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The effect of habitat continuity and management on species composition and diversity

Master´s thesis

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Prohlášení

Prohlašuji, že jsem závěrečnou práci zpracovala samostatně a že jsem uvedla všechny použité informační zdroje a literaturu. Tato práce ani její podstatná část nebyla předložena k získání jiného nebo stejného akademického titulu.

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Barbora Hubáčková

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Abstrakt

Polopřirozené louky východní Moravy disponují velkým potenciálem hostit druhově bohatá rostlinná společenstva. Nicméně změny ve způsobu využívání půdy během druhé poloviny minulého století byly rychlé a rozsáhlé. Mnoho přirozených luk bylo rozoráno. Koncem 80. a počátkem 90. let byla některá z obdělávaných polí oseta druhově chudou jetelotravní směsí a přeměněna zpět na louky. Obnova luk na bývalých polích je velkou výzvou. Zpětná kolonizace těchto polí může být značně komplikována počátečním osetím druhově chudou produktivní směsí.

Cílem této studie je určit rozdíly v druhové skladbě a druhové bohatosti travních porostů mezi uměle vysetými loukami (na bývalých polích) a fragmentech původních luk s kontinuitou více než 70 let nerušeného vývoje v severní části Bílých Karpat na severovýchodě České republiky a identifikovat druhové vlastnosti, omezující schopnost druhů kolonizovat louky vznikající na bývalých polích.

Vybrané rostlinné druhy (celkem 137 druhů) byly zkoumány na 66 loukách. Zkoumané louky byly klasifikovány podle kontinuity a typu managementu.

Prostorová korelace zkoumaných luk byla posuzována s použitím koordinát centroidu (těžiště) každého polygonu. Vliv kontinuity na druhovou skladbu a diverzitu byl testován až po odfiltrování managementu a abiotických faktorů (TWI, DAHI, svažitost, nadmořská výška). Rozdíly v reakcích druhů na kontinuitu habitatu byly vysvětleny jejich druhovými vlastnostmi (výška rostliny, zoochorie, obsah sušiny v listu, hmotnost semen, specifická listová plocha, šíření větrem, index epizoochorie, mykorrhiza). Ekologické indikační hodnoty byly použity pro rozlišení luk dle výskytu druhů a jejich reakce na několik gradientů (pH, vlhkost, světlo, teplota, živiny, salinity).

Výsledky potvrdily, že obojí – management a kontinuita travních porostů významně ovlivňuje druhovou skladbu. Kontinuita také ovlivňuje druhovou bohatost – bývalá pole přeměněná na louky před 30 lety hostí méně druhů než louky s delší dobou kontinuity. Nebyl zjištěn významný rozdíl v druhové bohatosti mezi kosenými a spásanými loukami. Environmentální proměnné mající významný efekt na druhovou skladbu jsou: koordináty (lokace vzhledem k ostatním loukám), svažitost a nadmořská výška. Koordináty také měli vliv na druhové skladbu a druhovou bohatost, což naznačuje potřebu zabývat se prostorovou korelací.

Klíčová slova: Karpatské louky, druhová bohatost, druhová skladba, management, kontinuita, vlastnosti druhů, obnova travních porostů, bývalá orná půda, abiotické faktory.

Abstract

Semi-natural grasslands of the eastern Moravia have big potential to host species-rich plant communities. However, changes in land-use during the second half of the last century were rapid and vast and many grasslands had been ploughed over. In the early 80s some arable lands were sown with low diversity clover-grass mixture and transferred back to grassland. Restoration of grasslands on former arable fields is a major challenge. Their colonisation by grassland species may be complicated by initial seeding productive low diversity seed mixtures. The aim of this study was to estimate differences in species composition and species diversity between ex-arable artificially seeded grasslands and fragments of grasslands with continuity over 70 years in the north part of White Carpathian Mts., SE Czech Republic and identify species traits limiting species ability to colonize the ex-arable grasslands.

Target plant species (total of 137) were surveyed on 66 grasslands. Surveyed grasslands were according to continuity and type of management.

Coordinates of centroids from each polygon (i. e. surveyed grassland) were used to treat the spatial correlation of the surveyed grasslands. The effect of continuity on species composition and diversity was tested after accounting for differences in the management and abiotic factors (TWI, TPI, DAHI, slope, elevation). Differences in species responses to habitat continuity have been explained by their functional traits (canopy height, zoochory, LDMC, seed mass, SLA and terminal velocity, epizoochory ranking index, and myccorhizal status). Ecological indicator values were used to distinguish grasslands according to species occurrence and their response to several gradients (pH, moisture, light, temperature, nutrients, salinity).

The results showed that both – management and continuity of grassland significantly affect the species composition. Continuity also affects the species diversity – ex-arable plots turned into grasslands 30 years ago host less species than continual plots. But there was no significant difference of species diversity between mown and grazed plots. Environmental variables that had significant effect on species composition were spatial position, slope and elevation. Spatial position also significantly affected the species diversity, which suggests the need to treat spatial correlation.

Keywords: Carpathian grasslands, plant richness, species composition, management, continuity, species traits, grassland restoration, ex-arable land, abiotic factors.

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1 Introduction

On the break into new millennium, we can observe in first site the end of traditional agriculture era. At the beginning of the 20th century, of the existing permanent grasslands (1.2 million hectares), two-thirds were meadows and one-third pasture. After World War II and in the following decades, about a third of permanent grasslands were ploughed, unified and cultivated as fields (Prach et al., 2009). The landscape also lost its characteristic heterogeneity during this time. The agriculture is intensifying and merging into centres, small land ownership had almost disappeared. At the end of 20. century and the beginning of 21st two trends have prevailed – an intensification of plant and animal production and the relocation of production centres to strategic areas, and at the same time an abandonment of land in less favored areas or its conversion into extensive grasslands (Lokoč a Lokočová 2010; Miko a Hošek 2009). An abandoned land is facing secondary succession which in our conditions leads to shrub development and woodland (Prach et al. 2013; Sojneková a Chytrý 2015; Partel et al. 2007). On the other hand, newly established grasslands have big potential to become species rich semi-natural grasslands and return diversity and heterogeneity into uniformed landscape (Jongepierová et al. 2008). Some less favoured agricultural grasslands were supported by the sowing of commercial clover-grass mixtures (a significant trend even today) to quickly reach the desired biomass production. However, as these mixtures are cultivated for the high biomass production, they lack many herbs, to the presence of which various species of animals, especially insects, can be bound. Events of the end of 20. century and the beginning of 21st, recultivation of arable land back to grassland, took place also in the district of Štítná nad Vláří – Popov and surroundings, the area of interest of this study. Plant communities emerging on ex-arable land serve as an example of ongoing events and are valuable when exploring the context of past and ongoing human activities on their establishment

Species composition and diversity of plant communities are traditionally explained by environmental factors and relationships between species in the community. Important abiotic factors are nutrient availability, water, pH and light (Austrheim et al. 1999; Hájkova a Hájek 2003). For example, sites with the highest diversity are found in habitats with lower than optimum nutrients (Janssens et al. 1998). Biotic factors influencing species composition and richness of permanent grasslands include interspecific and intraspecific competition for nutrient sources, light and space (Begon et al. 1986), the presence and composition of soil biota (Dostálek et al. 2013), dispersal abilities (Standish et al. 2007) and the effect of small and large herbivores (Correll et al. 2003). The relationship between diversity and habitat characteristics can also be opposite. The present species composition (dominant species, colonizers, specialists) and relationships between species (competition, mutualism) can determine ecosystem functions as well as abiotic factors (Hooper et al. 2005).

Species rich semi-natural man-utilized grasslands are found in mild conditions of temperate climate and on soils with moderate nutrition and moisture content. This suggests that abiotic and biotic factors, as important as they are, might not be the main or only predictors of species composition and richness. When the species diversity and composition of semi-natural grasslands and the processes shaping it, are studied, it should focus on the history of grasslands and at the same time consider selected abiotic and biotic factors mentioned above. In this study abiotic factors are represented by characteristic features of georelief such as: topography wetness index, topography position index, diurnal anisotropic heating index, slope, elevation and spatial position using coordinates. Biotic factors are represented by species functional traits as their predisposition to succeed in colonizing habitats and stand out from the competition (Hintze et al. 2013, Zobel et al. 1998) and ecological indicator values that characterise their response to several gradients (Ellenberg et al., 1992, Bartelheimer & Poschlod, 2015). Finally, this study examines to what extend can habitat continuity and management explain the species composition and diversity of semi-natural grasslands when other factors (abiotic and biotic) are considered.

And so, following questions are risen:

1. How do the species composition and diversity depend on continuity and management?
2. To what extent is the species composition of surveyed grasslands explained by their abiotic factors and spatial position?
3. How do species with different affinity for continuity and management vary in their traits?

2 Area description and historical context

The study site is located in the south-east part of the Czech Republic in Moravian hilly region called Valašsko (Wallachia) in the north part of geomorphological region of White Carpathian Mountains (Fig. 1).

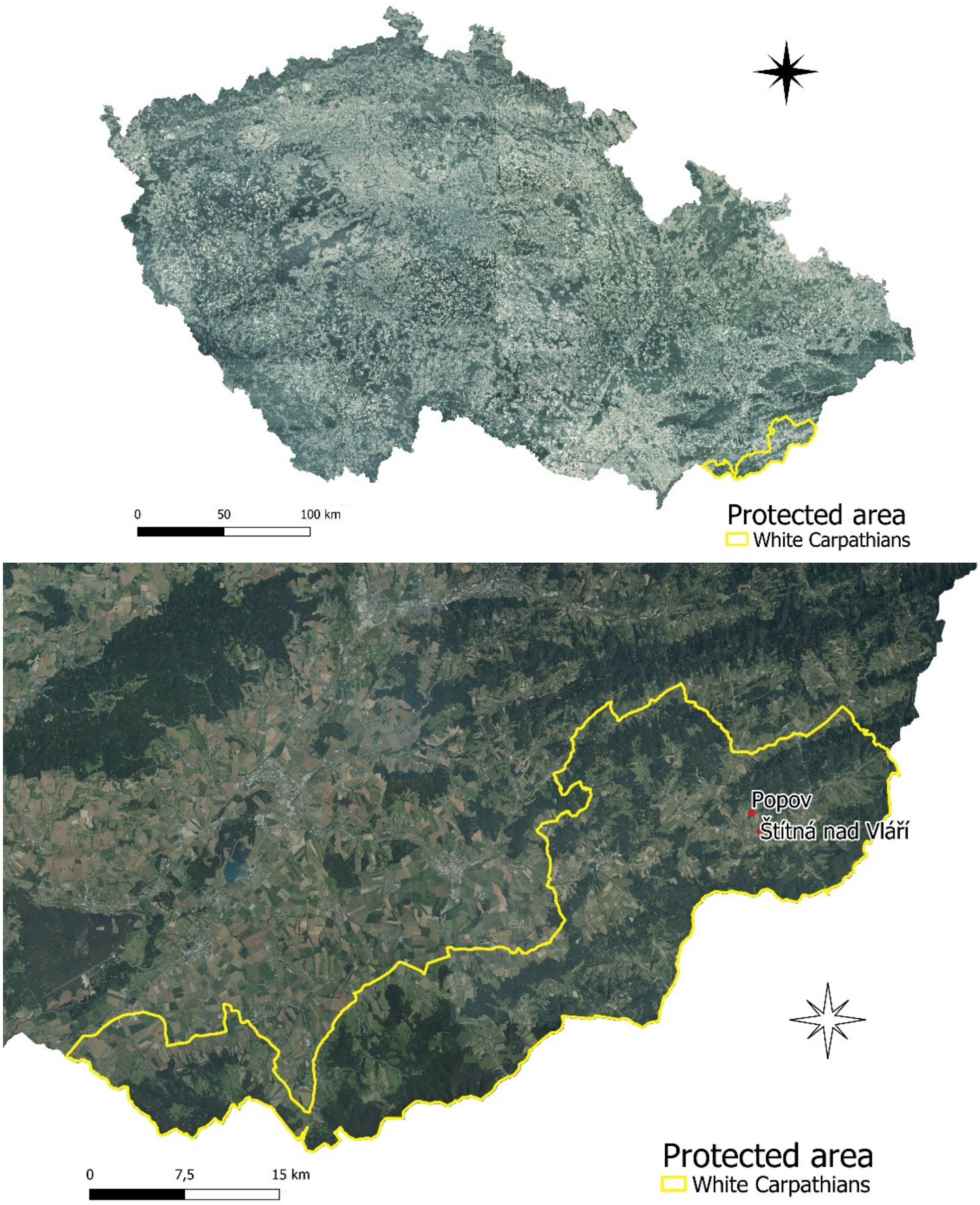

Fig. 1: upper – Position of Protected Area White Carpathians in Czech Republic, lower – position of study site in Protected Landscape Area White Carpathians. Source: base map – orthophoto of the Czech Republic, ČÚZK, processed in QGIS 3.18.1

The White Carpathian range belongs to outer Western part of broader mountain complex Carpathian Mountains which extends from the Morava river in the West to the central Romania and further south to Serbia. The study site is situated in the northern part of protected area of White Carpathian Mountains in the district of Štítná nad Vláří – Popov, Jestřabí and Brumov – Bylnice.

Geologically the area is based on Magura flysh, with predominant sandstone and claystone of variable thickness formed by Cretaceous and Paleogenic sea sediments (Čtyroký & Stráník, 1995). These sediments frequently contain higher amount of calcium carbonate which caused the formation of tufa deposits in springs. The flysh character of the Carpathians and its tendency toward landslides and different permeability might be one of the factors supporting the species richness of the local grasslands (Jongepierová 2008).

Surrounding of three settlements mentioned above is formed by river Vlára and its local tributaries thus, creating valley character extending west-east. Nearby, Vlára river cuts its way through the Carpathian massif further east leaving Czechia by the Vlárský průsmyk pass and continuing to Slovakia joining river Váh, later Danube and together mouthing to the Black Sea. The annual precipitation between years 2009-2012 was approximately 770,9 mm and the average annual temperature measured in the same years was 8,37 °C (czechglobe.cz).

The Vlárský průsmyk pass forms natural migration corridor from Váh lowlands in the east to the Moravian lowlands on the west. This corridor played important role as a gateway for hunters and gatherers and later became a strategical trade route. Archaeological findings document the settlement already in the Palaeolithic era, the so-called Vlárský Palaeolithic, since then, according to other finds, the area has been almost continuously inhabited until today (Kubánek, 1998). Continuous settlement was interrupted only after the fall of the Great Moravian Empire until the nearby castle Brumov was founded in the 13th century (Nekuda, 1995), for approximately 300 years. This was also the time when settlements as known today started to emerge around the castle.

According to the regional phytogeographical division of the Czech Republic (Skalický 1988), study site belongs to the district 78 - White Carpathian Forest, which is included in the Carpathian mesophytic. Potential natural vegetation of the area would consist mainly of flowering beech forest of the association *Carici pilosae-Fagetum*, which are complemented by oak hornbeams of the association *Carici pilosae-Carpinetum* in the lower parts.

However, this study is focusing on the semi-natural grasslands of the area whose origin was conditioned by human activity. When permanent settlements had established in lowland in the 13. century, the proportion of grasslands increased as the forest gave way to pastures and meadows. This culminated with Wallachian colonisation during 16.-17. century which had introduced the typical Carpathian way of farming (Kubánek 1998). The forest vegetation was supplemented by semi-natural grasslands usually represented by dry meadows and pastures with *Brachypodium pinnatum* and on base-rich soils, associations *Brachypodio pinnati-Molinietum arundinaceae* and *Scabioso ochroleucae-Brachypodietum pinnati.* On degraded grasslands which were intensively farmed and fertilised had been formed rather poor mesic *Arrhenatherum* meadows represented by the association *Pas tinaco sativae-Arrhenatheretum elatioris* dominated by *Arrhenatherum elatius* in upper layer and *Leontodon hispidus, Trifolium repens, Leucanthemum vulgare, Veronica chamaedrys,* rarely *Campanula glomerata, Salvia pratensis* in lower layer (Jongepierová 2008).

Until the 1930s the settlement had typical Carpathian character combining mostly shepherding and agriculture. The agricultural soil in the Vlára valley is of alluvial origin and is one of the most fertile in the region. It was common to use lowland fields and meadows for spring grazing earlier in the year and then, around the end of April or beginning of May, move herds higher into the mountains for pastures. Fields would be used to grow crops and meadows would be left until the beginning of July and mowed for winter supplies. This led to creation of semi-natural grasslands which are dependent on human management. This pattern was very similar across the whole Carpathian range. Nowadays however, we can observe traditional management remaining only in distant highland villages outside of Central Europe, which had escaped the unified agriculture of socialistic regime (Janišová et al. 2020). During the 20^{th} century small land ownership receded and almost disappeared. Farmers were forced to enter the local cooperatives and give up their land in favour of cooperative agriculture. Small fields, typically long and narrow oriented along the contour (in our region traditionally called "lokša") were merged and natural terrain or shrub barriers had been ploughed, as seen on the aerial shots (Fig. 2).

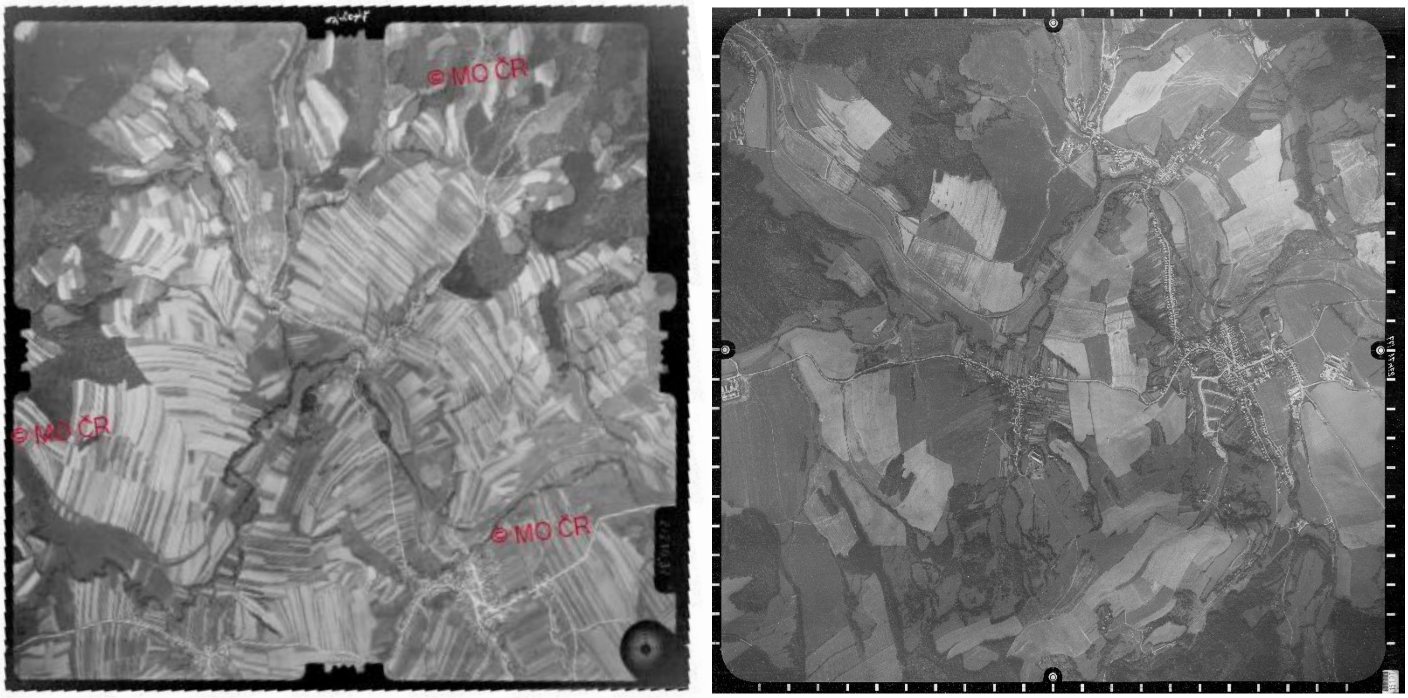

Fig. 2: Two aerial shots of the same landscape surrounding Štítná and Vláří – Popov. Small blocks of land managed individually are merged into large blocks of arable land, pattern of traditional countryside disappeared. Left – year 1955, right – year 1977; Source: archive of LMS - ČÚZK

Thus, large blocks of arable land were created in places that were not suitable for this type of agriculture.

Rapid runoff, erosion and loss of topsoil followed until the 1990s when finally, the least profitable croplands were converted to grasslands. Usually, it was carried out in controlled manner, when the ex-arable land was sown with a clover-grass mixture, usually containing: *Lolium perenne, Festuca rubra, Arrhenatherum elatius, Festuca pratensis, Dactylis glomerata, Phleum pratense, Poa pratensis, Trifolium repens, Trifolium pratense*. Grasslands were restored, but their size remained and the character of agriculture hadn´t return to the traditional way (Fig. 3). In Czech Republic, the ownership of land divided between individuals and/or legal entity (company, town) is about the same (1:1) but land is managed differently. In year 2018 70 % of the agricultural land resources were managed by legal entity and only 30 % were managed by individuals. The prospects are poor that big agro-companies would return to the traditional management, more suitable for the czech georelief and individual owners seem to not receive enough support for their small private farming, similar across Europe (Piras et al. 2021; Arponen et al. 2013)

And so today these restored grasslands are facing several problems concerning quality of soil and related biodiversity.

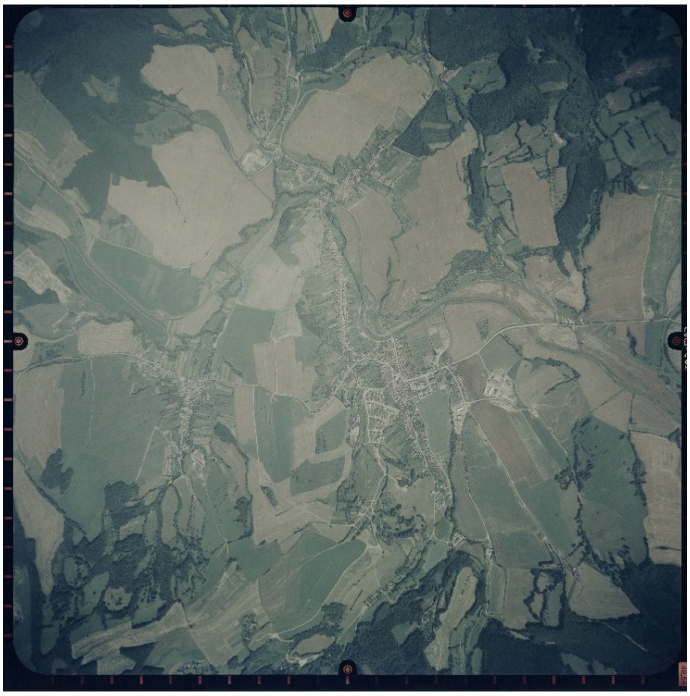

Fig. 3: Two aerial shots of landscape surrounding Štítná and Vláří – Popov. Changes in landscape structure as a result of restoration can be seen when compared. Large fields are divided and drawings are planted with fruit trees. Left – year 1983, right – year 2020. Source: archive of LMS - ČÚZK, orthophoto of the Czech Republic, ČÚZK

2.1 From cooperative to company

Several local cooperatives from neighbouring towns which used to manage the land in this area joined and transferred into company Javorník-CZ s. r. o. which has been operating in Bio organic mode since 1996. Out of 1000ha of cropland managed by these cooperatives only 414ha remained after the 1990s restoration, this means that almost 600ha of cropland was sown and restored back into grassland. Javorník-CZ s. r. o. is nowadays managing 1750 hectares including restored grassland. Part of the management plan is also participation in subsidy titles to maintain the landscape according to EU rules in terms of animal welfare, water quality and landscape condition. Since 2006, organization Biokont CZ, s.r.o provides control, certification, and supervision to the company (ekofarmajavornik.cz).

The company is mainly focusing on cow milk and cow meet production and additional dairy products, hay production and production of own feed mixtures. In addition to agricultural activities, company also focuses on the production of sulphur wicks, runs own distillery, bakery, and a newly built organic dairy. The company has recreational facilities that can be used by both employees and the public.

For a long time, the connection of agricultural production with nature protection has been an important topic in the company. Recently, the company is cooperating with the White Carpathians Protected Landscape Area Administration on the Model Management Method. It is a farming model that would preserve the natural and cultural values of the area along with profitable agricultural production.

Following the previous way of farming of the socialistic agriculture, the company is consciously trying to restore the natural appearance of the landscape. Drawings are planted with fruit trees; borders are created, and windbreaks are planted with the regional tree species (verbally Javorník-CZ, 2017).

Since the land managed by Javorník-CZ. and the surroundings belong to the Protected area of White Carpathian Mts (CHKO Bílé Karpaty), agriculture falls under restrictions and procedures defined by the *Act no. 114/1992 Sb., on Nature and landscape conservation (zakonyprolidi.cz).* Thus, any intensive agricultural technologies that could cause significant changes in biodiversity, structure and function of ecosystems or irreversibly damage the soil surface are strictly observed and counselled with the White Carpathians Protected Landscape Area Administration. It is forbidden to fertilize, use manure, silage liquids and other liquid wastes in grassland recultivation. Javorník-CZ is managing 40 hectares in I. zone, 170 hectares in II. zone and roughly 1000 hectares in III. and IV. zone.

2.1.1 Management of grassland

The pastures are grazed by Simental cattle (meat breed), starting around mid-May, and ending with the first snow. During winter months cattle remains indoors. The grazing regime is mainly dependent on weather, so the heavy animals don´t damage wet soil. The milk breed Český strakatý skot (Czech spotted cattle, Red Pied) is kept indoor and only goes out for couple of hours per day.

Several grasslands are both mown/grazed depending on the precipitation (drought) of the exact year and the production of biomass. It is important to mention that the question whether the plot is specially grazed or mown does not primarily depend on the previous usage (continuous/ex-arable). It rather depends on the environmental conditions and on the weather of particular year. Zootechnic makes the final decision where is the cattle going to graze and leads them between plots several times per season.

Some grasslands are only used as pastures (grazed) or meadows (mown). Mowing usually happens during the first half of June, depending on weather (verbally, Javorník-CZ 2021).

Not all studied grasslands are managed by Javorník-CZ and are owned and managed by small local farmers. These small farmers mostly raise sheep instead of cows which is related to the character of their land. The plots grazed by sheep are usually very steep and rather dry and thus poor at biomass production but on the other hand more diverse concerning species. But majority of plots owned by small farmers are mown on hay to be sold or to supply the animals kept at home (mostly rabbits).

3 Methods and materials

3.1 List of surveyed grasslands

Observed plots have two characters. The first are former fields, that were restored and reseeded with low-diversity commercial clover-grass seed mixture during the 1990s and transferred back to grasslands. These ex-arable plots are grazed or mown, some are undergoing landscape restoration and drawings are replanted with fruit trees (Fig. 4). The second are continual plots, long-term extensively managed meadows and pastures (Fig. 5). The area of ex-arable plots is highly variable, ranging from 0.24 ha to 13.7 ha. Ex-arable plots (total of 17) under registration numbers 0301/7, 1202/4, 1201/181, 1201/182, 0301/22, 0201/62, 0201/61, 9510/2, 1202/8, 1202/7, 1302/261, 1302/262, 1302/28, 1302/22, 1302/263, 0403/2, 506/35 (LPIS, eagri.cz) plots had been selected based on field research and comparison of aerial survey images obtained from Czech office for surveying, mapping and cadastre (ČÚZK, 2020) from 1950, 1961, 1977, 1983, 1990 and the present. Each ex-arable plot is located within 500 m distance from continual plot. The area of continual plots is also highly variable and is ranging from 0.05 ha to 9.5 ha and there is 49 of them. Continual plots were selected to cover the variability of the area and to indicate the colonization capabilities of the species and their potential to spread to ex-arable plots. The aerial surveying images mentioned above were also helpful determining the continuity of the plots. The total number of all plots is 66. For each of the plots, the degree of continuity (ex-arable / continual) (Fig. 6) and the type of management (grazed / mown) (Fig. 7) were recorded.

Fig. 4: Ex-arable site Podhájčí, currently grazed, upper part planted with fruit trees. Photo: author.

Fig. 5: continual site Višňové, currently grazed. Photo: author

As an important part of field observation, I tried to approach owners or managers of each plot to learn specifics in their agricultural practice. I was interested in the age of the plot (continuity – since what year has the plot been managed the same) and the recent management – whether the plot is mown or grazed and by what animal. Unfortunately, I was not as successful as I hoped and didn´t manage to gain such information. This was caused mainly by the age and memory of questioned farmers who didn´t remember the times before socialistic collectivisation, were disconnected with their ancestors or hadn´t own the plot for long enough. Javorník-CZ who manages most of the surveyed plots also had difficulty to offer complete information about history of the grassland since many of the paper documentation was destroyed after the revolution and before the creation of recent agro-company (verbally, Javorník-CZ 2017-2021).

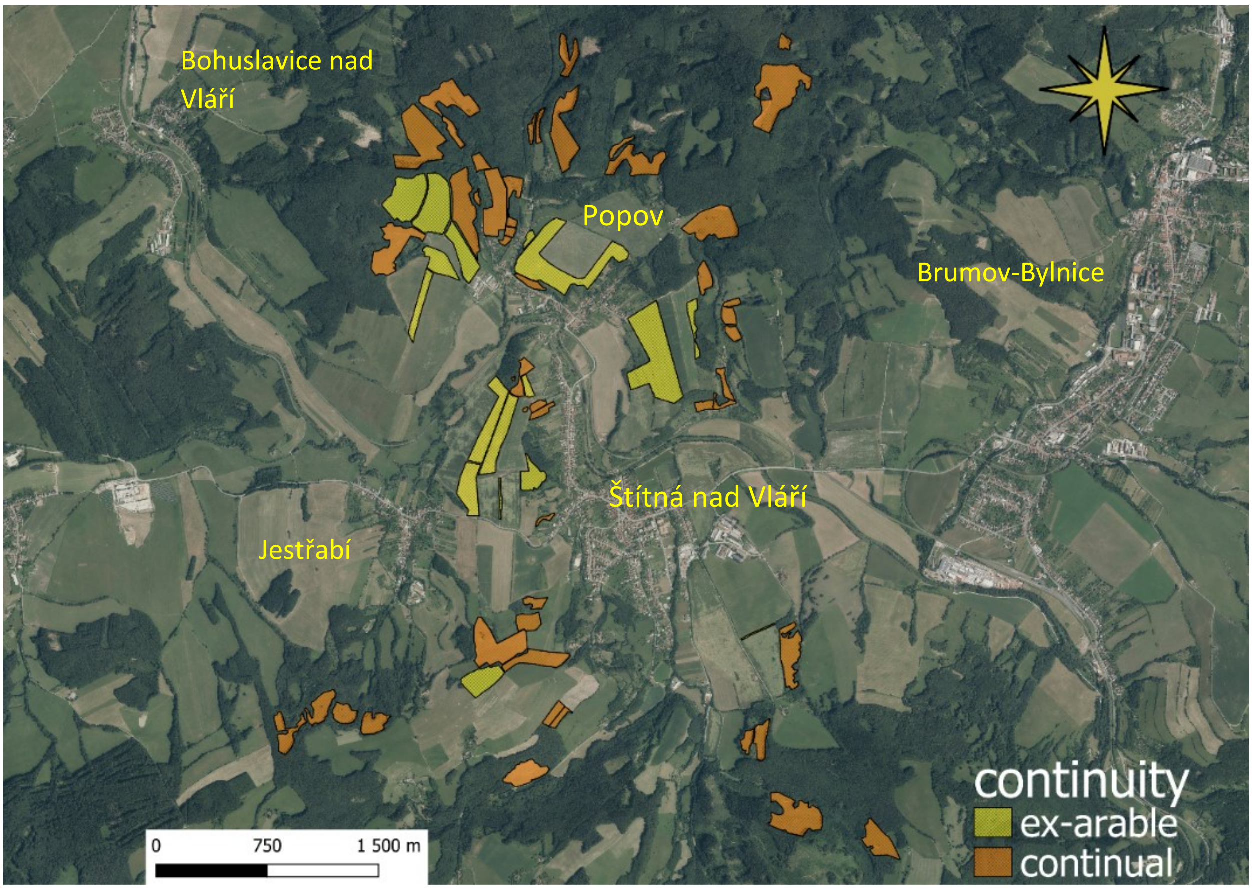

Fig. 6: the continuity of observed plots in districts of Štítná and Vláří – Popov and Jestřabí and surrounding towns. yellow – ex-arable plots, orange – continual plots. Source: base map – orthophoto of the Czech Republic, ČÚZK, processed in QGIS 3.18.1.

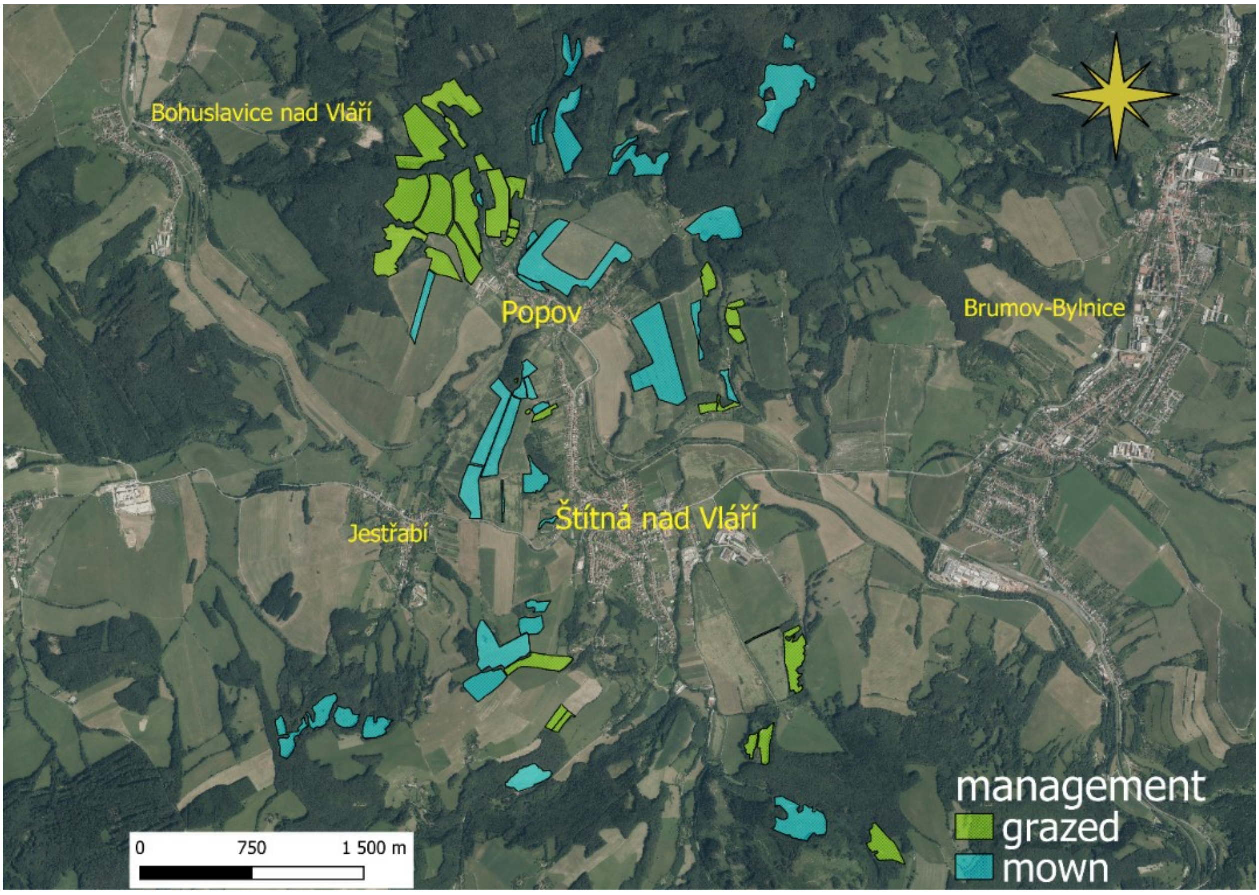

Fig. 7: the management of observed plots in districts of Štítná and Vláří – Popov and Jestřabí and surrounding towns. Green – grazed plots, blue – mown plots. Source: base map – orthophoto of the Czech Republic, ČÚZK, processed in QGIS 3.18.1.

3.3 Vegetation data collection

Based on field observation combining with Atlas of distribution of vascular plants of the White Carpathians Protected Landscape Area (Jongepier & Pechanec, 2006) and in cooperation with its co-editor Jan W. Jongepier, a list of 137 plant species was compiled (Tab. 1).

The list represents species of typical Carpathian mesophytic grassland, concerning both – pastures and meadows plant communities and several species typical for springs. Selected species have the greatest potential to occur in observed plots, and therefore do not occur, for example, in purely ruderal habitats. Forest species, alien species and species typical for non-natural habitats were not included. It is important to mention that selected species have never been sown here and colonized the surveyed grasslands spontaneously.

Data collection took place during the months of May to August in the years 2017 – 2020. Species observation was carried out in form of cross-out list of target species. Frequency of each species was noted on the scale 1 – 4, where expressed in percent: 1 < 10 %, 2 < 20 %, 3 < 30 %, 4 > = 30 % of the plot (in words: 1-rarely, 2-scattered, 3-regularly, 4-abundant). This method was chosen particularly for this type of observation, to consider different size of each plot.

Tab. 1: list of target species and their family, unified according to the Key to the flora of the Czech Republic, Kaplan et al. 2019

species	*family*
Achillea millefolium agg.	*Asteraceae*
Agrimonia eupatoria	*Rosaceae*
Anthyllis vulneraria	*Fabaceae*
Aquilegia vulgaris	*Ranunculaceae*
Arenaria serpyllifolia	*Caryophyllaceae*
Asperula cynanchica	*Rubiaceae*
Astragalus cicer	*Fabaceae*
Astragalus glycyphyllos	*Fabaceae*
Astrantia major	*Apiaceae*
Betonica officinalis	*Lamiaceae*
Campanula glomerata	*Campanulaceae*
Campanula patula	*Campanulaceae*
Campanula persicifolia	*Campanulaceae*
Carlina acaulis	*Asteraceae*
Carlina vulgaris	*Asteraceae*
Centaurea jacea	*Asteraceae*
Centaurea scabiosa	*Asteraceae*
Centaurium erythraea	*Gentianaceae*
Cerinthe minor	*Boraginaceae*
Circaea lutetiana	*Onagraceae*
Clinopodium vulgare	*Lamiaceae*
Colchicum autumnale	*Colchicaceae*
Convolvulus arvensis	*Convolvulaceae*
Dactylorhiza incarnata	*Orchidaceae*
Dactylorhiza majalis	*Orchidaceae*
Dactylorhiza sambucina	*Orchidaceae*
Dianthus armeria	*Caryophyllaceae*
Dianthus carthusianorum	*Caryophyllaceae*
Dianthus deltoides	*Caryophyllaceae*
Dorycnium herbaceum	*Fabaceae*
Echium vulgare	*Boraginaceae*

Epipactis helleborine	*Orchidaceae*
Epipactis palustris	*Orchidaceae*
Epipactis purpurata	*Orchidaceae*
Erigeron acris	*Asteraceae*
Eryngium campestre	*Apiaceae*
Euphorbia cyparissias	*Euphorbiaceae*
Filipendula vulgaris	*Rosaceae*
Fragaria viridis	*Rosaceae*
Galium album	*Rubiaceae*
Galium boreale	*Rubiaceae*
Galium pumilum	*Rubiaceae*
Galium verum	*Rubiaceae*
Genista germanica	*Fabaceae*
Genista tinctoria	*Fabaceae*
Geranium pratense	*Geraniaceae*
Geranium sanguineum	*Geraniaceae*
Gladiolus imbricatus	*Iridaceae*
Gymnadenia conopsea	*Orchidaceae*
Helianthemum grandiflorum	*Cistaceae*
Hylotelephium maximum	*Crassulaceae*
Hypericum hirsutum	*Hypericaceae*
Hypericum maculatum	*Hypericaceae*
Hypericum perforatum	*Hypericaceae*
Hypericum tetrapterum	*Hypericaceae*
Hypochaeris maculata	*Asteraceae*
Hypochaeris radicata	*Asteraceae*
Inula britannica	*Asteraceae*
Inula salicina	*Asteraceae*
Isopyrum thalictroides	*Ranunculaceae*
Juncus inflexus	*Juncaceae*
Knautia arvensis	*Caprifoliaceae*
Knautia kitaibelii	*Caprifoliaceae*
Laserpitium latifolium	*Apiaceae*
Lathyrus pratensis	*Fabaceae*
Lathyrus tuberosus	*Fabaceae*
Leontodon hispidus	*Asteraceae*
Leucanthemum vulgare	*Asteraceae*
Linaria vulgaris	*Plantaginaceae*
Lilium martagon	*Liliaceae*
Listera ovata	*Orchidaceae*
Lotus corniculatus	*Fabaceae*
Lotus maritimus	*Fabaceae*
Lychnis flos-cuculi	*Caryophyllaceae*
Lysimachia vulgaris	*Primulaceae*
Lythrum salicaria	*Lythraceae*
Medicago falcata	*Fabaceae*
Melampyrum nemorosum	*Orobanchaceae*
Muscari comosum	*Asparagaceae*

Odontites vernus ssp. serotinus	*Orobanchaceae*
Onobrychis viciifolia	*Fabaceae*
Ononis spinosa	*Fabaceae*
Orchis mascula	*Orchidaceae*
Orchis militaris	*Orchidaceae*
Orchis morio	*Orchidaceae*
Origanum vulgare	*Lamiaceae*
Peucedanum cervaria	*Apiaceae*
Phyteuma spicatum	*Campanulaceae*
Picris hieracioides	*Asteraceae*
Pimpinella major	*Apiaceae*
Pimpinella saxifraga	*Apiaceae*
Plantago lanceolata	*Plantaginaceae*
Plantago media	*Plantaginaceae*
Platanthera bifolia	*Orchidaceae*
Primula elatior	*Primulaceae*
Primula veris	*Primulaceae*
Prunella laciniata	*Lamiaceae*
Prunella vulgaris	*Lamiaceae*
Pulmonaria mollis	*Boraginaceae*
Pulmonaria officinalis	*Boraginaceae*
Ranunculus acris	*Ranunculaceae*
Ranunculus auricomus agg.	*Ranunculaceae*
Ranunculus bulbosus	*Ranunculaceae*
Ranunculus polyanthemos	*Ranunculaceae*
Reseda lutea	*Resedaceae*
Rhinanthus major	*Orobanchaceae*
Rhinanthus minor	*Orobanchaceae*
Salvia pratensis	*Lamiaceae*
Salvia verticillata	*Lamiaceae*
Sanguisorba minor	*Rosaceae*
Sanguisorba officinalis	*Rosaceae*
Scorzoneroides autumnalis	*Asteraceae*
Securigera varia	*Fabaceae*
Sedum sexangulare	*Crassulaceae*
Serratula tinctoria	*Asteraceae*
Silene latifolia	*Caryophyllaceae*
Silene nutans	*Caryophyllaceae*
Silene vulgaris	*Caryophyllaceae*
Solidago virgaurea	*Asteraceae*
Stachys palustris	*Lamiaceae*
Stellaria graminea	*Caryophyllaceae*
Succisa pratensis	*Caprifoliaceae*
Tanacetum corymbosum	*Asteraceae*
Teucrium chamaedrys	*Lamiaceae*
Thalictrum aquilegiifolium	*Ranunculaceae*
Thymus pulegioides	*Lamiaceae*
Tragopogon orientalis	*Asteraceae*

Traunsteinera globosa	*Orchidaceae*
Trifolium alpestre	*Fabaceae*
Trifolium medium	*Fabaceae*
Trifolium montanum	*Fabaceae*
Trifolium rubens	*Fabaceae*
Veronica chamaedrys	*Plantaginaceae*
Veronica maritima	*Plantaginaceae*
Veronica orchidea	*Plantaginaceae*
Veronica serpyllifolia	*Plantaginaceae*
Veronica teucrium	*Plantaginaceae*

3.4 Environmental variables

To process environmental variables (Tab. 2) the program QGIS version 3.18.1 (QGIS.org, 2021) was used.

Firstly, polygon for each plot was created and area was calculated using the function $area which is included in the attribute table. Centroid for each polygon was calculated and used to provide coordinates. To obtain the site environmental variables, European Digital Elevation Model (EU-DEM), version 1.1 at 25 m resolution was used (CLMS, land.copernicus.eu). Elevation data were already contained in the EU-DEM. The plug-in SAGA (2.3.2.) was used to calculate the parameters for Slope and Aspect both expressed in degrees. Topography Position Index (TPI) was calculated using the feature of SAGA Topography Position Index. Slope and Aspect were used to calculate the Diurnal Anisotropic Heating Index (DAHI) which is function of these two, the feature of SAGA Diurnal Anisotropic Heating was used. Topography Wetness Index (TWI) was calculated using feature of SAGA Topography Wetness Index.

Tab. 2: Environmental variables and their characteristics

Environmental variable	*characteristic*
TWI	quantification of topographic control on hydrological processes, estimation of water accumulation in the area
TPI	compares the elevation of each cell in a DEM to the mean elevation of a specified neighbourhood around that cell, Positive

	TPI – higher than the average of their surroundings, Negative TPI – lower than their surroundings
DAHI	amount of sunlight incident on the area
Area	expressed in m^2
Slope	expressed in degrees
Aspect	expressed in degrees, used for calculation of the diurnal anisotropic heating index
Elevation	expressed in meters above sea level
Coordinates	x, y, x*y, x^2, y^2

3.5 Functional traits

Species functional traits (Tab. 3) were extracted from several databases. From LEDA database were used seven traits: canopy height (measured in meters), zoochory (joined epi- and endo- zoochory), leaf dry matter content (LDMC), seed bank longevity, seed mass, specific leaf area (SLA) and terminal velocity (Kleyer et al. 2008). From D^3 database was extracted one trait – epizoochory ranking index (Hintze et al. 2013) and from MycoFlo database was used one trait determining mycorrhiza (Hempel et al. 2013). From the Pladias database, the phenological data was obtained, describing the start end the end of flowering season.

Tab. 3: Species traits and their ecological functions

Trait	*ecological functions*
Canopy height	Ability to compete for light, release hight for seed dispersal, interference with mowing
zoochory	Seed dispersal by epi- and endo- zoochory
Leaf dry matter content	Competitive ability, stress tolerance
Seed bank longevity	Potential to overcome long-lasting harsh conditions
Seed mass	Competitive ability of plant seedlings, generative reproduction rate, seed dispersal

Specific leaf area	Competitive ability, stress tolerance
Terminal velocity	Seed dispersal by wind
Epizoochory ranking index	Seed dispersal by epizoochory
Mycorrhiza	Establishment success of colonizing seedlings
Start of flowering season	Interference with mowing and with competitive dominants
End of flowering season	Interference with mowing and with competitive dominants

The data were also supplemented by Ellenberg-type indicator values for Czech flora (hereinafter EIV) describing the affinity of species for different environmental conditions (Ellenberg et al., 1992, Chytrý et al., 2018). The EIV is used to classify plant habitats. The numerical system was created for Central European species and describes the presence of species across light gradients, temperature, soil moisture, soil reaction (pH) nutrient content and salinity. Indication values were obtained based on vegetation knowledge, field observations and measurements of soil parameters. Thanks to this, they can themselves serve to describe the environment, they allow to connect functional mechanisms with the occurrence of the species in the field (Bartelheimer & Poschlod, 2015).

3.6 Data analysis

3.6.1 Species composition and Environmental variables

The analysis of the effect of environmental variables on species composition was carried out in Canoco 5 (ter Braak & Šmilauer, 2012). Dependent variables were species composition (occurrence of 137 target species) on 66 observed plots, explanatory variables were environmental data obtained in zonal statistics from QGIS (DAHI, TPI, TWI, Slope, Coordinates, Elevation) and data on continuity of two levels (ex-arable/continual) and management of two levels (grazed/mown).

Firstly, species with occurrence less than 3 were excluded from the dataset for all upcoming analyses. The constrained RDA analysis was performed using the species composition as response variable and coordinates x, y and their interactions ($x*y$, x^2, y^2) as explanatory variable in forward selection test. Significant variables were used as covariates in all the subsequent tests.

Second, I used DAHI, TPI, TWI, Slope, and Elevation as predictors and selected the significant ones in forward selection test. The significant variables selected in this step were used together with the significant coordinates as covariates when testing the effect of habitat continuity and management. Subsequently, the effect of each significant environmental variable on species composition was tested separately.

When testing the effect of continuity on species composition, beside the environmental variables and coordinates, management was also used as covariate. And again, when testing the effect of management, continuity was also used as covariate.

3.6.2 Species diversity

The analysis on species diversity was performed using ANOVA in RStudio version 1.1.383. The dependent variable was number of species. The analyses used the same logic as the analyses of species composition described above. The only difference was using area as an additional covariate as species number may be directly affected by the area. After the initial data exploration of the variables, a logarithmic transformation was used to bring distribution of number of species and of the area close to normal. Stepwise selection of coordinates and environmental variables (slope, elevation, DAHI, TWI, TPI) was performed.

3.6.3 Functional traits and EIVs

The analysis of species traits and EIVs was carried out in RStudio version 1.1.383 (Rstudio, 2016).

The predictors were species functional traits obtained for each species present at least on three plots. These functional traits were: Canopy height, Zoochory, Leaf dry matter content, Seed bank longevity, Seed mass, Specific leaf area, Terminal velocity, Epizoochory ranking index, Mycorrhiza, Start of flowering season, End of flowering season, obtained for 93 species. The dependent variable was species score on the first ordination axis for these 93 species obtained in partial RDA analysis with either continuity or management as predictors. These species scores indicate affinity of the species to continuity or management. Linear regression was created separately for each functional trait.

The record of the occurrence of species and their frequency at plots was used to calculate average EIVs for a given plot (light, temperature, salinity, soil moisture, pH, nutrients).

These data for each plot were compared depending on the management and continuity of the plot. The EIV value was used as a dependent variable and management and continuity were used as explanatory variables. The data contained six dependent variables - light, pH, salinity, nutrients, temperature, and moisture. The continuity has two levels – ex-arable and continual, the management also has two levels - grazed and mown. A model of analysis of variance (ANOVA) was created separately for each dependent variable and the dependence of individual EIVs on the continuity and management factor was tested.

4 Results

4.1 Species composition and environmental variables

Out of 137 target species, 93 of them were present on more than two plots.

Observed plots extend at an altitude ranging from 329 to 539 meters, with an area of 475 m^2 to 137 211 m^2. Average slope value was ranging from 2.86° to 20.25°. Average value of Topography wetness index ranged from 5.20 to 9.53, Topography position index ranged from -1.43 to 0.89 and Diurnal anisotropic heating index ranged from -0.07 to 0.11 (Tab. 4).

Tab. 4: Numerical characteristics of environmental variables

Environmental variable	*mean*	*median*	*min*	*max*
TWI	6.56	6.39	5.20	9.53
TPI	0.006	-0.1	-1.43	0.89
DAHI	0.005	0.001	-0.07	0.11
Area (m^2)	28585.55	17750.56	474.98	137211.20
Slope (°)	11.05	11.29	2.86	20.25
Elevation (m)	396.34	381.81	328.65	539.17

4.1.1 Effect of environmental variables on species composition

The forward selection test of the effect of coordinates on species composition showed that both x-coordinate and y-coordinate significantly affect species composition, but not their interactions. Using these as covariate, significant effect of elevation (Fig. 8) and slope (Fig. 10) on species composition was also discovered (Tab. 5). Species that tend to grow in places with higher altitude are among others: *Colchicum autumnate, Primula veris, Primula elatior*, in places with lower altitude are among others: *Plantago media, Thymus pulegioides, Galium verum, Teucrium chamaedrys.* Species that tend to grow on steeper plots are among others: *Plantago media, Salvia pratensis, Thymus pulegioides, Teucrium* *chamaedrys*, on more gradual or flat plots are among others: *Primula elatior, Betonica officinalis, Securigera varia.*

Tab. 5: The effect of coordinates, elevation and slope on species composition

	explains %	F	p
x	3.2	2.1	0.004
y	2.5	1.6	0.025
elevation	4.95	3.2	0.001
slope	3.35	2.1	0.002

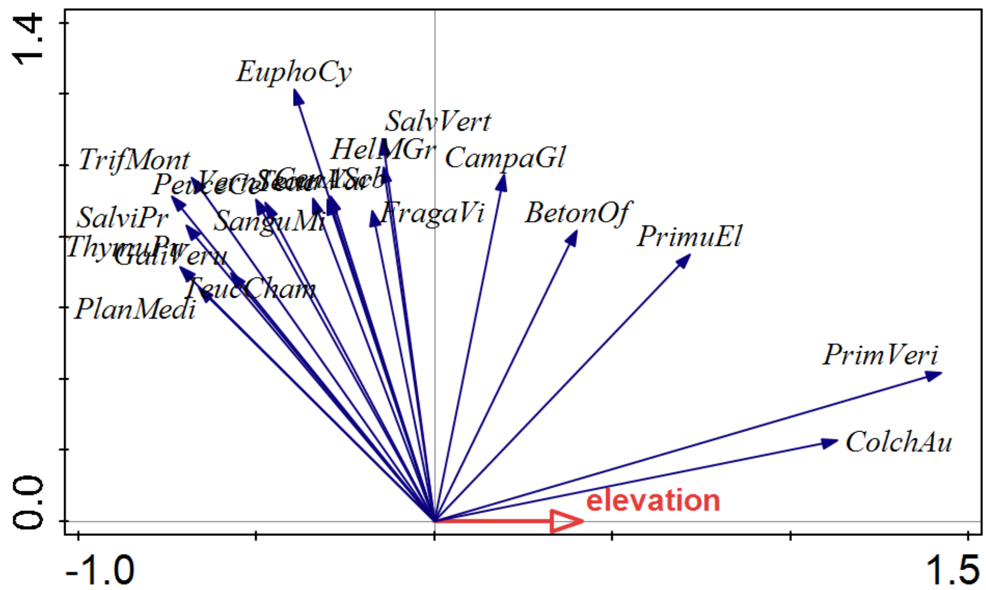

Fig. 8: The effect of elevation on species composition. Shown first twenty species most strongly responding to elevation that best fit into ordination space.

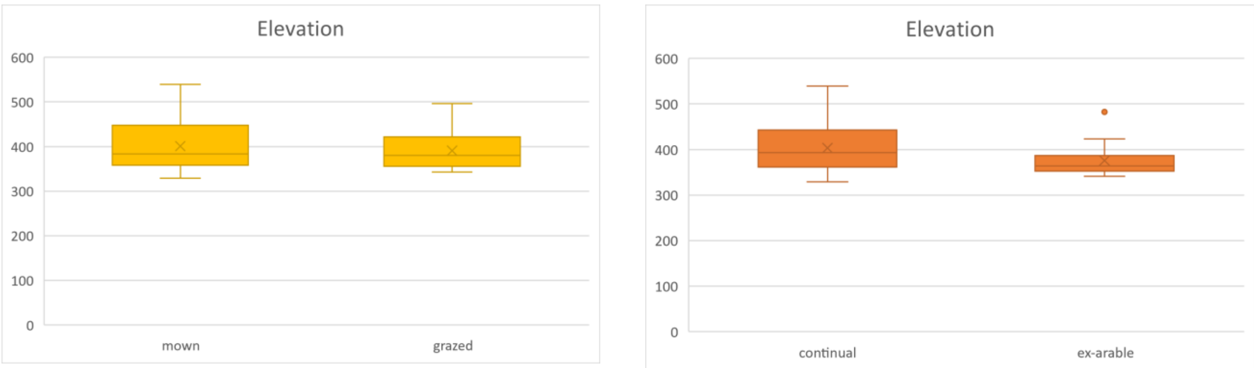

Fig. 9: Distribution of studied plots along the altitude gradient.

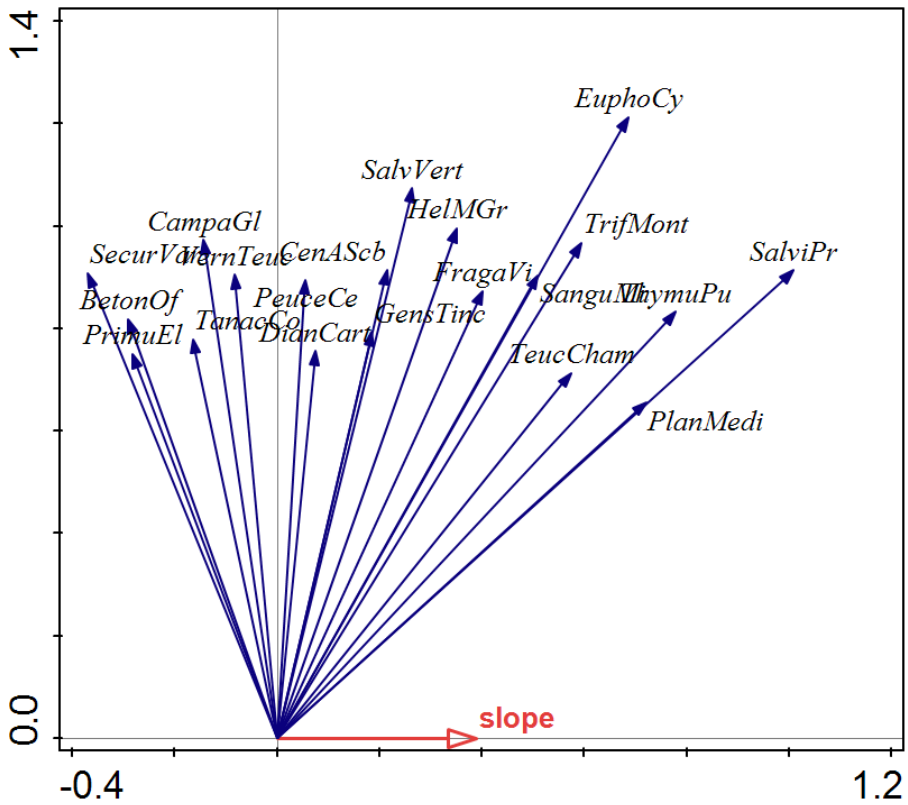

Fig. 10: the effect of slope on species composition. Shown first twenty species most strongly responding to slope that best fit into ordination space.

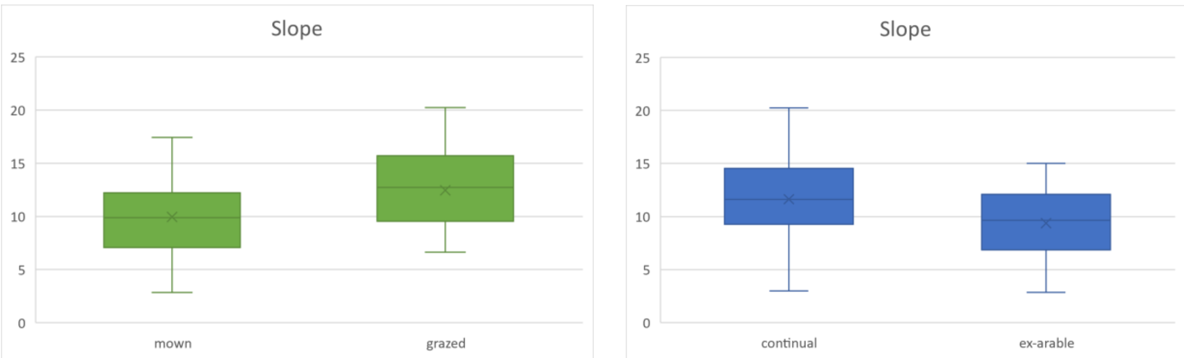

Fig. 11: Distribution of studied plots along the slope gradient.

4.1.2 The effect of continuity on species composition

Coordinates, elevation, slope and management were used as covariates to test the clear effect of continuity. The effect of continuity explained 5.43 % of variability with significancy p=0.001, F=3.4. Affinity to occur rather on ex-arable plots showed *Scorzoneroides autumnalis, Odontites vernus ssp. serotinus,* on continual plots: *Trifolium medium, Campanula glomerata, Betonica officinalis, Pimpinella saxifraga, Peucedanum cervaria, Helianthemum grandiflorum*, *Sanguisorba officinalis, Salvia verticilata, Salvia pratensis, Euphorbia cyparissias, Fragaria viridis.* (Fig. 12)

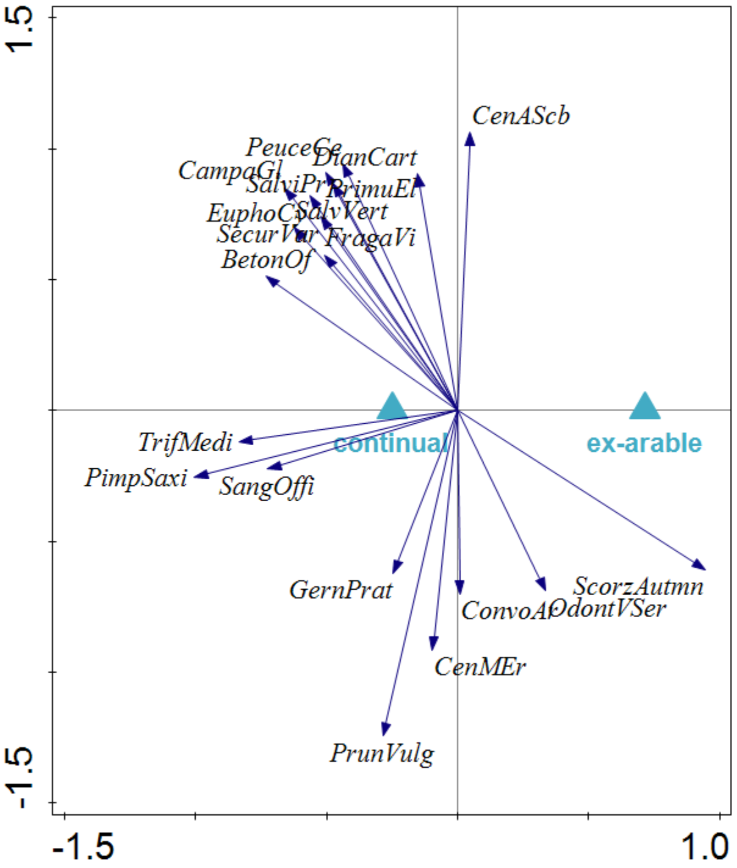

Fig. 12: The effect of continuity on species composition. Shown first twenty species with largest relative contribution to ordination space.

Out of 137 target species, 31 had established on ex-arable plots, these species are: *Scorzoneroides autumnalis, Lotus corniculatus, Linaria vulgaris, Erigeron acris, Veronica serpyllifolia, Campanula patulla, Galium album, Odontites vernus ssp. serotinus, Ranunculus acris, Plantago lanceolata, Astragalus glyciphyllos, Lythrum salicaria, Leontodon hispidus, Lysimachia vulgaris, Origanum vulgare, Leucanthemum vulgaris, Achilea millefoli, Lychnis flos-cuculi, Carlina vulgaris, Medicago falcata, Veronica chamaedrys, Juncus inflexus, Pimpinella major, Centaurea scabiosa, Agrimonia eupatoria, Ranunculus polyanthemos, Hypericum perforatum, Lathyrus tuberosus, Genista germanica, Stellaria graminea,* *Convolvulus arvensis,* first species with strongest affinity to ex-arable plots, sorted descending.

4.1.3 The effect of management

Coordinates, elevation, slope and continuity were projected as covariates to test the clear effect of management. The effect of management explained 4.16 % of the variability with significancy p=0.001, F=2.6. Affinity to occur rather on grazed plots showed among others: *Agrimonia eupatoria, Ononis spinosa, Plantago media, Origanum vulgare, Convolvulus arvensis, Euphorbia cyparissias, Salvia verticilata, Scorzoneroides autumnalis, Odontites vernus ssp. serotinus,* on mown plots: *Campanula glomerata, Primula elatior, Trifolium montanum, Centaurium erythraea, Geranium pratense, Colchicum autumnale* (Fig. 13).

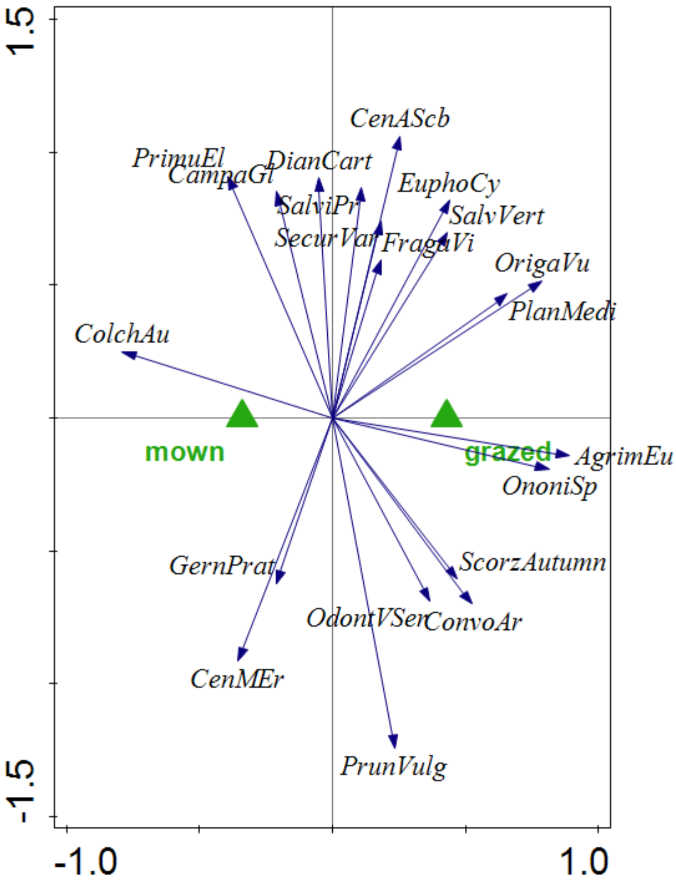

Fig. 13: The effect of management on species composition. Shown first twenty species with largest relative contribution to ordination space.

4.2 Species diversity

Species diversity is significantly correlated with the size of the plot ($p=0.006$, $F=12.98$) – the larger the plot, the more species occurred. The stepwise selection test showed that out of seven environmental variables, only y-coordinate significantly affected the species diversity when accounting size of the plot ($p=0.006$, $F=7.94$).

The effect of continuity accounting the area and y-coordinate was significant ($p<0.001$, $F=21.83$) and showed that continual plots host more target species (the number of target species varied from 16 to 59, average 36 target species) than ex-arable plots (the number of target species varied from 16 to 47, average 28 target species) (Fig. 14). The effect of management depending on the area was not significant and showed no difference in number of species on grazed or mown plots (Tab. 6).

Tab. 6: The effect of management and continuity on species composition and species diversity when considering environmental variables.

	species composition	species diversity
continuity	p=0.001	p<0.001
management	p=0.001	p=0.194

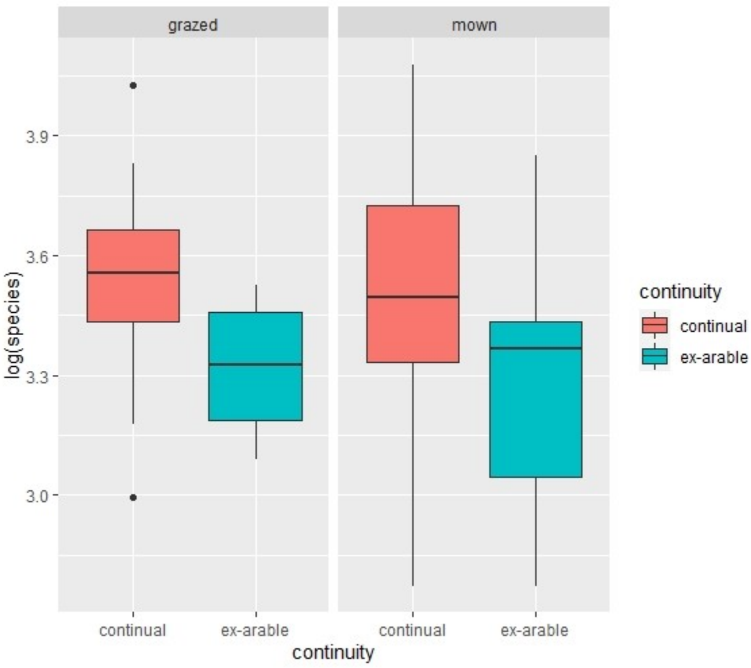

Fig. 14: The effect of continuity and management on the number of species on the plot. Continual plots host more species than ex-arable plots, but the management doesn´t affect the diversity. The number of species has undergone logarithmic transformation.

The plot hosting the most target species (total 59) is southeast oriented continual grassland of area 9.5 ha with registration number 9102/1. The inclination is 11.4 ° and the elevation is 540 m. Phytosociological affiliation of this grassland is represented by alliance *Bromion erecti*, association *Brachypodio pinnate-Molinietum arundinaceae* and according to LPIS (eagri.cz) must be mown at least once per season during July or August. This meadow is managed by Javorník-CZ and cannot be manured nor grazed. This grassland belongs to the III. zone of Protected Landscape Area. The age of the grassland is at least 180 years as seen on the map from 2nd military survey from the years 1836-1840 the plot is marked as grassland, probably partly meadow, partly pasture.

Ex-arable plot hosting most species (total 47) is west oriented mown plot of area 13.7 ha with inclination 11.7 ° and elevation 368m managed by Javorník-CZ with registration number 0301/7. The mowing must be done before the end of July and grazing or manuring is not allowed (eagri.cz).

4.3 Species traits

None of the eleven species traits showed significant effect on species response to continuity and management. Only some variables showed marginal significance (Tab. 7).

There is marginal dependence between Canopy height and the affinity of species to continuity. Ex-arable plots tend to host species of higher canopy. The marginal dependence between SLA and the affinity of species to continuity shows that ex-arable plots tend to host species with higher values of specific leaf area. There is also marginal dependence between end of flowering season and affinity of species to continuity, where ex-arable plots tend to host species of late flowering.

There was no significant dependence between any traits and the affinity of species to management.

Tab. 7: dependence between species traits and the affinity to continuity and management. Marginal dependence is marked by the symbol · .

Trait	*continuity*		*management*	
	F	*p*	*F*	*p*
Canopy height	2.884	**0.093·**	1.998	0.161
Zoochory	0.003	0.957	0.068	0.795

LDMC	2.215	0.141	0.256	0.614
Seed bank longevity	0.267	0.607	0.194	0.661
Seed mass	0.039	0.843	0.465	0.497
SLA	3.106	**0.082·**	0.159	0.691
Terminal velocity	1.865	0.176	0.007	0.932
Epizoochory ranking index	0.047	0.828	0.001	0.973
Mycorrhiza	1.302	0.257	0.001	0.967
Start of flowering season	0.055	0.815	1.222	0.272
End of flowering season	3.234	**0.075·**	0.033	0.856

4.4 Ecological indicator values

Results showed that the EIVs light, moisture and salinity were significantly correlated with species occurrence and affinity to continuity and management (Tab. 8). Mown and also continual plots tend to host species which prefer more light, mown plots tend to host species which prefer humidity, ex-arable and mown plots rather host species that can withstand salinity (Fig. 15 and Fig. 16).

*Tab. 8: Dependence of EIV on continuity and management. Strong dependence is marked by the symbol *, the marginal dependence is marked by · .*

		light	*temperature*	*moisture*	*ph*	*nutrients*	*salinity*
continuity	F	2.841	0.575	0.074	0.715	0.381	11.345
	p	**0.097 ·**	0.451	0.787	0.401	0.539	**0.001 ***
management	F	4.631	0.105	6.419	0.199	0.135	7.982
	p	**0.035 ***	0.748	**0.014***	0.657	0.715	**0.006 ***

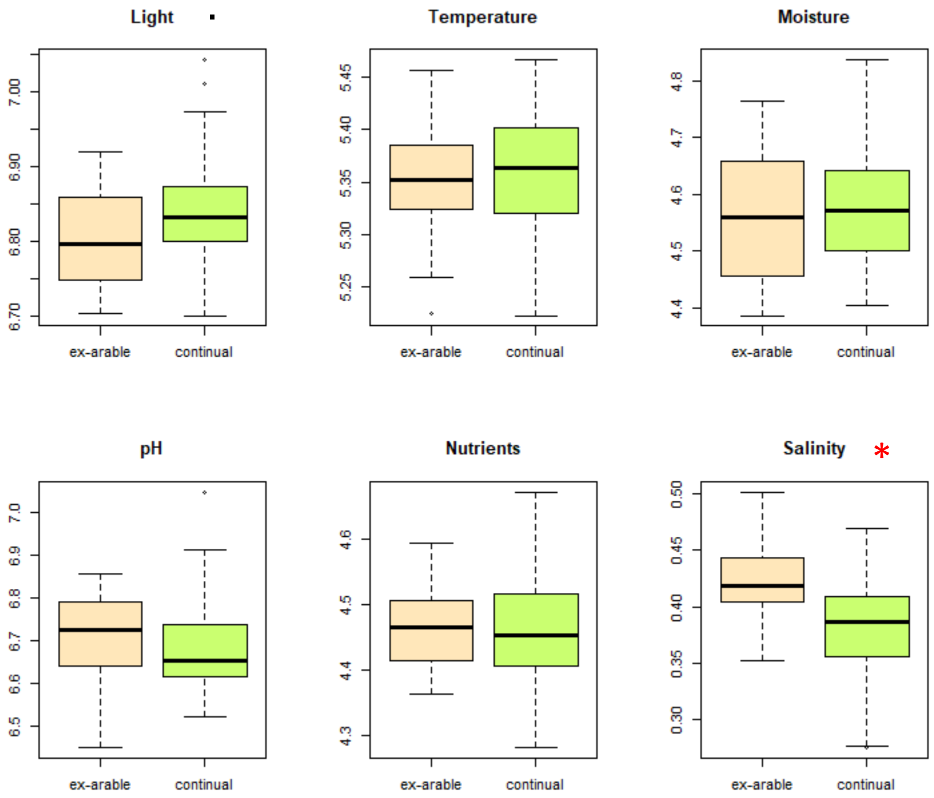

Fig. 15: dependence between EIVs and continuity, significance is marked by *

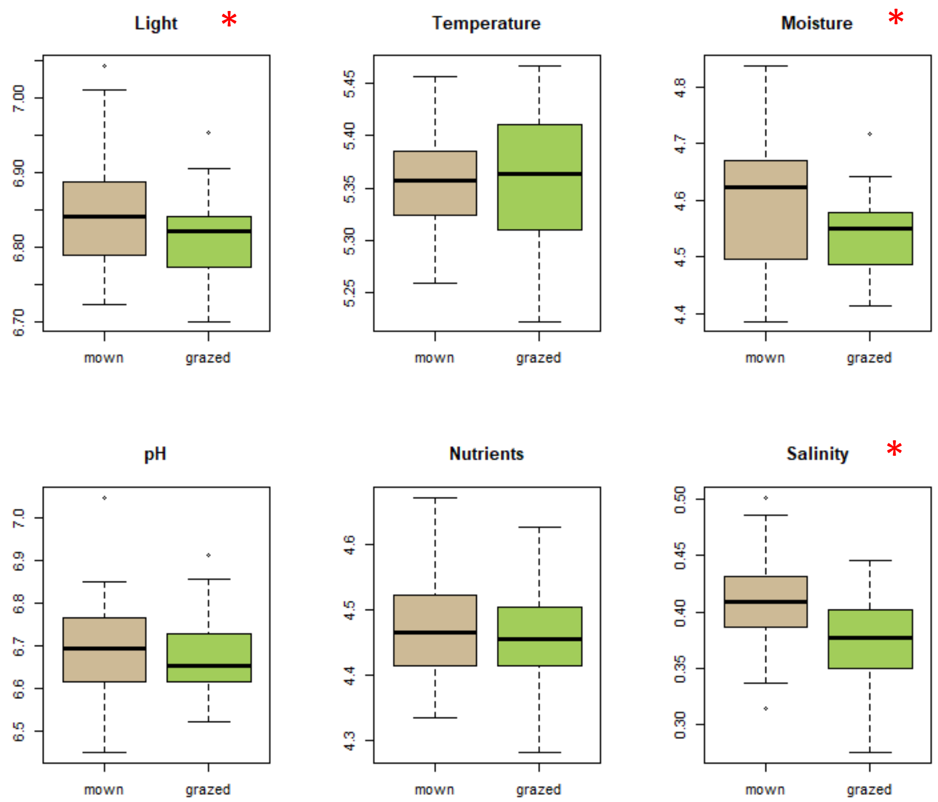

Fig. 16: dependence between EIVs and management, significance is marked by *

5 Discussion

This study focused on ex-arable land in North of White Carpathians that was restored in late 1980s and early 1990s by initial seeding with artificial commercial clover-grass mixture. Target species were observed and their occurrence and frequency were compared between ex-arable plots and those of continuous character (70 years +). The type of management (grazing, mowing) currently carried out on both type of plots was recorded together with other environmental abiotic factors. The occurrence of species and their ecological indicator values was averaged for each plot concerning the continuity (continual, ex-arable) and management (grazing, mowing). The affinity of species to continual or ex-arable plots and to mown or grazed plots and their functional traits were tested to explore whether functional traits can predict species colonisation success on restored grassland.

5.1 The effect of continuity and management on species composition and diversity

The factor of continuity explained more variability in species composition than the factor of management. That suggests that the overall effect of the age of grassland is stronger than current managing practices which is in line with other studies (Karlík a Poschlod 2009; Redhead et al. 2014; Jongepierová et al. 2003) and is affirmed when the effect on species richness is questioned.

Habitat continuity seems to be one of the strongest factors shaping the species communities (Krause & Culmsee 2013; Straubinger et al. 2021; Johansson et al. 2008). The results of this study contributed to this knowledge and showed that the history of grassland significantly affects species composition and richness. Older grasslands that were grasslands at least 70 years ago significantly differ in composition when compared to ex-arable grassland restored 30 years ago. Age of the plot and spontaneous succession leads to differentiation in communities over time (Sojneková a Chytrý 2015) and the age of the plot is strongly linked to the species richness (Valkó et al. 2017). These continual plots tend to host more target species, thus are more diverse than ex-arable plots. Out of 137 target species, 31 had established on ex-arable plots. The community on ex-arable plot inclines towards mesic vegetation, alliance of *Arrhenatherion elatioris* (Prach et al. 2014). When considering the continuity of grassland and its species richness, 30 years do not seem like enough time to develop rich plant communities (Krause a Culmsee 2013) and the processes might be blocked by other variables as discussed later.

Management also has significant effect on the species composition when comparing grazed and mown plots which corresponds with studies dealing with similar topic (Bell et al. 2020; Benthien et al. 2018), although species richness between grazed and mown plots does not differ, similar to Benthien et al. 2018. The difference in species richness would occur when the lack of management would be questioned. Studies show that application of management on abandoned grassland leads to higher numbers of present species (Rysiak et al. 2021) but when abandoned, species richness decreases in first decades (Swacha et al. 2018). Disturbance in the form of mowing or grazing is necessary for the survival of less dominant species. However, the choice of management is important, species which are not good competitors show better growth after salvation, due to physiological plasticity and reduced competition (Mariotte et al. 2012). Others, however, prefer mowing over grazing (Csergő & Demeter, 2012).

Although management is necessary for improvement, diversification of communities on ex-arable grassland and facilitates re-colonisation of desired species, there is no direct link to species richness and the reassembly of species rich communities is generally slow (Walker et al. 2004), thus the continuity of grassland is probably more important.

5.2 The effect of abiotic factors and spatial correlation on species composition and diversity

The effect of coordinate interaction with themselves and each other was not significant, although x-coordinate and y-coordinate separately significantly affected the species composition and therefore were reduced in further analyses. Also species richness was affected by the spatial correlation (Raduła et al. 2020).

The size of the plot is strongly correlated with the number of species (Krauss et al. 2004). The bigger the plot the better the chance to cover geomorphological diversity of area and thus to host more species adapted to different conditions. The alpha diversity mostly responds to the heterogeneity of landscape. With increasing diversity of natural and semi-natural habitats also the alpha diversity increases (Janišová et al. 2014). In this way, heterogeneity of individual plots is ensured by their size and thus partly supplements the heterogenous landscape of traditional farming.

Out of eleven variables tested in forward selection test, only slope and elevation significantly affected species composition on observed plots. Looking at species rather occurring in higher altitudes I suggest the effect of elevation might be strong because continual plots cover wider range of altitudes and are approximately found in higher places. This is probably due to preference of agronomists; some grasslands were distant and high in the countryside that even intensive agriculture did not favour this land. Ex-arable plots also extent on milder slopes which can be explained by a similar reasoning of less favoured areas. Mown and grazed plots are found in similar altitudes but when considering the slope, grazed plots extend on steeper slopes while mown are on milder slopes. Same logic as before can be applied but for current preferences of farmers and the use of heavy machinery to graze on steep and mow milder land.

The effect of elevation and slope on species composition is strong, however when reduced, the continuity and management still proved to significantly affect the species composition.

Neither inclination (slope) nor altitude (elevation) had effect on species diversity.

It is certain that a link exists between environmental variables and species composition and thus should be considered when exploring the processes shaping its formation.

5.3 Affinity of species to continuity and management and their functional traits

No significant effect was discovered that would distinguish species according to their traits and affinity to continuity and management. The disadvantage of this study may be in the chosen method of species sampling. List of target species is convenient when exploring higher number of sites which vary greatly in size. Thus, the variability of the site can be covered as was a case of this study. However, if complemented by sampling plots, comprehensive vegetation data would better indicate the composition of species communities and probably would better reflect the significance of individual species traits. Still, marginal effect exists between canopy height, SLA and species affinity to continuity. Ex-arable plots tend to host species of higher canopy and higher values of SLA. Also, ex-arable plots tend to host species of later flowering as in Mudrák et al., 2017.

When testing EIVs, grazed plots tend to host species which prefer dryer conditions. This dependence is probably caused by the preference of farmer or zootechnic and agronomist (in case of plot being managed by company) who would lead the cattle to graze rather on dry pastures so that topsoil does not suffer too much damage from the hooves. So wet plots are mown by preference. Mown plots and continual plots (marginally) host species which prefer more light. This can be linked to the fact that ex-arable plots host species that are good light competitors and thereby oppress species that prefer sun exposure.

Ex-arable plots tend to host species that withstand salinity. This might reflect condition of ex-arable land as further explored in Sahab et al. 2021 as soil salinisation seems to be a global agronomical issue. Some might view the salinity issue in central-European conditions as insignificant, but soil salinity is not limited by region nor altitude (Singh a Chatrath, 2001). Salinity negatively affects the plant development (Yadav, Kumari, a Ahmed 2011), micro (Kennedy a Stubbs 2006) and macro fauna (Škarková et al. 2016). It also causes changes to soil properties and aggravate hydraulic conductivity, water infiltration and porosity (Amini et al. 2016) and lowers pH (Zaman et al. 2018).
Although the data of this study doesn´t support the importance of epi-zoochory, it is presumable that the species distribution from rich plots to poorer plots could be supported by dynamical usage pattern concerning both the ex-arable (poorer) plots and the continual (richer) ones. In these terms it would be better to prefer sheep grazing for sheep are much better seed distributors than cows and might positively affect the species richness (Socher et al. 2013). However, this would require close cooperation between the Javorník-CZ and the conservationists of White Carpathian protected landscape area.

The effect of isolation was not tested after all. It is probable that there would be no significant dependence as it seems that dispersal of seed is not a problem (Mudrák et al. 2017; Knappova et al. 2017) and although ancient grasslands suffered heavy losses remaining grasslands still serve as source of diaspores (Johanidesová et al. 2015) and each examined ex-arable plot is located within 500 m distance from continual plot. It rather occurs when the quality of ex-arable soil is questioned.

5.4 On low diversity of ex-arable plots

The past land use echoes in current character of species community of continual and ex-arable plots. The question rises whether it is the cropland history of ex-arable land or initial seeding with commercial seed mixture that holds back the establishment of species rich community. Honnay et al., 2017 suggest that the lack of microbial communities and arbuscular mycorrhizal fungi might could negatively affect the species establishment. Their hypothesis was not confirmed, and the microbiome was close to that of ancient grasslands whereas the plant community remained distinct. Lack of well-established microbiome may not be the problem after all, but soil structure and its retention properties might play a role.

Although this study is not exploring the effect of initial seeding, since all the ex-arable plots were seeded in the beginning, I would like to discuss this aspect furthermore. Initial seeding with commercial clover-grass seed mixture could hold back the process of natural succession and prevent variety of grassland flowering species from establishing populations in seeded plots (Knappová et al., 2013). The phenomenon was observed that on plots of different continuity which were neighbouring, the species usually occurring on continual plots were present on the ex-arable plots only up to 1- or 2-meter distance from the continuous plot. This suggest that the problem of establishing species rich communities would not be in the lack of suitable species pool (Krauss et al. 2004) or the effect of habitat isolation (Knappova et al., 2012), but in other issue which could be linked to the condition, quality of the soil on ex-arable plot or the already artificially established community on the plot . Negative effect of initial seeding could support the fact that ex-arable plots tend to host species of higher canopy and of higher values of specific leaf area. This marks good competitors (Westoby 1998). The fact that ex-arable plots are dominated by competitor species (Knappová et al. 2017) only contributes into the fact that majority of artificially seeded species from clover-grass mixture are competitors (Klotz S. & Kühn I. 2002). This could most probably block the spontaneous succession and be one of factors blocking enrichment of new species from local species pool.

5.4.1 Traditional farming and species richness

Grasslands in our climatic conditions are a work of man and thus human management mustn't be overlooked. The question: How to restore and preserve the richness of semi-natural grasslands? should be tightly followed by the question: How this richness was achieved? Field observations are showing that actively heterogeneously managed grasslands are reaching to host the most species rich communities (Janišová et al. 2020). Traditional heterogenous management includes grazing, mowing, the process of manuring and ploughing, sometimes complemented by sowing hayseed residual as regular practices. Manuring was traditionally carried out in form of "*košár*" (verb "*košárování*") (Jongepierová 2008; Podolák 2008; Šťastný 1971) which was wicker or wooden fence where the herd was gathered after the morning pasture and overnight. This *košár* would be left on one place for two or three days (on rainy days only one) and then mowed in a way that one side would stay in place and three sides would be mowed around. Grassland managed this way would be mown for three years and then *košáred* again, as described in detail in Šťastný (1971). In addition to fertilization, this technique also had the other advantage of breaking turf and incorporating manure into the soil. The use of ash to fertilize meadows was also very common, sometimes directly burning wood on the soil, sometimes ashes were stored over winter and applied on meadows in spring (Šťastný, 1971). Wooden ash possess the ability to neutralize soil acidity (Ohno 1992) and was readily available in most households.

The use of manure and ploughing in conventional farming management is risky to say at least. Performed on a large scale, manuring could be fatal for already established species communities. But when applied consciously with manure from a good known local source, the effect on species diversity can be enriching. As recently observed in Serbia, local farmers perform manuring as their regular practice. Often when pasture or meadow is damaged by wild boars or does not produce enough biomass to feed the cattle, farmer spreads manure onto the grassland at the end of grazing season and before the first snow (verbally, Serbia 2021). These grasslands are very diverse and rich as observed personally in Homolje region in Serbia (Fig. 17) and as explored in other studies (Janišová et al. 2021, 2020). Such practices used to be common in central European farming as mentioned above but had vanished.

 

Fig. 17: Traditional farming still alive in Homolje, Serbia, 2021. Source: author

When I asked the agronomist of Javorník-CZ Ing. Petr Pastorek about his opinion on bad condition (Fig. 18) of ex-arable restored grassland I was surprised to hear that he is mostly concerned about the quality of the soil. In his words: "The soil is in very bad condition. It is very compacted from the use of heavy techniques and quite eroded with the topsoil almost missing. Soil has low nutrition content and has poor water retention, even of hydrophobic character". He also mentioned restriction arising from managing land that is part of Protected Landscape Area and impossible application of some traditional farming techniques such as manuring. Since Javorník -CZ closely cooperates with the conservationists of Protected Landscape Area Bílé Karpaty an experiment was established in year 2019 (Barbořík, 2021) to improve the quality of soil and thus the harvested provender.

Fig. 18: Poor condition of species community and soil on ex-arable plot Hrby. Source: author

Experiment was done on two ex-arable plots Zbytky and Köšliska (Zbytky is one of 17 plots explored in this study, the experiment was established after the data for this study were collected). Ploughing, manuring, combination of both and seeding with two types of seed mixture – regional seed mixture and commercial seed mixture were applied on these plots, divided into lines. Ploughing and manuring was done in November 2019 and seeding with both mixtures was done in March 2020, plots were harvested in summer 2020. The effect on biomass harvested on lines seeded with nursery crop was positive but species community on lines seeded with regional seed mixture had not yet been established in the first year. Although it might be presumed that nurse crop could reduce the number of grass species (Pywell et al. 2002). The effect on species diversity improvement was not tested for this experiment was focused on improvement of harvested provender, but species diversity might be positively correlated with productivity (Mittelbach et al. 2001). However, vegetation sampling should be done and will be proposed as this could bring light to what extent is species richness affected by the condition of soil on ex-arable plots. As Javorník-CZ is a company reliable on its incomes and subsidies, they are concerned the overall cost of restoration including higher prize of regional seed mixtures. That could be supplemented by transferring fresh seed-containing hay from nearby species rich ancient grassland. This method is very successful (Kiehl a Pfadenhauer 2007) and might be even more effective when compared to sowing with regional seed mixture (Albert et al. 2019).

6 Conclusion

Semi-natural grasslands are secondary habitat and cultural ecosystem which was cocreated by mankind and its ability to engineer it into his ideas and needs. Thus, unintentionally creating a very precious ecosystem where many animals and plants found their home.

Improving condition of semi-natural grasslands emerging on ex-arable land might be one of the biggest conservationist challenges of 21. century. Processes of species community establishment are studied across scientific fields and results often vary. This study tried to consider several aspects and examined to what extent can habitat continuity and management explain the species composition and diversity of semi-natural grasslands and what role plays other abiotic and biotic processes in establishing the grassland communities.

The time truly plays big role in establishing species rich well-developed communities. However, effect of spatial position, hill slope and altitude were also proven and thus must be considered when exploring these processes. Restored grasslands have the potential to became species rich with time, but the chances are big that spontaneous succession is blocked by initial seeding of clover-grass mixture and the poor condition of the ex-arable soil. Thus, action must be taken to improve the condition of ex-arable grassland and help the establishment of stable and diverse community.

Based on gained information from my study and from other studies dealing with diversity of semi-natural grasslands and traditional ways of farming I boldly and optimistically propose following restoration scenario: An ex-arable plot would be manured for several days during early August by the *košár* technique using sheep herd of local shepherd grazing the slopes of nearby Pláňava hill (598 m). At the end of August plot would be mulched by autochthonous fresh seed-containing hay from species rich ancient grassland (PR Lazy) which extends under the summit of Pláňava hill. Following year, the plot would be grazed in early spring (when enough biomass is produced, and the soil is not soaked from melted snow anymore) until the end of April or beginning of May. Spring grazing seems to be good eliminator of strong competitors. Then the plot would be left ungrazed and until the mid July or early August and mown. This procedure would simulate the traditional farming techniques in their high frequency rotation but extensive character.

Close cooperation between conservationists and ecological farms is a great chance to return the farming and habitat diversity into the landscape and hopefully improve the position of small farmers in the agricultural economy.

7 References

Albert, Ágnes-Júlia, Ondřej Mudrák, Ivana Jongepierová, Karel Fajmon, Ivana Frei, Magdalena Ševčíková, Jitka Klimešová, a Jiří Doležal. 2019. „Grassland Restoration on Ex-Arable Land by Transfer of Brush-Harvested Propagules and Green Hay". *Agriculture, Ecosystems & Environment* 272 (únor): 74–82. https://doi.org/10.1016/j.agee.2018.11.008.

Amini, Sevda, Hossein Ghadiri, Chengrong Chen, a Petra Marschner. 2016. „Salt-Affected Soils, Reclamation, Carbon Dynamics, and Biochar: A Review". *Journal of Soils and Sediments* 16 (3): 939–53. https://doi.org/10.1007/s11368-015-1293-1.

Arponen, Anni, Risto K. Heikkinen, Riikka Paloniemi, Juha Pöyry, Jukka Similä, a Mikko Kuussaari. 2013. „Improving Conservation Planning for Semi-Natural Grasslands: Integrating Connectivity into Agri-Environment Schemes". *Biological Conservation* 160 (duben): 234–41. https://doi.org/10.1016/j.biocon.2013.01.018.

Austrheim, G., E. Gunilla, A. Olsson, a E. Grontvedt. 1999. „Land-Use Impact on Plant Communities in Semi-Natural Sub-Alpine Grasslands of Budalen, Central Norway". *Biological Conservation* 87 (3): 369–79. https://doi.org/10.1016/S0006-3207(98)00071-8.

ter Braak CJF, Šmilauer P (2012) Canoco reference manual and user's guide: software for ordination, version 5.0. Microcomputer Power, Ithaca, USA. www.canoco5.com

Begon, M., J. L. Harper, a C. R. Townsend. 1986. *Ecology: Individuals, Populations an Communities*. Oxford: Blackwell Scientific Publications.

Bell, Matt J., Zoë J. Huggett, Kimberley R. Slinger, a Felicity Roos. 2020. „The Effect of Grazing by Cattle and Sheep on Diverse Pastures>". *Livestock Science* 241 (listopad): 104261. https://doi.org/10.1016/j.livsci.2020.104261.

Benthien, Oda, Matthias Braun, Jana C. Riemann, a Caroline Stolter. 2018. „Long-Term Effect of Sheep and Goat Grazing on Plant Diversity in a Semi-Natural Dry Grassland Habitat". *Heliyon* 4 (3): e00556. https://doi.org/10.1016/j.heliyon.2018.e00556.

Correll, O., J. Isselstein, a V. Pavlu. 2003. „Studying Spatial and Temporal Dynamics of Sward Structure at Low Stocking Densities: The Use of an Extended Rising-Plate-Meter Method". *Grass and Forage Science* 58 (4): 450–54. https://doi.org/10.1111/j.1365-2494.2003.00387.x.

Csergő, Anna & Demeter, Laszlo. (2012). Plant species diversity and traditional management in the Eastern Carpathian grasslands. European Forum on Nature Conservation and Pastoralism.

Český úřad zeměměřický a katastrální, Pod sídlištěm 1800/9 Kobylisy 18211 Praha 8, IČO: 00025712, https://www.cuzk.cz/

Dostálek, Tomáš, Hana Pánková, Zuzana Münzbergová, a Jana Rydlová. 2013. „The Effect of AMF Suppression on Plant Species Composition in a Nutrient-Poor Dry Grassland". *Journal Plos one*. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0080535.

European Environment Agency (EEA): EU-DEM v1.1, (2016). http://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1.1/view

Hájkova, P., a M. Hájek. 2003. „Species Richness and above-Ground Biomass of Poor and Calcareous Spring Fens in the Flysch West Carpathians, and Their Relationships to Water and Soil Chemistry". *Preslia* 75 (3): 271–87.

Hempel, Stefan, Lars Götzenberger, Ingolf Kühn, Stefan G. Michalski, Matthias C. Rillig, Martin Zobel, a Mari Moora. 2013. „Mycorrhizas in the Central European Flora: Relationships with Plant Life History Traits and Ecology". *Ecology* 94 (6): 1389–99. https://doi.org/10.1890/12-1700.1.

Hintze, Christina, Felix Heydel, Christina Hoppe, Sarah Cunze, Andreas König, a Oliver Tackenberg. 2013. „D3: The Dispersal and Diaspore Database – Baseline Data and Statistics on Seed Dispersal". *Perspectives in Plant Ecology, Evolution and Systematics* 15 (3): 180–92. https://doi.org/10.1016/j.ppees.2013.02.001.

Honnay, Olivier, Kenny Helsen, a Maarten Van Geel. 2017. „Plant community reassembly on restored semi-natural grasslands lags behind the assembly of the arbuscular mycorrhizal fungal communities". *Biological Conservation* 212 (srpen): 196–208. https://doi.org/10.1016/j.biocon.2017.06.017.

Hooper, D. U., F. S. Chapin, J. J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J. H. Lawton, et al. 2005. „Effects of Biodiversity on Ecosystem Functioning: A Consensus of Current Knowledge". *Ecological Monographs* 75 (1): 3–35. https://doi.org/10.1890/04-0922.

Janišová, Monika, Alina-Sorina Biro, Anamaria Iuga, Pavel Sirka, a Iveta Škodová. 2020. „Species-Rich Grasslands of the Apuseni Mts (Romania): Role of Traditional Farming and Local Ecological Knowledge". ResearchGate. 2020. https://doi.org/http://dx.doi.org/10.14471/2020.40.017.

Janišová, Monika, Anamaria Iuga, Cosmin Marius Ivașcu, a Martin Magnes. 2021. „Grassland with Tradition: Sampling across Several Scientific Disciplines". *Vegetation Classification and Survey* 2() (únor): 19–35. https://doi.org/10.3897/VCS/2021/60739.

Janišová, Monika, Dana Michalcová, Giovanni Bacaro, a Anne Ghisla. 2014. „Landscape effects on diversity of semi-natural grasslands". *Agriculture, Ecosystems & Environment*, Biodiversity of Palaearctic grasslands: processes, patterns and conservation, 182 (leden): 47–58. https://doi.org/10.1016/j.agee.2013.05.022.

Janssens, F., A. Peeters, J. R. B. Tallowin, J. P. Bakker, R. M. Bekker, F. Fillat, a M. J. M. Oomes. 1998. „Relationship between Soil Chemical Factors and Grassland Diversity". *Plant and Soil* 202 (1): 69–78. https://doi.org/10.1023/A:1004389614865.

Johanidesová, E., K. Fajmon, I. Jongepierová, a K. Prach. 2015. „Spontaneous Colonization of Restored Dry Grasslands by Target Species: Restoration Proceeds beyond Sowing Regional Seed Mixtures". *Grass and Forage Science* 70 (4): 631–38. https://doi.org/https://doi.org/10.1111/gfs.12144.

Johansson, Lotten J., Karin Hall, Honor C. Prentice, Margareta Ihse, Triin Reitalu, Martin T. Sykes, a Merit Kindström. 2008. „Semi-natural grassland continuity, long-term land-use change and plant species richness in an agricultural landscape on Öland, Sweden". *Landscape and Urban Planning* 84 (3): 200–211. https://doi.org/10.1016/j.landurbplan.2007.08.001.

Jongepierová, Ivana. 2008. *Louky Bílých Karpat*. Veselí nad Moravou: ZO ČSOP Bílé Karpaty.

Jongepierová, Ivana & Poková, Hana & Konvička, Ondřej. (2008). Obnova travních porostů. In: Louky Bílých Karpat (pp.445-451), Editors: Ivana Jongepierová, 2008

Jongepierová, Ivana, Jan Mládek, Vilém Pechanec, Karla Vincenecová, Petr Kment, Igor Malenovský, Václav Pižl, et al. 2003. „Vliv pastvy na biodiverzitu lučních porostů MZCHÚ v CHKO Bílé Karpaty", 2003.

Kaplan Z., Danihelka J., Chrtek J., Kirchner J., Kubát K., Štech M. & Štěpánek J. (eds) (2019) Klíč ke květeně České republiky [Key to the flora of the Czech Republic]. Ed. 2. – Academia, Praha

Karlík, Petr, a Peter Poschlod. 2009. „History or Abiotic Filter: Which Is More Important in Determining the Species Composition of Calcareous Grasslands?" *Preslia* 81 (4): 321–40.

Kennedy, Ann C., a Tami L. Stubbs. 2006. „Soil Microbial Communities as Indicators of Soil Health". https://pubag.nal.usda.gov/catalog/44267.

Kiehl, Kathrin, a Jörg Pfadenhauer. 2007. „Establishment and Persistence of Target Species in Newly Created Calcareous Grasslands on Former Arable Fields". *Plant Ecology* 189 (1): 31–48. https://doi.org/10.1007/s11258-006-9164-x.

Kleyer, M., R.m. Bekker, I.c. Knevel, J.p. Bakker, K. Thompson, M. Sonnenschein, P. Poschlod, et al. 2008. „The LEDA Traitbase: A Database of Life-History Traits of the Northwest European Flora". *Journal of Ecology* 96 (6): 1266–74. https://doi.org/10.1111/j.1365-2745.2008.01430.x.

Klotz S. & Kühn I. (2002) Ökologische Strategietypen. – In: Klotz S., Kühn I. & Durka W. (eds), BIOLFLOR: eine Datenbank mit biologisch-ökologischen Merkmalen zur Flora von Deutschland, Schriftenreihe für Vegetationskunde 38: 119–126.

Knappova, Jana, Lucie Hemrova, Michal Knapp, a Zuzana Munzbergova. 2017. „Establishment Limitation May Be More Important than Species Dispersal: Insights from Dry Grasslands and Old-Fields". *Journal of Vegetation Science* 28 (1): 34–42. https://doi.org/10.1111/jvs.12462.

Knappova, Jana, Lucie Hemrova, a Zuzana Muenzbergova. 2012. „Colonization of Central European Abandoned Fields by Dry Grassland Species Depends on the Species Richness of the Source Habitats: A New Approach for Measuring Habitat Isolation". *Landscape Ecology* 27 (1): 97–108. https://doi.org/10.1007/s10980-011-9680-5.

Knappová, Jana, Michal Knapp, a Zuzana Münzbergová. 2013. „Spatio-Temporal Variation in Contrasting Effects of Resident Vegetation on Establishment, Growth and Reproduction of Dry Grassland Plants: Implications for Seed Addition Experiments". *PLOS ONE* 8 (6): e65879. https://doi.org/10.1371/journal.pone.0065879.

Krause, Benjamin, a Heike Culmsee. 2013. „The significance of habitat continuity and current management on the compositional and functional diversity of grasslands in the uplands of Lower Saxony, Germany". *Flora - Morphology, Distribution, Functional Ecology of Plants* 208 (5): 299–311. https://doi.org/10.1016/j.flora.2013.04.003.

Krauss, Jochen, Alexandra-Maria Klein, Ingolf Steffan-Dewenter, a Teja Tscharntke. 2004. „Effects of Habitat Area, Isolation, and Landscape Diversity on Plant Species Richness of Calcareous Grasslands". *Biodiversity & Conservation* 13 (8): 1427–39. https://doi.org/10.1023/B:BIOC.0000021323.18165.58.

Kubánek, Petr. 1998. *Zlomky z historie obce Popov*. Štítná nad Vláří: MAP.

Lokoč, Radim, a Michaela Lokočová. 2010. *Vývoj krajiny v České republice*.

Mariotte, P., A. Buttler, D. Johnson, A. Thebault, a C. Vandenberghe. 2012. „Exclusion of Root Competition Increases Competitive Abilities of Subordinate Plant Species through Root-Shoot Interactions". *Journal of Vegetation Science* 23 (6): 1148–58. https://doi.org/10.1111/j.1654-1103.2012.01432.x.

Miko, Ladislav, a Michael Hošek. 2009. *Příroda a krajina České republiky.* Praha.

Mittelbach, Gary G., Christopher F. Steiner, Samuel M. Scheiner, Katherine L. Gross, Heather L. Reynolds, Robert B. Waide, Michael R. Willig, Stanley I. Dodson, a Laura Gough. 2001. „What Is the Observed Relationship Between Species Richness and Productivity?" *Ecology* 82 (9): 2381–96. https://doi.org/10.1890/0012-9658(2001)082[2381:WITORB]2.0.CO;2.

Mudrák, Ondřej, Karel Fajmon, a Ivana Jongepierová. 2017. „(PDF) Mass Effects, Clonality, and Phenology but Not Seed Traits Predict Species Success in Colonizing Restored Grasslands". ResearchGate. 2017. https://doi.org/http://dx.doi.org/10.1111/rec.12588.

Nekuda, Vladimír. 1995. *Zlínsko*. Brno: Muzejní a vlastivědná společnost.

Ohno, Tsutomu. 1992. „Neutralization of Soil Acidity and Release of Phosphorus and Potassium by Wood Ash". *Journal of Environmental Quality* 21 (3): 433–38. https://doi.org/https://doi.org/10.2134/jeq1992.00472425002100030022x.

Osawa, Takeshi, Kazunori Kohyama, a Hiromune Mitsuhashi. 2016. „Trade-off Relationship between Modern Agriculture and Biodiversity: Heavy Consolidation Work Has a Long-Term Negative Impact on Plant Species Diversity". *Land Use Policy* 54 (červenec): 78–84. https://doi.org/10.1016/j.landusepol.2016.02.001.

Partel, Meelis, Aveliina Helm, Triin Reitalu, Jaan Liira, a Martin Zobel. 2007. „Grassland Diversity Related to the Late Iron Age Human Population Density". *Journal of Ecology* 95 (3): 574–82. https://doi.org/10.1111/j.1365-2745.2007.01230.x.

Piras, Simone, Svetlana Botnarenco, Matteo Masotti, a Matteo Vittuari. 2021. „Post-Soviet Smallholders between Entrepreneurial Farming and Diversification. Livelihood Pathways in Rural Moldova". *Journal of Rural Studies* 82 (únor): 315–27. https://doi.org/10.1016/j.jrurstud.2021.01.006.

Podolák, Ján. 2008. *Tradičné poľnohospodárstvo na Slovensku*. Bratislava: ASCO Art &Science.

Prach, Karel, Ivana Jongepierová, Klára Řehounková, a Karel Fajmon. 2014. „Restoration of grasslands on ex-arable land using regional and commercial seed mixtures and spontaneous succession: Successional trajectories and changes in species richness". *Agriculture, Ecosystems & Environment*, Biodiversity of Palaearctic grasslands: processes, patterns and conservation, 182 (leden): 131–36. https://doi.org/10.1016/j.agee.2013.06.003.

Prach, Karel, Klára Řehounková, Kamila Lencová, a Alena Jírová. 2013. „Vegetation Succession in Restoration of Disturbed Sites in Central Europe: The Direction of Succession and Species Richness across 19 Seres". *ResearchGate*. https://doi.org/10.1111/avsc.12064.

Prach, K., Jongepierová, I., Jírová, A., Lencová, K., 2009b. Ekologie obnovy – IV. Obnova travinných ekosystémů. Živa 4, 165-168.

Pywell, Richard F., James M. Bullock, Alan Hopkins, Kevin J. Walker, Tim H. Sparks, Mike J. W. Burke, a Steve Peel. 2002. „Restoration of Species-Rich Grassland on Arable Land: Assessing the Limiting Processes Using a Multi-Site Experiment". *Journal of Applied Ecology* 39 (2): 294–309. https://doi.org/10.1046/j.1365-2664.2002.00718.x.

QGIS Geographic Information System. QGIS Association. http://www.qgis.org

Raduła, Małgorzata W., Tomasz H. Szymura, Magdalena Szymura, Grzegorz Swacha, a Zygmunt Kącki. 2020. „Effect of Environmental Gradients, Habitat Continuity and Spatial Structure on Vascular Plant Species Richness in Semi-Natural Grasslands". *Agriculture, Ecosystems & Environment* 300 (září): 106974. https://doi.org/10.1016/j.agee.2020.106974.

Redhead, John W., John Sheail, James M. Bullock, Andrea Ferreruela, Kevin J. Walker, a Richard F. Pywell. 2014. „The Natural Regeneration of Calcareous Grassland at a Landscape Scale: 150 Years of Plant Community Re-Assembly on Salisbury Plain, UK". *Applied Vegetation Science* 17 (3): 408–18. https://doi.org/10.1111/avsc.12076.

RStudio Team (2016). RStudio: Integrated Development for R. RStudio, Inc., Boston, MA URL http://www.rstudio.com/.

Rysiak, Anna, Witold Chabuz, Wioletta Sawicka-Zugaj, Jan Zdulski, Grzegorz Grzywaczewski, a Mariusz Kulik. 2021. „Comparative Impacts of Grazing and Mowing on the Floristics of Grasslands in the Buffer Zone of Polesie National Park, Eastern Poland". *Global Ecology and Conservation* 27 (červen): e01612. https://doi.org/10.1016/j.gecco.2021.e01612.

Sahab, Sinha, Ibha Suhani, Vaibhav Srivastava, Puneet Singh Chauhan, Rajeev Pratap Singh, a Vishal Prasad. 2021. „Potential risk assessment of soil salinity to agroecosystem sustainability: Current status and management strategies". *Science of The Total Environment* 764 (duben): 144164. https://doi.org/10.1016/j.scitotenv.2020.144164.

Skalický V. (1988) Regionálně fytogeografické členění [Regional phytogeographic division]. -In: Hejný S., Slavík B., Chrtek J., Tomšovic P. & Kovanda M. (eds), Květena České socialistické republiky [Flora of the Czech Socialistic Republic] 1: 103-121, Academia, Praha

Socher, Stephanie A., Daniel Prati, Steffen Boch, Jörg Müller, Henryk Baumbach, Sonja Gockel, Andreas Hemp, et al. 2013. „Interacting Effects of Fertilization, Mowing and Grazing on Plant Species Diversity of 1500 Grasslands in Germany Differ between Regions". *Basic and Applied Ecology* 14 (2): 126–36. https://doi.org/10.1016/j.baae.2012.12.003.

Sojneková, Martina, a Milan Chytrý. 2015. „From Arable Land to Species-Rich Semi-Natural Grasslands: Succession in Abandoned Fields in a Dry Region of Central Europe". *Ecological Engineering* 77 (duben): 373–81. https://doi.org/10.1016/j.ecoleng.2015.01.042.

Standish, R. J., V. A. Cramer, S. L. Wild, a R. J. Hobbs. 2007. „Seed Dispersal and Recruitment Limitation Are Barriers to Native Recolonization of Old-Fields in Western

Australia". *Journal of Applied Ecology* 44 (2): 435–45. https://doi.org/10.1111/j.1365-2664.2006.01262.x.

Straubinger, Cornelia, Christoph Reisch, a Peter Poschlod. 2021. „The influence of historical management on the vegetation and habitat properties of semi-dry grassland". *Agriculture, Ecosystems & Environment* 320 (říjen): 107587. https://doi.org/10.1016/j.agee.2021.107587.

Swacha, Grzegorz, Zoltán Botta-Dukát, Zygmunt Kącki, Daniel Pruchniewicz, a Ludwik Żołnierz. 2018. „The Effect of Abandonment on Vegetation Composition and Soil Properties in Molinion Meadows (SW Poland)". *PLOS ONE* 13 (5): e0197363. https://doi.org/10.1371/journal.pone.0197363.

Škarková, P., Kos, M., Drobne, D., Vávrová, M., Jemec, A., 2016. Effects of food salinization on terrestrial crustaceans Porcellio scaber. Appl. Soil Ecol. 100. https://doi.org/10.1016/j.apsoil.2015.11.007

Šťastný, Jaroslav. 1971. *Tradiční zemědělství na Valašsku*. Praha: Univerzita Karlova Praha.

Valkó, Orsolya, Balázs Deák, Péter Török, András Kelemen, Tamás Miglécz, a Béla Tóthmérész. 2017. „Filling up the gaps—Passive Restoration Does Work on Linear Landscape Elements". *Ecological Engineering* 102 (květen): 501–8. https://doi.org/10.1016/j.ecoleng.2017.02.024.

Walker, Kevin J, Paul A Stevens, David P Stevens, J. Owen Mountford, Sarah J Manchester, a Richard F Pywell. 2004. „The Restoration and Re-Creation of Species-Rich Lowland Grassland on Land Formerly Managed for Intensive Agriculture in the UK". *Biological Conservation* 119 (1): 1–18. https://doi.org/10.1016/j.biocon.2003.10.020.

Westoby, Mark. 1998. „A Leaf-Height-Seed (LHS) Plant Ecology Strategy Scheme". *Plant and Soil* 199 (2): 213–27. https://doi.org/10.1023/A:1004327224729.

Yadav, Vikas Patade, Maya Kumari, a Zakwan Ahmed. 2011. „Seed Priming Mediated Germination Improvement and Tolerance to Subsequent Exposure to Cold and Salt Stress in Capsicum". 2011. https://doi.org/10.3923/rjss.2011.125.136.

Zaman, M., Shahid, S.A., Heng, L., 2018. Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques, Guideline for Salinity Assessment, https://doi.org/10.1007/978-3-319-96190-3

Zobel, M., van der Maarel, E., Dupré, C., 1998 Species pool: the concept, its determination and significance for community restoration. Applied Vegetation Science 1:55-66

Online sources:

Act no. 114/1992 Sb., on Nature and landscape conservation, www.zakonyprolidi.cz

https://geoportal.cuzk.cz/WMS_ORTOFOTO_PUB/WMService.aspx

https://ags.cuzk.cz/archiv/?start=lms

Public land register LPIS, http://eagri.cz/public/app/lpisext/lpis/verejny2/plpis/

www.czechglobe.cz, Ecosystem station in Štítná nad Vláří – Popov
www.eagri.cz
www.pladias.cz