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INFLUENCE OF LAND USE ON PLANT COMMUNITY COMPOSITION IN VYSOCINA REGION GRASSLANDS, CZECH REPUBLIC

Human disturbance is an important factor in forming vegetation. According to our hypothesis, anthropogenic activity and changes in the species composition of grass communities occur in the process of co-evolution. Understanding co-evolution, to better predict future changes in the entire ecosystem. Five grassland sites were selected with different methods of use and hence different anthropogenic disturbance regimes. The results show that the composition of grassland communities responds to the methods of their use. The needs and demands of our civilization are changing. Humans co-create plant communities the preservation of which depends on their use by humans.

1. INTRODUCTION

At the beginning of the Neolithic revolution, when humans kept animals, a need arose to ensure food for them [1]. Since the period of pastoralism, people have been using grassland communities as a source of food for ruminants and horses [2]. In the past, they were moving to places with plenty of green grass biomass (forage) to have

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food for the animals [3]. Later, they settled down and started to use some sites permanently as pastures, particularly those inappropriate to become arable land. However, even the arable land was used for grazing if the fields lay idle (fallow). Later, grasslands started to be used as a source of hay for forage outside the vegetation period. Meadows were established primarily in flooded alluvia of rivers.

Grasslands are closely related to agriculture and some human activities [4]. Grassland management (grazing and mowing) is necessary to prevent succession leading to the formation of scrub and trees [5]. Semi-natural permanent grassland extensively managed is relatively rich in species and is dominated by grasses and perennial herbs. Plant species composition reflects soil conditions (pH, humus content, contents of nutrients) and climatic conditions which depend primarily on the altitude.

The dawn of the industrial revolution witnessed changes in livestock breeding and in the system of acquiring forage. Year-round cattle housing brought a need for high-quality forage, rich in nitrogenous substances. Fodder crops started to be grown on arable land. Clover crops (red clover, alfalfa) or clover grass mixtures could cover the need for forage for cattle during the whole year [6]. Subsequently, the need for forage from grasslands decreased. Fodder crops create communities poor in species on arable land [7] consisting of seeded crops and weeds. The intensification of agriculture after World War II led to the ploughing of meadows [8] and the expansion of growing fodder crops on arable land. The cultivation of fodder crops was often connected with intensification elements such as the use of industrial fertilizers, irrigation systems and pesticides. The aim was the production of high volumes of forage from arable land, with a high content of nitrogenous substances [8]. In some places, the lands formerly used for farming are currently being abandoned [9]. This sudden absence of human interventions leads to the development of specific vegetation [10]. Abandoned sites provide conditions favourable for the development of ruderal vegetation, after a long time of succession to shrubs and woods with a considerable representation of allochthonous species [11].

Understanding the factors and processes that influence the taxonomic and functional composition of biological communities is crucial for conservation ecology and biology [12]. The character of human disturbances (human activities) is an important factor in forming the vegetation species composition. Human activities are changing too, responding to the development of human civilization. According to our hypothesis: anthropogenic activity and changes in the species composition of grasslands occur in the process of co-evolution. Understanding the co-evolution of human civilization and vegetation will allow us to better predict future changes in the entire ecosystem. Therefore, our research aimed to i) determine how human management affected the plant species composition of studied grassland, ii) determine the share of plant species tolerant to diverse levels of disturbance on sites used for different purposes, iii) establish directions in changes in the species composition of vegetation as a result of human civilization.

2. MATERIAL AND METHODS

Study area. The study was situated in the Vysocina Region (Bohemian-Moravian Highlands), Czech Republic (CR) (Fig. 1). The region is located in the transport and population centre of the CR [13]. The economy of the eastern part of the region is influenced by the neighbouring Brno agglomeration, while the north-western part of the region is already the catchment area of the capital city of Prague (CR). The Vysocina Region is characterized by a high percentage of agricultural and arable land, the lowest population density of all regions in the country, and many small municipalities [14]. The region is typical of landscape degradation and the urgency of environmental problems. Extreme expansion and amalgamation of fields under the communism era resulted in large fields (frequently >100 ha) that are both erosion-prone and increase the risk of flooding. Much of the historical mosaic and species-rich habitat such as pasture was also destroyed [15]. In terms of the typology of rural space, it is underdeveloped countryside, characterized by poor civic amenities, small numbers of public transport connections, low municipal budgets, and negligible investment opportunities [16].

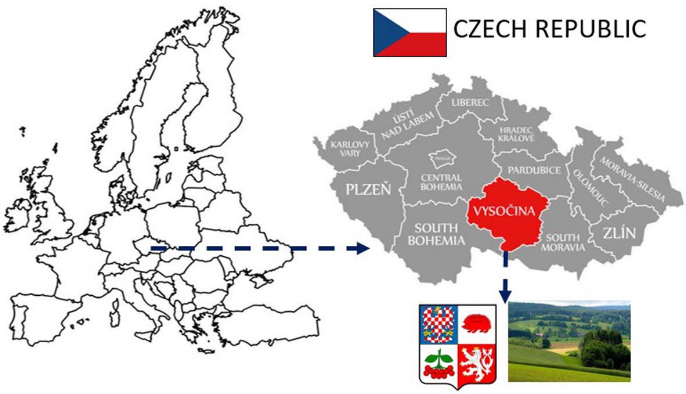

Fig. 1. The Vysocina Region; location of the study site

The region is a typical highland with a high share of grasslands in contrast to low elevations with prevailing arable lands. The Vysocina Region is characterized by the mean altitude of 500 m above sea level (ranging between 239 and 837 m a.s.l.), in the two distinct mountain ranges of Zdarske vrchy in the north of the region and Jihlavske vrchy in the south-west. The Vysocina Region is one of the colder regions of the CR. The long-term mean annual temperature ranges from 6 to 8 °C and the long-term mean total annual precipitation amount is 500–800 mm (Fig. 2) [13].

The original vegetation has been transformed by human activity into an undulating cultivated steppe with low hills and valleys and a wealth of forests and groves. The mass of cultivated forests covers most of the highest areas of the region. A large part of the stands are monocultures of Norway spruce (*Picea abies*), which have been seriously damaged by the bark beetles since 2018 [13]. The lack of large ore deposits has spared the highlands from the devastation of mining activities.

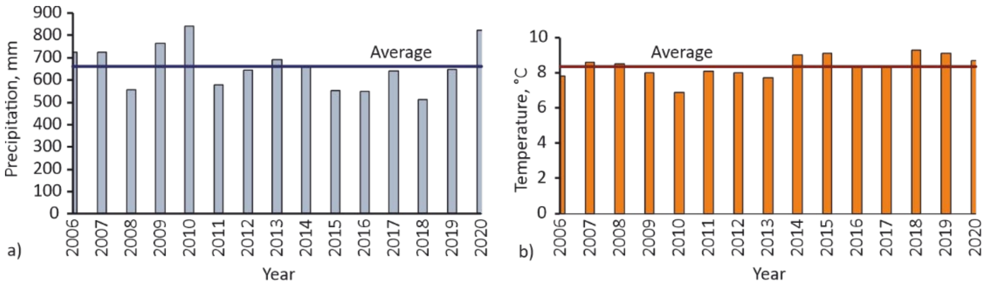

Fig. 2. Meteorological conditions of the Vysocina Region: a) average precipitation, b) average temperature

Fig. 3. Selected grassland sites: a) cattle grazing (Pasture), b) occasional sheep grazing (Extensive), c) arable land with the clover-grass forage mixture (Clover), d) mowed meadow (Meadow), e) abandoned ruderal grassland (Ruderal)

Characteristics of sites with different methods of use:

• Cattle grazing (Pasture, Fig. 3a): The site is situated in the Rovečné cadastral area (49.5841028N, 16.3685472E). It was ploughed in the autumn of 2016, and the compost was worked into the soil. In the spring of 2017, a presowing treatment was made, and a cover crop was seeded (oats). The seeding rate was 100 kg/ha; subsequently, a UNI-P-10 grazing mixture was seeded separately at 30 kg/ha. The seeding was followed by rolling and a collection of stones. In 2017– 2019, the site was used as a pasture for 20–30 heads of spotted cattle.

• Occasional sheep grazing (Extensive, Fig. 3b): The site is situated in the cadastral area of Vysoká u Jevíčka (49.6623514N, 16.8086858E). Since 2015, it has been used as a paddock and occasional pasture for hobby animals: four ouessant sheep, two sheep of meat type and two Cameroon goats. In 2015, self-seeded woody plants were removed, and the site was cleaned. Currently, there is no other site maintenance. The animals use the site only sporadically, and being additionally fed, they do not depend on grazing.

• Arable land with the clover-grass forage mixture (Clover, Fig. 3c): The site is situated in the Rovečné cadastral area (49.5919833N, 16.3662300E). In the autumn of 2015, it was ploughed with the incorporation of compost into the soil. In the spring of 2016, pre-sowing treatment was made, and the cover crop was sown. The sowing rate of spring wheat was 80 kg/ha. Then, the UNI-J-90 clover-grass mixture was seeded separately at a rate of 23 kg/ha together with a starting dose of nitrogen at 3 kg/ha. The sowing was followed by rolling and a collection of stones.

• Cut meadow (Meadow, Fig. 3d): The site is situated in the Ubušínek cadastral area (49.6159086N, 16.2867633E). The permanent grassland has been there for at least 40 years. During that period, it has been neither repeatedly seeded nor treated with additional sowing. Once a year, the site is fertilized with calcium nitrate at 150 kg/ha (40 kg of nitrogen per hectare). The permanent stand is regularly cut twice in the growing season with the first cut at the turn of May and June, and the second at the end of September.

• Abandoned ruderal grassland (Ruderal, Fig. 3e): The site is situated in the cadastral area of Bystřice nad Pernštejnem (49.5189211N, 16.2657394E), near a gardening colony. Formerly, it was mowed by gardeners who fed their rabbits. After 1989, the site was returned to its original owners. Since that time, it has not been used and no cultivation measures are implemented there.

Method of vegetation assessment. The vegetation was assessed using phytocoenological relevés. Five plots (Fig. 3) were chosen at each of the five studied sites for the phytocoenological relevés sized 10 m^2. The phytocoenological vegetation assessment took place twice each year in 2018 and 2019. The first one was before the first cut (if made on the site) from May to June. The second one was before the last cut in September. For each phytocoenological relevé, all species of plants growing in a defined area were recorded, and the total coverage of the herb layer and the cover of individual plant species were estimated directly in percent. Scientific names of plant species were unified according to the Pladias database of Czech flora and vegetation [17]. Plant species were divided into basic functional groups (perennial grasses, annual grasses, legumes, other dicots, and non-flowering plants). Other parameters evaluated in the detected species included indicative values for herb layer disturbance (structural index), frequency of herb layer disturbance, and intensity of herb layer disturbance [18].

Indicative values for disturbance express the relation of common taxa both to the frequency and to the intensity of disturbance. Individual types of disturbance are not distinguished; however, the values cover a wide range of disturbance types such as timber logging, felling, grazing, trampling, use of herbicides, fires, windthrows, soil erosion, ploughing, digging by animals, the action of water (waves or flow) and floods. There are three types of indicative values for a disturbance [18, 19]:

- Indicative values for disturbance set up as structural index express disturbance regime through community parameters. The structural index is standardized for a range from 0 to 1 with higher values indicating a higher degree of disturbance.
- Indicative values for the frequency of disturbance are expressed as a reversed value of time between two disturbances on the logarithmic scale (in years, decimal logarithms). For example, value –2 means a hundred years between two disturbances, value –1 means ten years, while value 0 means a disturbance coming on average once a year. A unit difference corresponds to the ten-times increased frequency of disturbances.
- Indicative values for the intensity of disturbance are expressed on an arbitrary scale from 0 (mildest) to 1 (most intensive). They are based on an estimated share of removed biomass and the area share of soil surface affected by one disturbance. Although the indicative values for frequency and intensity partly correlate, they can serve to express these two components of the disturbance niche of taxa separately.

Values of the coverage of individual plant species on the observed sites were processed by the multidimensional analysis of ecological data. The choice of optimum analysis was governed by the length of the gradient determined by the segment-detrended correspondence analysis (DCA). Further, canonical correspondence analysis (CCA) was used. Statistical significance was determined using the Monte-Carlo test with 999 permutations calculated. The data were processed using the Canoco5 computer programme [20].

3. RESULTS

94 plant taxa were found during two years of monitoring. The numbers of species and average values of disturbance characteristics are presented in Table 1.

Table 1

Total numbers of species found, average numbers of species per plot area, and mean indicative values of disturbance characteristics in the monitored stand types

Site	Number of species		Indicative value of herb layer disturbance		
	Total	Average (per10 m^2)	Structural index	Frequency	Intensity
Pasture	63	14.25	0.66	–0.22	0.97
Meadow	63	16.65	0.62	–0.30	1.18
Clover	34	6.40	0.68	–0.22	0.76
Ruderal	40	8.35	0.62	–0.34	0.63
Extensive	42	10.35	0.51	–0.41	0.41

Shares of the coverage of the groups of taxa on the monitored sites are shown in Fig. 4.

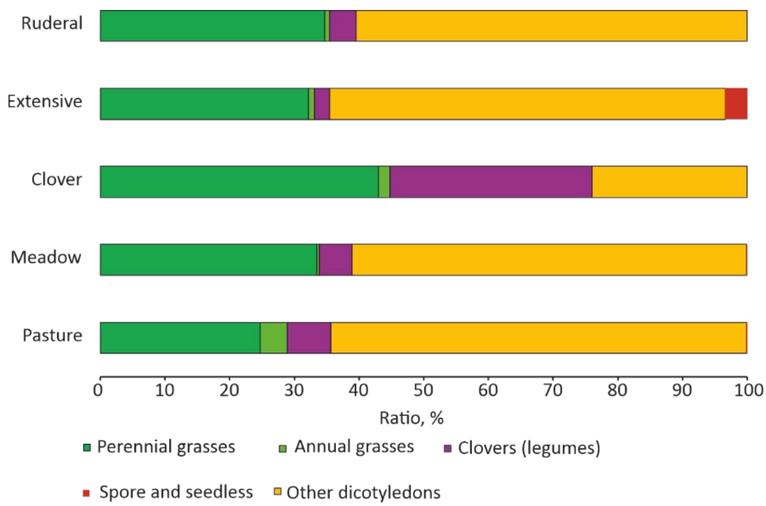

Fig. 4. Percentage of each group of plants on the sites of different use

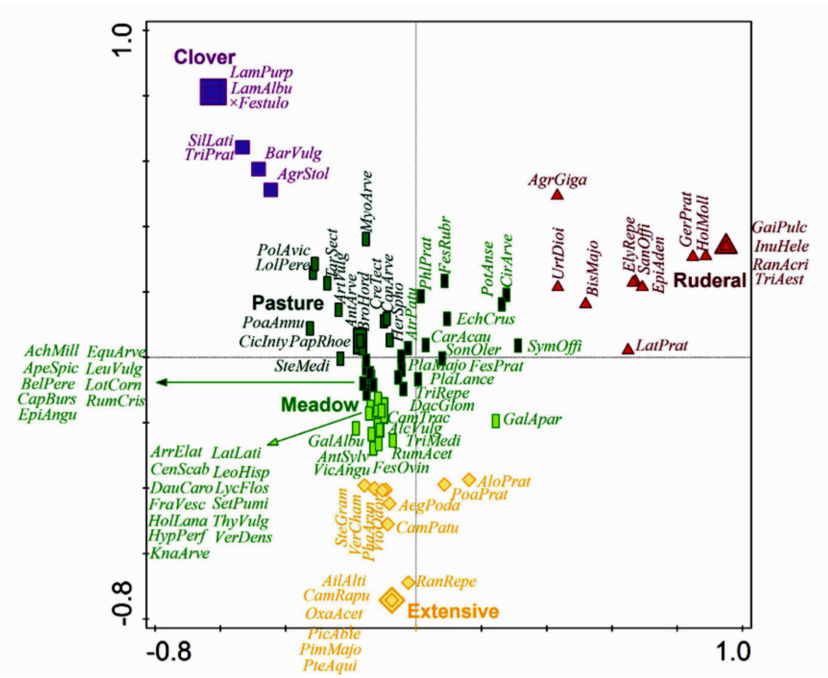

Fig. 5. Occurrence of plant taxa on the sites of different use;
Ruderal means ruderal site, Extensive – extensively used stand, Clover – clover crop on arable land, Pasture, Meadow – cutted grassland, overall explained variability 20.9%, *F*-ratio 6.3, *P*-value 0.001

Results of the CCA analysis which evaluated the coverage of plant taxa on the monitored sites were significant at a significance level $\alpha = 0.001$ for all canonical axes. A graphical illustration of the results is presented in Fig. 5. Based on the CCA analysis, the detected plant taxa can be divided into six groups. The division of taxa into groups according to CCA analysis is given in Table 2.

Table 2

Groups of plant species according to CCA analysis

Group	Plant species[a]	Taxon
1. Extensive	perennial grasses	*AloPrat* – *Alopecurus pratensis*, *PhaArun* – *Phalaris arundinacea*, *PoaPrat* – *Poa pratensis*
	other	*AegPoda* – *Aegopodium podagraria*, *AilAlti* – *Ailanthus altissima*, *CamPatu* – *Campanula patula*, *CamRapu* – *Campanula rapunculoides*, *PimMajo* – *Pimpinella major*, *Oxa acet* – *Oxalis acetosella*, *RanRepe* – *Ranunculus repens*, *SteGram* – *Stellaria graminea*, *VerCham* – *Veronica chamaedrys*, *VioOdor* – *Viola odorata*
	spore and non-flowering plants	*PicAbie* – *Picea abies*, *PteAqui* – *Pteridium aquilinum*
2. Clover	perennial grasses	*×Festulo* – *×Festulolium*, *AgrStol* – *Agrostis stolonifera*
	legumes	*TriPrat* – *Trifolium pratense*
	other	*BarVulg* – *Barbarea vulgaris*, *LamAlbu* – *Lamium album*, *LamPurp* – *Lamium purpureum*, *SilLati* – *Silene latifolia*
3. Pasture	perennial grasses	*LolPere* – *Lolium perenne*
	annual grasses	*BroHord* – *Bromus hordeaceus*, *PoaAnnu* – *Poa annua*,
	other	*AntArve* – *Anthemis arvensis*, *ArtVulg* – *Artemisia vulgaris*, *CicInty* – *Cichorium intybus*, *ConArve* – *Convolvulus arvensis*, *CreTect* – *Crepis tectorum*, *HerSpho* – *Heracleum sphondylium*, *MyoArve* – *Myosotis arvensis*, *PapRhoe* – *Papaver rhoeas*, *PolAvic* – *Polygonum aviculare*, *SteMedi* – *Stellaria media*, *TarSect* – *Taraxacum* sect. *Taraxacum*
4. Pasture and meadow	perennial grasses	*DacGlom* – *Dactylis glomerata*, *FesPrat* – *Festuca pratensis*, *FesRubr* – *Festuca rubra*, *PhlPrat* – *Phleum pratense*
	annual grasses	*ApeSpic* – *Apera spica-venti*, *EchCrus* – *Echinochloa crus-galli*
	legumes	*LotCorn* – *Lotus corniculatus*, *TriRepe* – *Trifolium repens*
	other	*AchMill* – *Achillea millefolium*, *AtrPatu* – *Atriplex patula*, *BelPere* – *Bellis perennis*, *CapBurs* – *Capsella bursa-pastoris*, *CarAcau* – *Carlina acaulis*, *CirArve* – *Cirsium arvense*, *EpiAngu* – *Epilobium angustifolium*, *GalApar* – *Galium aparine*, *LeuVulg* – *Leucanthemum vulgare*, *PlaLance* – *Plantago lanceolata*, *PlaMajo* – *Plantago major*, *PotAnse* – *Potentilla anserina*, *RumCris* – *Rumex crispus*, *SonOler* – *Sonchus oleraceus*, *SymOffi* – *Symphytum officinale*
	spore and non-flowering plants	*EquArve* – *Equisetum arvense*

Table 2

Groups of plant species according to CCA analysis

Group	Plant species[a]	Taxon
5. Meadow	perennial grasses	*ArrElat – Arrhenatherum elatius, HolLana – Holcus lanatus, FesOvin – Festuca ovina*
	annual grasses	*SetPumi – Setaria pumila*
	legumes	*LatLati – Lathyrus latifolius, TriMedi – Trifolium medium*
	other	*AlcVulg – Alchemilla vulgaris, AntSylv – Anthriscus sylvestris, CamTrac – Campanula trachelium, CenScab – Centaurea scabiosa, DauCaro – Daucus carota, FraVesc – Fragaria vesca, GalAlbu – Galium album, HypPerf – Hypericum perforatum, Kna arve – Knautia arvensis, LeoHisp – Leontodon hispidus, Lyc flos – Lychnis flos-cuculi, RumAcet – Rumex acetosa,ThyVulg – Thymus vulgaris, VerDens – Verbascum densiflorum, VicAngu – Vicia angustifolia*
6. Ruderal	perennial grasses	*AgrGiga – Agrostis gigantea, HolMoll – Holcus mollis, ElyRepe – Elymus repens,*
	annual grasses	*TriAest – Triticum aestivum,*
	legumes	*LatPrat – Lathyrus pratensis*
	other	*BisMajo – Bistorta major, GaiPulc – Gaillardia pulchella, GerPrat – Geranium pratense, EpiAden – Epilobium adenocaulon, InuHele – Inula helenium, RanAcri – Ranunculus acris, SanOffi – Sanguisorba officinalis, UrtDioi – Urtica dioica*

[a]In column 2 (Plant species), "other" means "other dicotyledons".

4. DISCUSSION

The impact of humans on plant communities has been documented in the scientific literature [21–23]. According to Falcão et al. [21], human impacts, such as land use and habitat disturbance, can affect species composition and drive plant invasiveness. Changes in the species composition of vegetation generated by changes in human activities are documented also in other climatic zones [23].

The research result shows that the vegetation of the monitored site – Pasture creates a plant community rich in species, which is accommodated to the strong disturbance of the herb layer, with a high frequency of disturbance connected with the removal of most biomass. The Meadow site recorded the highest average number of taxa. The vegetation can be characterized as a community that is accommodated to the disturbance of the herb layer connected with the removal of most biomass – with a lower frequency of disturbance though. Clover crops create the poorest species community on arable land, which is best adapted to the strong disturbance of herb layer that is of high frequency and connected with the removal of most biomass. The Ruderal community had the second-lowest average number of plant species. The community is accommodated to the herb layer's disturbance similarly to Meadows. It includes species indicating a less frequent disturbance, which relates to the removal of lower amounts of biomass.

The Extensive use site had a higher average number of species than the Ruderal site and the site of Clover on arable land but a lower average number of species than the Meadow and Pasture sites. This community was the worst tolerant to disturbance, requiring less frequent disturbances and removal of only a limited amount of biomass.

The results show that long-term management induced by agricultural activities leads to the development of rich-in-species grass communities on monitored Meadows and Pastures. It was confirmed that the intensification of land use practices reached the mountain meadows of alpine valleys [24]. The authors pay attention to the fact that the average number of species found in 2008 was lower than in the 1940s. This result supports a trend that has been frequently observed in managed grasslands over the last 60 years [24]. Long-term agricultural use of meadows and pastures leads to the creation of specific plant communities. The dominant plant species are those suitable for livestock food, such as the grasses *Lolium perenne*, *Festuca pratensis*, *Arrhenatherum elatius*, the clover *Trifolium repens*, *Lotus corniculatus* and the herbs *Daucus carota*, *Plantago lanceolata*. The representation of these and other plant species is significant in terms of the fulfilment of the productive functions of grasslands.

The species diversity of European grasslands considerably depends on their prehistorical origin, a unique combination of local abiotic factors, and the regional pool of species [25]. It was also shown that traditional land use systems are important for the preservation of species diversity of grasslands [25]. Agricultural grasslands are an important resource and biodiversity in the context of the European landscape. Species-rich grasslands can be a source of regional populations for many plant species. These populations can be used in the breeding of new fodder varieties with specific characteristics. However, the high level of biodiversity is linked to the nature of land management.

Intensification of forage production leads to the development of communities that are poor in species. The process started in the period of the industrial revolution, after World War II, and culminated in the second half of the 20th century. The massive use of industrial fertilizers and the sowing of mixtures of non-native species or new varieties are the main signs of intensification. Intensification leads to the dominance of supported grass species ×*Festulolium* (hybrid of genus *Festuca* and *Lolium*) and clover *Trifolium pratense*. Dominant species compete with other species, which will result in a decrease in vegetation biodiversity.

Reduction of anthropogenic pressure is generally considered as contributing to biological diversity. Nevertheless, termination of certain land use can lead either to regeneration or loss of biological diversity in response to changes in physical and biological processes [26]. Extensive approach or withdrawal from agricultural procedures induces changes in the species composition of vegetation and a slight decrease in the number of plant species. This process began in the 1990s and relates to agriculture's transformation and changes in the European agricultural policy. Sitzia et al. [26] inform that spontaneous afforestation following the discontinuation of agricultural procedures is currently common in Europe due to socioeconomic factors. Although this brought a certain recovery to wildlife, a greater part of the traditional heterogeneous landscape and valuable open sites such as pastures, extensive pastures and grasslands were lost or often went through transformation into new ecosystems composed of a mixture of native and foreign species [27]. Nitrophilous species such as *Elymus repens*, *Urtica dioica*, *Geranium pratense* and possibly species that are easy to spread (*Epilobium adenocaulon*) are among the original species growing on nutrient-rich lands. Extensive farming can create space for Archaeophyte *Viola odorata* and/or agriculturally unsuitable species (*Aegopodium podagraria*). Changes in human activity provoke a response in the composition of vegetation.

A dramatic decrease in biodiversity can be observed as a diversity crisis. The impacts of humans on entire ecosystems but also the occurrence of specific species are very conspicuous. Humans and plants have a complex relationship extending far back into our joint evolutionary history. Understanding the co-evolution of humans and vegetation may contribute to the prediction of further development.

5. CONCLUSIONS

The results show that the vegetation of monitored pastures and meadows creates a species-rich plant community. This vegetation can be characterized as a community that is adapted to the disturbance of the herb layer and associated with the removal of most of the biomass. Less frequent disturbance and the removal of a smaller amount of biomass leads to lower species diversity, as was the case in the Ruderal and Extensive habitats. The poorest community was found with clover on arable land. Very frequent disturbance and removal of most of the biomass leads to a decrease in plant species diversity. The results show that species-rich grass communities are formed in monitored meadows and pastures. Pastures belong to the oldest ways of use, so we can assume that some plant species have already fully adapted to the conditions. On the contrary, the intensification or extensification of the use of grasslands causes changes in the species composition and a decrease in the species diversity of plants.

The long-term and stable management of grassland communities by anthropogenic activity led to the creation of species-rich and specific vegetation in the agricultural landscape. Changes in the use of grasslands caused by the needs of our civilization will lead to a decrease in the number of species and a change in the species composition.

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