago sylvatica (Besser) Rchb.		Apiaceae	6	x	

Species name	Species name with author	Selected synonyms	Family	No.	Diver-sity	Cons.
Festuca arundinacea	Festuca arundinacea Schreb.	Schedonorus arundinaceus (Schreb.) Dumort., Lolium arundinaceum (Schreb.) Darbysh.	Poaceae	31	x	
Festuca pratensis	Festuca pratensis Huds.	Schedonorus pratensis (Huds.) P. Beauv., Lolium pratense (Huds.) Darbysh.	Poaceae	45	x	
Festuca stricta subsp. sulcata	Festuca stricta subsp. sulcata (Hack.) Pils	Festuca rupicola Heuff.	Poaceae	63	x	
Festuca valesiaca	Festuca valesiaca Gaudin		Poaceae	2		
Filipendula vulgaris	Filipendula vulgaris Moench	Filipendula hexapetala Gilib., nom. inval.	Rosaceae	90	x	
Fragaria viridis	Fragaria viridis Weston		Rosaceae	58	x	
Galium album	Galium album Mill.		Rubiaceae	1		
Galium boreale	Galium boreale L.		Rubiaceae	34	x	
Galium glaucum	Galium glaucum L.		Rubiaceae	1	x	
Galium lucidum	Galium lucidum All.		Rubiaceae	1		
Galium mollugo	Galium mollugo L.		Rubiaceae	46		
Galium palustre	Galium palustre L.		Rubiaceae	2		
Galium rubioides	Galium rubioides L.		Rubiaceae	2		
Galium verum	Galium verum L.		Rubiaceae	82	x	
Genista tinctoria	Genista tinctoria L.		Fabaceae	20	x	
Gentiana cruciata	Gentiana cruciata L.		Gentianaceae	6	x	
Gentiana pneumonanthe	Gentiana pneumonanthe L.		Gentianaceae	17	x	v (B)
Geranium dissectum	Geranium dissectum L.		Geraniaceae	1		
Geranium pratense	Geranium pratense L.		Geraniaceae	5	x	
Geranium sanguineum	Geranium sanguineum L.		Geraniaceae	23	x	
Gladiolus imbricatus	Gladiolus imbricatus L.		Iridaceae	1	x	r (D)
Glechoma hederacea	Glechoma hederacea L.		Lamiaceae	9	x	
Glechoma hirsuta	Glechoma hirsuta Waldst. & Kit.		Lamiaceae	4	x	
Gymnadenia conopsea	Gymnadenia conopsea (L.) R. Br.		Orchidaceae			r (O)
Helictochloa pratensis	Helictochloa pratensis (L.) Romero Zarco	Avena pratensis L., Helictotrichon pratense (L.) Besser	Poaceae	1		
Heracleum sphondylium	Heracleum sphondylium L.		Apiaceae	10	x	
Hieracium umbellatum	Hieracium umbellatum L.		Asteraceae	4	x	
Hypericum perforatum	Hypericum perforatum L.		Hypericaceae	7	x	
Inula britannica	Inula britannica L.		Asteraceae	20	x	
Inula germanica	Inula germanica L.		Asteraceae	2	x	
Inula helenium	Inula helenium L.		Asteraceae	1		
Inula hirta	Inula hirta L.		Asteraceae	11	x	
Inula salicina	Inula salicina L.		Asteraceae	46	x	

Species name	Species name with author	Selected synonyms	Family	No.	Diver-sity	Cons.
Iris aphylla	Iris aphylla L.	Iris hungarica Waldst. & Kit.	Iridaceae	1		HD*, r (D)
Iris graminea	Iris graminea L.		Iridaceae			
Iris pseudacorus	Iris pseudacorus L.		Iridaceae	1		
Iris sibirica	Iris sibirica L.		Iridaceae	9	x	r (D), v (B)
Iris variegata	Iris variegata L.		Iridaceae			
Jacobaea erucifolia	Jacobaea erucifolia (L.) G. Gaertn. & al.	Senecio erucifolius L.	Asteraceae	3		
Jacobaea vulgaris	Jacobaea vulgaris Gaertn.	Senecio jacobaea L.	Asteraceae	16		
Juncus articulatus	Juncus articulatus L.		Juncaceae	5		
Juncus compressus	Juncus compressus Jacq.		Juncaceae	1	x	
Juncus effusus	Juncus effusus L.		Juncaceae	2	x	
Juncus inflexus	Juncus inflexus L.		Juncaceae	6		
Juncus tenuis	Juncus tenuis Willd.		Juncaceae	1		
Jurinea transylvanica	Jurinea transylvanica (Spreng.) Simonk.	Jurinea mollis subsp. transylvanica (Spreng.) Nyman, Serratula transylvanica Spreng.	Asteraceae	1	x	e; r (D, O)
Klasea radiata	Klasea radiata (Waldst. & Kit.) Á. Löve & D. Löve	Serratula radiata (Waldst. & Kit.) M. Bieb.	Asteraceae	1		r (O)
Knautia arvensis	Knautia arvensis (L.) Coult.		Dipsacaceae	60	x	
Koeleria macrantha	Koeleria macrantha (Ledeb.) Schult.	Koeleria gracilis Pers.	Poaceae	19	x	
Laserpitium latifolium	Laserpitium latifolium L.		Apiaceae	2	x	
Lathyrus latifolius	Lathyrus latifolius L.		Fabaceae	22	x	
Lathyrus pallescens	Lathyrus pallescens (M. Bieb.) K. Koch		Fabaceae	1		
Lathyrus pratensis	Lathyrus pratensis L.		Fabaceae	15	x	
Lathyrus tuberosus	Lathyrus tuberosus L.		Fabaceae	1	x	
Lembotropis nigricans	Lembotropis nigricans (L.) Griseb.	Cytisus nigricans L.	Fabaceae	5	x	
Leontodon hispidus	Leontodon hispidus L.		Asteraceae	58	x	
Lepidium campestre	Lepidium campestre (L.) W. T. Aiton		Brassicaceae	1	x	
Leucanthemum vulgare	Leucanthemum vulgare Lam.	Chrysanthemum leucanthemum L.	Asteraceae	56	x	
Linaria vulgaris	Linaria vulgaris Mill.		Plantaginaceae	2		
Linum austriacum	Linum austriacum L.		Linaceae	3	x	
Linum catharticum	Linum catharticum L.		Linaceae	21	x	
Linum flavum	Linum flavum L.		Linaceae	6	x	
Linum hirsutum	Linum hirsutum L.		Linaceae	3		
Linum nervosum	Linum nervosum Waldst. & Kit.		Linaceae	5	x	
Linum perenne	Linum perenne L.		Linaceae	8	x	
Lotus corniculatus	Lotus corniculatus L.		Fabaceae	69	x	
Lotus maritimus	Lotus maritimus L.	Tetragonolobus maritimus (L.) Roth	Fabaceae	12		
Luzula campestris	Luzula campestris (L.) DC.		Juncaceae	3	x	

Species name	Species name with author	Selected synonyms	Family	No.	Diver-sity	Cons.
Lysimachia nummularia	Lysimachia nummularia L.		Primulaceae	15	x	
Lysimachia vulgaris	Lysimachia vulgaris L.		Primulaceae	25	x	
Lythrum salicaria	Lythrum salicaria L.		Lythraceae	24	x	
Lythrum virgatum	Lythrum virgatum L.		Lythraceae	1		
Medicago falcata	Medicago falcata L.	Medicago sativa subsp. falcata (L.) Arcang.	Fabaceae	59	x	
Medicago lupulina	Medicago lupulina L.		Fabaceae	17	x	
Melampyrum cristatum	Melampyrum cristatum L.		Orobanchaceae	2	x	
Melilotus altissimus	Melilotus officinalis (L.) Lam.		Fabaceae	1	x	
Melilotus officinalis	Melilotus officinalis (L.) Lam.		Fabaceae	2		
Mentha aquatica	Mentha aquatica L.		Lamiaceae	2		
Mentha arvensis	Mentha arvensis L.		Lamiaceae	6	x	
Mentha longifolia	Mentha longifolia (L.) L.		Lamiaceae	12	x	
Mentha pulegium	Mentha pulegium L.		Lamiaceae	4		
Mercurialis ovata	Mercurialis ovata Sternb. & Hoppe		Euphorbiaceae	2		r (O)
Molinia arundinacea	Molinia arundinacea Schrank	Molinia caerulea subsp. arundinacea (Schrank) H. K. G. Paul	Poaceae	29	x	
Myosotis arvensis	Myosotis arvensis (L.) Hill		Boraginaceae	1		
Nepeta cataria	Nepeta cataria L.		Lamiaceae	1	x	
Nepeta nuda subsp. nuda	Nepeta nuda subsp. nuda L.	Nepeta pannonica L.	Lamiaceae	13	x	
Nepeta ucranica	Nepeta ucranica L.		Lamiaceae	1	x	v (O), r (B)
Nonea pulla	Nonea pulla DC.		Boraginaceae			
Ochlopoa annua	Ochlopoa annua (L.) H. Scholz	Poa annua L.	Poaceae	1		
Onobrychis arenaria	Onobrychis arenaria (Kit.) DC.		Fabaceae	8		
Onobrychis viciifolia	Onobrychis viciifolia Scop.		Fabaceae	22	x	
Ononis spinosa subsp. hircina	Ononis spinosa subsp. hircina (Jacq.) Gams	Ononis arvensis L., Ononis hircina Jacq.	Fabaceae	61	x	
Origanum vulgare	Origanum vulgare L.		Lamiaceae	16	x	
Ornithogalum pyramidale	Ornithogalum pyramidale L.		Asparagaceae	2	x	
Ornithogalum umbellatum agg.			Asparagaceae			
Orobanche alba	Orobanche alba Willd.		Orobanchaceae			
Peucedanum cervaria	Peucedanum cervaria (L.) Lapeyr.		Apiaceae	8	x	
Peucedanum oreoselinum	Peucedanum oreoselinum (L.) Moench		Apiaceae	6	x	
Phleum montanum	Phleum montanum K. Koch		Poaceae	1		
Phleum phleoides	Phleum phleoides (L.) H. Karst.		Poaceae	13	x	

Species name	Species name with author	Selected synonyms	Family	No.	Diver-sity	Cons.
Phleum pratense	Phleum pratense L.		Poaceae	15	x	
Phlomis tuberosa	Phlomis tuberosa L.		Lamiaceae	1	x	
Phragmites australis	Phragmites australis (Cav.) Steud.		Poaceae	6	x	
Picris hieracioides	Picris hieracioides L.		Asteraceae	20	x	
Pilosella bauhini	Pilosella bauhini (Schult.) Arv.-Touv.	Hieracium bauhini Schult.	Asteraceae	1		
Pimpinella saxifraga	Pimpinella saxifraga L.		Apiaceae	50	x	
Plantago altissima	Plantago altissima L.		Plantaginaceae	2		
Plantago lanceolata	Plantago lanceolata L.		Plantaginaceae	62	x	
Plantago media	Plantago media L.		Plantaginaceae	57	x	
Poa angustifolia	Poa angustifolia L.	Poa pratensis subsp. angustifolia (L.) Dumort.	Poaceae	18	x	
Poa compressa	Poa compressa L.		Poaceae	14	x	
Poa pratensis	Poa pratensis L.		Poaceae	6	x	
Poa trivialis	Poa trivialis L.		Poaceae	4		
Polygala comosa	Polygala comosa Schkuhr		Polygalaceae	3	x	
Polygala major	Polygala major Jacq.		Polygalaceae	12	x	
Polygonatum odoratum	Polygonatum odoratum (Mill.) Druce		Asparagaceae	2	x	
Polygonum aviculare	Polygonum aviculare L.		Polygonaceae	1		
Pontechium maculatum	Pontechium maculatum (L.) Böhle & Hilger	Echium maculatum L., Echium rubrum Jacq. [non Forssk.], Echium russicum J. F. Gmel.	Boraginaceae	4	x	HD
Potentilla alba	Potentilla alba L.		Rosaceae	23	x	
Potentilla argentea	Potentilla argentea L.		Rosaceae	4	x	
Potentilla heptaphylla	Potentilla heptaphylla L.		Rosaceae	10	x	
Potentilla incana	Potentilla incana G. Gaertn. & al.	Potentilla cinerea Chaix ex Vill.	Rosaceae	3	x	
Potentilla inclinata	Potentilla inclinata Vill.		Rosaceae	2	x	
Potentilla recta	Potentilla recta L.		Rosaceae	7	x	
Potentilla reptans	Potentilla reptans L.		Rosaceae	24	x	
Primula veris	Primula veris L.	Primula officinalis (L.) Hill	Primulaceae	6	x	
Prunella grandiflora	Prunella grandiflora (L.) Scholler		Lamiaceae	33	x	
Prunella laciniata	Prunella laciniata (L.) L.		Lamiaceae	1	x	
Prunella vulgaris	Prunella vulgaris L.		Lamiaceae	15		
Prunus spinosa	Prunus spinosa L.		Rosaceae	15	x	
Pulmonaria mollis	Pulmonaria mollis Hornem.		Boraginaceae	6	x	
Pulsatilla montana	Pulsatilla montana (Hoppe) Rchb.		Ranunculaceae	4	x	
Pyrus communis subsp. pyraster	Pyrus communis subsp. pyraster (L.) Ehrh.		Rosaceae	2		
Ranunculus acris	Ranunculus acris L.		Ranunculaceae	28	x	
Ranunculus polyanthemos	Ranunculus polyanthemos L.		Ranunculaceae	57	x	

Species name	Species name with author	Selected synonyms	Family	No.	Diver-sity	Cons.
Ranunculus repens	Ranunculus repens L.		Ranunculaceae	15	x	
Rhinanthus angustifolius	Rhinanthus angustifolius C. C. Gmel.		Orobanchaceae	1		
Rhinanthus minor	Rhinanthus minor L.		Orobanchaceae	19	x	
Rhinanthus rumelicus	Rhinanthus rumelicus Velen.		Orobanchaceae	19	x	
Rosa canina	Rosa canina L.		Rosaceae	14	x	
Rosa gallica	Rosa gallica L.		Rosaceae	4	x	
Rosa micrantha	Rosa micrantha Sm.		Rosaceae	1		r (O)
Rubus caesius	Rubus caesius L.		Rosaceae	8	x	
Rumex acetosa	Rumex acetosa L.		Polygonaceae	20	x	
Rumex acetosella	Rumex acetosella L.		Polygonaceae	1		
Salix cinerea	Salix cinerea L.		Salicaceae	2		
Salvia austriaca	Salvia austriaca Jacq.		Lamiaceae			
Salvia nemorosa	Salvia nemorosa L.		Lamiaceae	10	x	
Salvia nutans	Salvia nutans L.		Lamiaceae	2		v (D)
Salvia pratensis	Salvia pratensis L.		Lamiaceae	36	x	
Salvia verticillata	Salvia verticillata L.		Lamiaceae	42	x	
Sanguisorba minor	Sanguisorba minor Scop.		Rosaceae	9	x	
Sanguisorba officinalis	Sanguisorba officinalis L.		Rosaceae	38	x	
Scabiosa ochroleuca	Scabiosa ochroleuca L.		Dipsacaceae	40	x	
Scorzoneroides autumnalis	Scorzoneroides autumnalis (L.) Moench	Leontodon autumnalis L.	Asteraceae	8	x	
Securigera varia	Securigera varia (L.) Lassen	Coronilla varia L.	Fabaceae	57	x	
Serratula coronata	Serratula coronata L.	Serratula wolffii Andrae	Asteraceae	8		r (D, O)
Serratula tinctoria	Serratula tinctoria L.		Asteraceae	33	x	
Seseli annuum	Seseli annuum L.		Apiaceae	24	x	
Seseli peucedanoides	Seseli peucedanoides (M. Bieb.) Koso-Pol.		Apiaceae	14	x	r (O)
Silene flos-cuculi	Silene flos-cuculi (L.) Clairv.	Lychnis flos-cuculi L.	Caryophyllaceae			
Silene vulgaris	Silene vulgaris (Moench) Garcke		Caryophyllaceae	1	x	
Solidago virgaurea	Solidago virgaurea L.		Asteraceae	3	x	
Stachys officinalis	Stachys officinalis (L.) Trevis.	Betonica officinalis L.	Lamiaceae	79	x	
Stachys recta	Stachys recta L.		Lamiaceae	13	x	
Stellaria graminea	Stellaria graminea L.		Caryophyllaceae	9	x	
Stipa capillata	Stipa capillata L.		Poaceae	2		
Stipa tirsa	Stipa tirsa Steven	Stipa stenophylla (Czern. ex Lindem.) Trautv.	Poaceae	4	x	
Succisa pratensis	Succisa pratensis Moench		Dipsacaceae	2		
Symphytum officinale	Symphytum officinale L.		Boraginaceae	13	x	
Tanacetum corymbosum	Tanacetum corymbosum (L.) Sch. Bip.	Chrysanthemum corymbosum L.	Asteraceae	1	x	

Species name	Species name with author	Selected synonyms	Family	No.	Diver-sity	Cons.
Taraxacum sect. Taraxacum	Taraxacum sect. Taraxacum F. H. Wigg.	Taraxacum officinale F. H. Wigg., Taraxacum sect. Ruderalia Kirschner & al.	Asteraceae	2	x	
Teucrium chamaedrys	Teucrium chamaedrys L.		Lamiaceae	18	x	
Teucrium montanum	Teucrium montanum L.		Lamiaceae	1		r (D)
Thalictrum aquilegiifolium	Thalictrum aquilegiifolium L.		Ranunculaceae	1		
Thalictrum flavum	Thalictrum flavum L.		Ranunculaceae	5	x	
Thalictrum lucidum	Thalictrum lucidum L.		Ranunculaceae	15		
Thalictrum minus	Thalictrum minus L.		Ranunculaceae	47	x	
Thalictrum simplex subsp. galioides	Thalictrum simplex subsp. galioides (DC.) Korsh.	Thalictrum galioides (DC.) Pers.	Ranunculaceae	1		
Thesium linophyllon	Thesium linophyllon L.		Santalaceae	30	x	
Thymus odoratissimus	Thymus odoratissimus Mill.	Thymus glabrescens Willd.	Lamiaceae	3		
Thymus pulegioides subsp. pannonicus	Thymus pulegioides subsp. pannonicus (All.) Kerguélen	Thymus marschallianus Willd., Thymus pannonicus All.	Lamiaceae	23	x	
Torilis arvensis	Torilis arvensis (Huds.) Link		Apiaceae	2	x	
Tragopogon pratensis subsp. orientalis	Tragopogon pratensis subsp. orientalis (L.) Čelak.	Tragopogon orientalis L.	Asteraceae	14	x	
Trifolium alpestre	Trifolium alpestre L.		Lamiaceae	1	x	
Trifolium campestre	Trifolium campestre Schreb.		Lamiaceae	8	x	
Trifolium hybridum	Trifolium hybridum L.		Lamiaceae	2		
Trifolium medium	Trifolium medium L.		Lamiaceae	12	x	
Trifolium montanum	Trifolium montanum L.		Lamiaceae	46	x	
Trifolium ochroleucon	Trifolium ochroleucon Huds.		Lamiaceae	13	x	
Trifolium pannonicum	Trifolium pannonicum Jacq.		Lamiaceae	19	x	
Trifolium pratense	Trifolium pratense L.		Lamiaceae	6	x	
Trifolium repens	Trifolium repens L.		Lamiaceae	6	x	
Trifolium rubens	Trifolium rubens L.		Lamiaceae	6	x	
Trinia kitaibelii	Trinia kitaibelii M. Bieb.	Trinia ramosissima (Trevir.) W. D. J. Koch	Apiaceae	1	x	r (B)
Trisetum flavescens	Trisetum flavescens (L.) P. Beauv.		Poaceae	29	x	
Valeriana officinalis	Valeriana officinalis L.		Valerianaceae	6	x	
Veratrum nigrum	Veratrum nigrum L.		Melanthiaceae	1		r (O)
Verbascum chaixii	Verbascum chaixii Vill.		Scrophulariaceae	1	x	
Veronica austriaca	Veronica austriaca L.		Plantaginaceae	19	x	
Veronica austriaca subsp. teucrium	Veronica austriaca subsp. teucrium (L.) D. A. Webb	Veronica teucrium L.	Plantaginaceae	2		
Veronica chamaedrys	Veronica chamaedrys L.		Plantaginaceae	25	x	

Species name	Species name with author	Selected synonyms	Family	No.	Diver-sity	Cons.
Veronica orchidea	Veronica orchidea Crantz		Plantaginaceae	14	x	
Veronica persica	Veronica persica Poir.		Plantaginaceae	1		
Veronica prostrata	Veronica prostrata L.	Veronica teucrium L. subsp. prostrata (L.) Rouy	Plantaginaceae	1	x	
Veronica spicata	Veronica spicata L.		Plantaginaceae	4	x	
Vicia cracca	Vicia cracca L.		Fabaceae	17	x	
Vicia hirsuta	Vicia hirsuta (L.) Gray		Fabaceae	1		
Vicia sativa	Vicia sativa L.		Fabaceae	1	x	
Vicia sepium	Vicia sepium L.		Fabaceae	2	x	
Vicia tetrasperma	Vicia tetrasperma (L.) Schreb.		Fabaceae	1	x	
Vincetoxicum hirundinaria	Vincetoxicum hirundinaria Medik.		Apocynaceae	20	x	
Viola canina	Viola canina L.		Violaceae	15	x	
Viola hirta	Viola hirta L.		Violaceae	51	x	
Xanthium strumarium	Xanthium strumarium L.		Asteraceae	4	x	
Xeranthemum cylindraceum	Xeranthemum cylindraceum Sm.		Asteraceae	5	x	

The taxonomy of vascular plants follows the Euro+Med PlantBase (Euro+Med 2006+), except for *Festuca pratensis* Huds. and *Festuca arundinacea* Schreb., which are listed as *Schedonorus pratensis* (Huds.) P. Beauv. and *Schedonorus arundinaceus* (Schreb.) Dumort. in the Euro+Med PlantBase.

No.: number of occurrences in phytosociological relevés; Diversity: occurrence in diversity relevés; Cons.: conservation concern including the Habitats Directive (HD) or national specifications according to (D) = Dihoru and Dihoru (1994), (O) = Oltean et al. (1994), (B) = Boşcaiu et al. (1994), abbreviated by: v = vulnerable, r = rare, e = endemic, k = insufficiently known.

HD*: *Iris aphylla* may be protected by the Habitats Directive, if it is synonymised with *Iris aphylla* subsp. *hungarica*, the latter being listed in the Habitats Directive. *Iris aphylla* subsp. *hungarica* is not mentioned in the floras of Săvulescu (1952-1976) and Ciocârlan (2000), neither in the Euro+Med database (Euro+Med 2006+). Instead, Ciocârlan (2000) and Euro+Med (2006+) list *Iris aphylla* with the synonym *Iris hungarica*, neither of which are included in the Habitats Directive.

Annex 4: Table of the nested-plot series (plot size 10 m^2)

The table is inserted as an attachment.

Annex 5: Nested-plot series 1203 with new species richness record

The following table shows the nested-plot series no. 1203 containing the maximum vascular plant species richness value on 0.01 m^2 which is higher than the published world and Palaearctic record (26 versus 25 species). The series also includes the maximum richness values in the whole dataset for 0.001 m^2, 0.1 m^2, 10 m2, and 25 m^2 and was recorded in the year 2012 in a parcel of land mown for at least two previous years in the Great Meadow (see also Chapter 5.3.1).

Plot name	**Sub-series A**				**Sub-series B**				**Sub-series C**				**1203 D**	**1203 E**
Edge length (cm)	3.16	10.0	31.6	100	3.16	10.0	31.6	100	3.16	10.0	31.6	100	316	500
Area (m^2)	0.001	0.01	0.1	1	0.001	0.01	0.1	1	0.001	0.01	0.1	1	10	25
Vascular plant species richness	**15**	**26***	**37**	**46**	**8**	**17.0**	**27**	**48**	**5**	**14.0**	**32**	**55**	**81**	**87**
Achillea millefolium	x	3.0	x	x				x					1.00	0.50
Agrostis capillaris								x					0.50	0.50
Anthericum ramosum			x	x		2.0	x	x				x	1.50	2.00
Anthoxanthum odoratum								x				x	0.50	0.50
Asperula cynanchica												x	0.10	0.10
Brachypodium pinnatum				x		0.5	x	x		1.5	x	x	2.00	3.50
Briza media			x	x			x	x				x	0.50	0.20
Bromopsis erecta			x	x									0.01	0.01
Bupleurum falcatum											x	x	0.20	0.10
Campanula glomerata								x				x	1.50	1.00
Carex caryophyllea	x	2.0	x	x									1.00	1.00
Carex montana		20.0	x	x	x	3.0	x	x	x	30.0	x	x	35.00	22.00
Carex filiformis		3.0	x	x		10.0	x	x			x	x	1.00	0.50
Centaurea phrygia				x				x					6.00	3.00
Centaurea scabiosa				x				x				x	1.00	0.50
Cerastium pumilum subsp. glutinosum	x	1.0	x	x									0.05	0.01
Cytisus albus				x				x			x	x	2.50	1.50
Cirsium pannonicum		4.0	x	x				x			x	x	2.50	3.00
Colchicum autumnale												x	0.50	0.10
Securigera varia											x	x	0.10	0.10
Crataegus monogyna (herb layer)														0.10
Crepis species													0.10	0.05
Cruciata glabra												x	0.20	0.10
Cruciata laevipes		1.0	x	x			x	x					0.10	0.20
Dactylis glomerata								x					1.00	0.50
Danthonia alpina	x	4.0	x	x					x	8.0	x	x	3.00	2.00
Dorycnium pentaphyllum subsp. herbaceum					x	1.0	x	x					0.50	0.30
Echium vulgare														0.05

Plot name	**Sub-series A**				**Sub-series B**				**Sub-series C**				**1203 D**	**1203 E**
Edge length (cm)	3.16	10.0	31.6	100	3.16	10.0	31.6	100	3.16	10.0	31.6	100	316	500
Area (m^2)	0.001	0.01	0.1	1	0.001	0.01	0.1	1	0.001	0.01	0.1	1	10	25
Vascular plant species richness	**15**	**26***	**37**	**46**	**8**	**17.0**	**27**	**48**	**5**	**14.0**	**32**	**55**	**81**	**87**
Elytrigia intermedia	x	0.5	x	x									20.00	3.00
Euphorbia species			x	x		3.0	x	x					0.01	0.001
Schedonorus pratensis													1.00	1.50
Festuca stricta subsp. sulcata	x	7.0	x	x	x	3.0	x	x		2.0	x	x	15.00	20.00
Filipendula vulgaris	x	20.0	x	x	x	1.0	x	x		18.0	x	x	4.50	4.00
Fragaria viridis	x	3.0	x	x				x			x	x	1.00	0.30
Galium verum			x	x									0.20	0.10
Gentiana cruciata														0.01
Geranium sanguineum				x				x	x	3.0	x	x	4.00	2.00
Heracleum sphondylium												x	1.50	0.50
Hieracium cf praealtum subsp. bauhinii											x	x	0.10	0.10
Inula germanica										2.5	x	x	0.01	0.01
Inula salicina								x					1.50	0.50
Koeleria macrantha	x	1.5	x	x									0.20	0.01
Leontodon hispidus	x	10.0	x	x	x	50.0	x	x		30.0	x	x	3.00	4.00
Leucanthemum vulgare		7.0	x	x		0.5	x	x		2.0	x	x	1.50	0.50
Linum catharticum	x	0.5	x	x				x		0.3	x	x	0.20	0.10
Linum flavum												x	0.10	0.10
Lotus corniculatus												x	0.20	0.20
Medicago falcata				x			x	x				x	1.50	2.50
Onobrychis viciifolia	x	5.0	x	x								x	1.00	1.00
Ononis spinosa subsp. hircina		2.0	x	x				x	x	40.0	x	x	18.00	4.00
Origanum vulgare											x	x	0.05	0.01
Phleum phleoides													0.50	0.10
Picris hieracioides														0.10
Pimpinella saxifraga			x	x		1.0	x	x		0.5	x	x	0.50	0.10
Plantago lanceolata			x	x								x	0.20	0.10
Plantago media			x	x	x	10.0	x	x			x	x	3.00	2.00
Polygala major								x				x	0.30	0.20
Polygonatum odoratum													0.10	0.10
Potentilla species	x	2.0	x	x			x	x					0.40	0.10
Primula veris				x			x	x			x	x	3.00	1.50
Prunella grandiflora		1.5	x	x		3.0	x	x			x	x	20.00	10.00
Prunus spinosa (herb layer)		1.0	x	x			x	x					0.10	0.10
Ranunculus polyanthemos			x	x	x	2.0	x	x				x	1.50	1.00
Rhinanthus rumelicus	x	1.0	x	x				x				x	3.00	1.50

Plot name	**Sub-series A**				**Sub-series B**				**Sub-series C**				**1203 D**	**1203 E**
Edge length (cm)	3.16	10.0	31.6	100	3.16	10.0	31.6	100	3.16	10.0	31.6	100	316	500
Area (m^2)	0.001	0.01	0.1	1	0.001	0.01	0.1	1	0.001	0.01	0.1	1	10	25
Vascular plant species richness	**<u>15</u>**	**<u>26*</u>**	**<u>37</u>**	**46**	**8**	**17.0**	**27**	**48**	**5**	**14.0**	**32**	**55**	**<u>81</u>**	**<u>87</u>**
Rosa canina (herb layer)														0.10
Rumex acetosa													0.10	0.01
Salvia nemorosa								x					0.10	0.01
Salvia pratensis			x	x				x	x	1.0	x	x	2.50	1.20
Salvia verticillata													0.50	0.20
Scabiosa ochroleuca								x			x	x	1.00	0.50
Seseli peucedanoides											x	x	0.50	1.00
Stachys officinalis							x	x			x	x	10.00	3.50
Tanacetum corymbosum											x	x	1.00	1.00
Teucrium chamaedrys								x					0.10	0.10
Thalictrum minus								x			x	x	1.00	0.20
Thesium linophyllon		1.0	x	x			x	x				x	1.00	0.50
Thymus pulegioides subsp. pannonicus												x	1.00	1.00
Tragopogon pratensis subsp. orientalis			x	x			x	x			x	x	0.50	0.40
Trifolium montanum		4.0	x	x		1.0	x	x				x	2.50	0.70
Trifolium pannonicum				x			x	x				x	1.00	1.50
Trifolium pratense											x	x	0.30	0.10
Trisetum flavescens													1.00	0.20
Veronica austriaca				x	x	1.5	x	x				x	0.10	0.05
Veronica chamaedrys												x	0.01	0.01
Veronica orchidea		1.5	x	x									0.05	0.01
Viola hirta	x	0.5	x	x		1.0	x	x		5.0	x	x	3.00	2.50
Xanthium strumarium														0.01

Marked by *: new vascular plant species richness record; underlined species richness numbers: maxima of the whole dataset

Species data: x stands for the presence of the taxon in the plot; empty cells indicate that the taxon is not present; numbers are cover values (in percent)

Header data: date: 28.06.2012; locality: Great Meadow; coordinates: 46.8879, 23.69873; land use variant: mown 2010 and 2011; plant community: *Polygalo majoris -Brachypodietum pinnati*; survey method: any-part; surveyors: Inge Paulini, Beatrice Biro, Monica Beldean; altitude: 419 m; exposition: N; inclination: 12°

Additional header data for the 10 m^2-plot: total cover of plant species: 96 %; cover of bryophyte layer: 10 %; cover of litter layer: 95; cover of bare ground: 0.3 %; no shrub layer; mean lower/higher hight herbs and grasses layer: 30 cm/60 cm