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Original Research

Changes of Biodiversity and Species Composition of *Molinia* Meadow Depending on Use Method

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Abstract

This paper evaluates the influence of the use of methods of *Molinia* meadows in eastern Poland on changes in its biodiversity and species composition. Research was carried out in 2006-10 on Molinia meadows near Uściwierz lake, located in the Pojezierze Łęczyńsko-Włodawskie (Lake District). The studied complex was classified to [*Selino carvifoliae-Molinietum*] meadows. Meadows were used in a specific method: 1. 1-cut meadow (June), 2. 1-cut meadow (June) + grazing (August), 3. abandoned meadow (since 2000). The above-mentioned methods of use caused the transformation of the typical structure of *Selino-Molinietum* meadow. I observed the initial succession of forest associations with a large share of *Salix rosmarinifolia* and *Betula pubescens* on unused meadow. The highest share of the characteristic species of the *Selino-Molinietum* association was characterized by abandoned meadow.

Keywords: biodiversity, *Molinia* meadow, use method

Introduction

Upon Poland's accession to the European Union, we assumed a number of obligations concerning the protection of the natural environment, including the agricultural environment. One of the rare elements of the agricultural landscape are the floristically rich *Molinia* meadows that belong to the most valuable semi-natural associations in Poland [1-5] and all of Europe [6-13], and play an important role in the preservation of biodiversity. Due to their unique properties, these habitats have been put under protection within the agro-environmental scheme for the 2007-13 period, which provides financial assistance to farmers who use the land in an environmentally-friendly manner. This habitat is important not only for rare plant species but also for conserving meadow-nesting birds [14]. The physiognomic name of that meadow originates from the *Molinia caerulea*, which is not a diagnostic species but frequently dominates over large areas to the exclusion of all other flowering plants [15-18]. *Molinia* meadows require a peculiar type of extensive use with traditional late annual mowing without mineral fertilizers [1-6, 11, 19, 20]. There are also different ideas about how to protect and restore *Molinia* meadows. Some researchers recommend a one-cut system with limited fertilizer application for hay or biomass production [14] or extensive grazing, as an appropriate strategy to provide regeneration of some species [14, 16, 21]. Abandoned *Molinia* meadows undergo succession and are transformed into unvaried associations dominated by tall herbaceous plants with shrubs and trees [1, 4, 5, 10, 17, 22, 23]. Many of them have been abandoned and invaded by *Molinia* [15-18, 24]. Succession of *Molinia* meadows results in a significant decrease of species diversity, which is most dangerous for rare and protected plants [2, 3, 17, 25, 26]. The accumulation of litter is one of the most important mechanisms, changing species composition after abandonment [23, 26]. Changes are caused not only by competitive exclusion of subordinate plant species, but also by their inability to establish from seeds [27]. Characteristic species are often replaced by invaded ones, e.g. *Molinia caerulea*, which has

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Table 1. Quantitative character of studied meadow.

Use method	No. of record	Years	Mean cover (%)			Number of species					
			Mosses	Shrubs and trees	Herbs	Total	Trees and shrubs	ChAll. *Selino-Molinietum*	DAll. *Selino-Molinietum*	ChAll. *Molinio-Arrhenathe retea*	Protected species
M	1	2006	0.5	0.5	99.0	24	1	2	1	6	1
		2008	-	0.5	99.5	30	1	2	1	8	1
		2010	-	1.0	99.0	39	1	1	2	11	0
	2	2006	0.5	-	100	17	0	0	0	4	0
		2008	0.5	-	100	15	0	0	1	6	0
		2010	0.5	0.5	99.0	25	1	0	2	10	0
	3	2006	1.0	1	93.0	21	1	3	1	5	1
		2008	0.5	1	98.5	21	1	3	2	6	0
		2010	0.5	1.5	97.5	25	2	2	2	9	0
	4	2006	1.0	0.5	98.5	31	1	3	3	8	3
		2008	1.0	0.5	98.5	27	1	3	4	8	1
		2010	1.0	1.5	97.5	31	3	3	4	10	0
P	5	2006	0.5	-	84.5	17	0	3	0	5	1
		2008	0.5	-	89.5	17	0	3	0	5	1
		2010	-	-	85.0	16	0	2	0	6	1
A	6	2006	1.0	20.5	78.5	21	3	4	3	1	2
		2008	1.0	32.0	67.5	26	6	4	3	1	2
		2010	1.0	40.0	59.0	27	7	4	3	1	2
	7	2006	1.0	30.0	69.0	20	2	3	3	1	1
		2008	1.0	40.5	58.5	19	3	3	3	0	0
		2010	1.0	54.5	44.5	22	5	2	3	1	0

M – meadow, P – meadow + pasture, A – abandoned meadow

a low relative growth rate but high leaf dry matter content [28]. That species is also very sensitive for grazing [15], which is an appropriate strategy to restore *Molinia*-invaded meadows [14, 16, 21]. Some authors recommend intensive mowing (twice annually) on such degraded meadows [18] or some combinations of treatments in different places, claiming that late-season mowing is not efficient, especially in the initial phase after restoration [29]. Changes in *Molinia* meadows depend not only on land management, but also on fen drainage during the last centuries and intensification of agriculture, as well as climate change [30-32]. Many of these meadows in European countries have been replaced by species-poor meadows or agricultural fields [3, 6, 10, 33]. The aim of this paper was to evaluate the influence of the use of methods of *Molinia* meadows in eastern Poland on changes in biodiversity and species composition.

Materials and Methods

Research was carried out in 2006-10 on *Molinia* meadows in Ostrów Nadrybski, located near Uściwierz – the biggest lake of the Pojezierze Łęczyńsko-Włodawskie (Lake District). According to Kącki and Załuski [1], the studied complex was classified to *Selino carvifoliae-Molinietum* Kuhn 1937 [34] meadows (syn. *Molinietum caeruleae*). The abovementioned association was also observed in other parts of the lake's littoral zone [35-37]. The *Caricetum gracilis* phytocoenosis was also included in the study. Although it is different from the phytosociological perspective, it was decided to analyze this association in view of its location (in the centre of the meadow, in a local depression) and occurrence of *Molinia caerulea* in it. The grassland discussed (51º21'59" N; 23º3'58" E), covering approximately 2 ha, belongs to individual farmers. Since 2006, three use methods have been considered:

M – 1-cut meadow (June)
P – 1-cut meadow (June) + grazing (August)
A – abandoned meadow (since 2000, previously cut sporadically)

As reported by farmers, these meadows have been used for about 16 years in a peculiar method that is inappropriate for *Molinia* meadows [1-6, 10, 11, 19, 20]. No mineral fertilizer has been used in the meadows. The species com-

position was classified using the Braun-Blanquet [38] method, with 7 phytosociological relevés established each year between May and August in an area of 25 m^2 (Tables 1 and 2; Fig. 2). In this study, the Braun-Blanquet method was modified – the cover abundance for all the layers (trees, shrubs, herbs, and mosses), was estimated together to compare objects with trees and shrubs (uncut meadow) and objects without this group of plants. Cover abundance was recorded using the 7-grade scale of Braun-Blanquet. The relevés were entered in TURBOVEG version 2.98 [39]. Four indices (Richness-index, Shannon-index, Eveness-index and Simpson-index) were calculated using that program according to the following formula:

n_i – the abundance of species i

S – the number of species in a relevé (= Richness-index)

p_i – the relative abundance of each species (as a percentage of cover), calculated as the proportion of the total number of species (S)

$$\text{Shannon-index} = -\text{Sum}\,(p_i \times \text{Ln}(p_i));$$
$$\text{Eveness-index} = \text{Shannon-index} / \text{Ln}(S);$$
$$\text{Simpson-index} = -\text{Sum}(p_i^2).$$

To estimate changes in communities caused by different methods of meadow use, the disturbance index [20] was calculated.

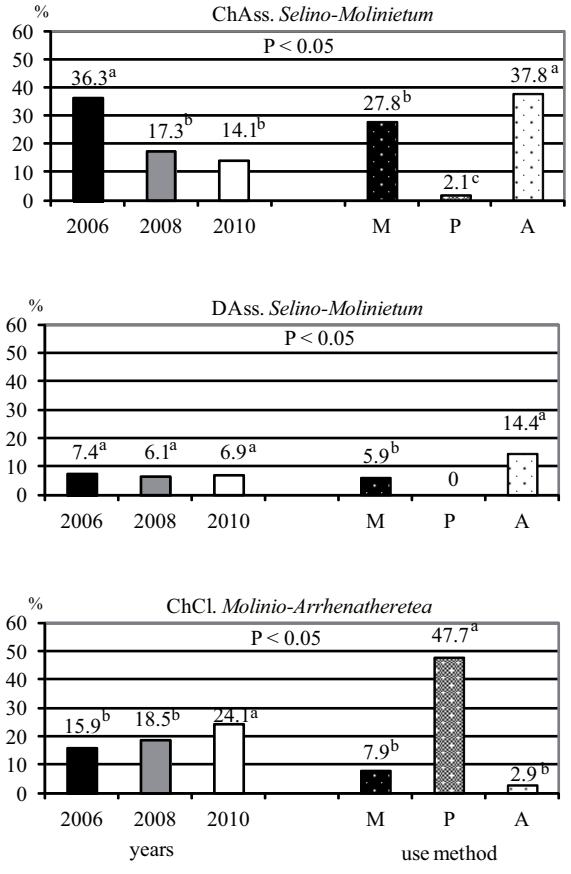

Fig. 1. Share of characteristic and differential species depending on year and use method.
Different letters indicate significant differences; other explanations are as in Table 1.

The abundance of particular species was recorded as the mean cover of cover-abundance scale transformed as follows: r = 0.1%, + = 0.5%, 1 = 1%, 2 = 17.5%, 3 = 37.5%, 4 = 62.5%, 5 = 87.5%. For every object, the following ecological indices were calculated: F – soil moisture value, R – soil acidity value, and N – nitrogen content value [40] to compare them to chemical proprieties of soil. For this purpose, representative soil samples were collected from distinctive plant associations. Chemical proprieties of soils were specified in the laboratory of the Chemical-Agricultural Station in Lublin, accordingly with Polish Norms or researching procedures. Reaction of the soil as well as content of phosphorus, potassium, magnesium and organic matter was estimated. The species composition of the sward also was determined in designated plots (M – meadow, P – meadow + pasture, A – abandoned meadow) by means of botanical-weight analyses with 4 replications (Fig. 1). Samples for the analyses were collected from places featuring herbal vegetation, and did not include trees or shrubs (except *Salix rosmarinifolia*). Achieved results of percentage share of particular groups were put to the ANOVA analysis complemented by the Tukey test ($P<0.05$). Using the pragmaTax program, a cluster analysis (Fig. 2) was carried out for changes in biodiversity, the number of tree and shrub species, the characteristic and differential species of the *Selino-Molinietum caerulea* association, and the characteristic species of the *Molinio-Arrhenatheretea* class in 2006-10.

The names of vascular plants were used according to Mirek et al. [41].

Results and Discussion

The research revealed the influence of the method used on the species composition of *Molinia* meadows. Among species characteristic of the *Selino-Molinietum* associations, *Molinia caerulea* and *Selinum carvifolia* had the largest abundance, whereas *Succisa pratensis*, *Dianthus superbus*, *Gentiana pneumonanthe*, and *Inula salicina* had a considerably smaller one. *M. caerulea* is not only a characteristic species but there are also some meadows invaded by that grass [15-18, 24]. High cover of *Selinum carvifolia* in this association also confirms Balátová-Tuláčková [19]. *Selino-Molinietum* is one of the two *Molinion* associations that have been recorded more widely in Europe [1, 7-9, 11-13]. In the complex under study, the occurrence of differential species was also ascertained (*Salix rosmarinifolia*, *Potentilla erecta*, *Carex flava*, and *Briza media*).

Significant flora changes were observed in 2006-10. In the period analyzed, the number of trees and shrubs as well as species characteristic of the *Molinio-Arrhenatheretea* class and differential of *Selino-Molinietum* association increased while the number of species characteristic of the *Selino-Molinietum* association and protected one decreased (Table 1). Compared to 2006, a fall in the abundance of species characteristic of the *Selino-Molinietum* association was observed. All characteristic species of the *Selino-Molinietum* association decreased abundance in the follow-

Table 2. Phytosociological character of studied meadow.

Use method	M												P			A					
No. of record	1			2			3			4			5			6			7		
Years a (2006), b (2008), c (2010)	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Mosses	+	.	.	+	+	+	1	+	+	1	1	1	+	+	.	1	1	1	1	1	1
Trees and shrubs																					
Betula humilis	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Betula pubescens	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	2	3	2	2	3
Frangula alnus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	+
Populus tremula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	+
Prunus cerasifera	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.
Salix cinerea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	+	1
Salix pentandra	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.
ChAss. *Selino-Molinietum* = ChAll. *Molinion*																					
Dianthus superbus	+	+	.	.	.	.	.	.	.	.	.	.	1	1	+	.	.	.	.	.	.
Gentiana pneumonanthe	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	.	.	.
Inula salicina	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	.	.	.	.	.	.
Molinia caerulea	.	.	.	+	.	.	1	1	1	3	2	1	+	.	.	4	3	2	3	2	2
Selinum carvifolia	+	+	+	+	.	.	1	+	+	2	1	+	.	.	.	2	+	+	1	+	.
Succisa pratensis	.	.	.	.	.	.	+	+	.	1	+	+	1	+	.	1	+	1	+	+	+
DAss. *Selino-Molinietum* = DAll. *Molinion*																					
Briza media	.	.	+	.	+	+	.	.	.	1	1	+	.	.	.	.	.	.	.	.	.
Carex flava	.	.	.	.	.	.	.	.	.	1	1	+	.	.	.	1	1	+	1	1	+
Potentilla erecta	.	.	.	.	.	.	.	+	+	2	1	+	.	.	.	1	1	+	1	+	+
Salix rosmarinifolia	+	+	1	.	.	+	1	1	1	.	+	+	.	.	.	2	2	2	2	2	2
ChO. *Molinietalia caeruleae*																					
Cirsium palustre										r	+	+					r	+		+	+
Deschampsia caespitosa	1	1	2	2	3	3	3	3	3	r	+	1							r	r	+
Equisetum palustre				+																	
Lychnis flos-cuculi				+	+		1	1	+								+	1		+	+
Sanguisorba officinalis	1	1	1	r					+	1	1	1	+	+			+	+	1	1	1
ChCl. *Molinio-Arrhenatheretea*																					
Alopecurus pratensis	.	+	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Avenula pubescens	3	3	2	1	1	1	.	.	.	r	r	+	3	2	2	.	.	.	.	.	.
Centaurea jacea	.	.	.	.	.	.	r	r	+	r	.	.	.	.	.	+	.	.	.	.	.
Cerastium holosteoides	.	.	+	.	.	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.
Euphrasia rostkoviana	.	.	.	.	.	.	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.
Festuca pratensis	.	.	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Festuca rubra	1	1	2	2	2	1	.	+	+	r	+	+	2	2	2	.	.	.	r	.	.
Holcus lanatus	2	2	2	3	2	2	1	2	3	+	1	2	1	1	+	r	+	1	r	+	1
Lathyrus pratensis	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leontodon hispidus	.	.	.	.	.	.	.	.	.	r	+	+	1	+	+	.	.	.	.	.	.

Table 2. Continued.

Use method	M												P			A					
No. of record	1			2			3			4			5			6			7		
Years a (2006) b (2008) c (2010)	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Mosses	+	.	.	+	+	+	1	+	+	1	1	1	+	+	.	1	1	1	1	1	1
Phleum pratense	.	+	1	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plantago lanceolata	r	+	+	.	.	.	r	+	1	+	+	1	.	.	+	.	.	.	.	.	.
Poa pratensis	2	1	1	.	+	+	.	.	+	.	.	+	2	2	2	.	.	.	.	.	.
Ranunculus acris	r	r	.	+	+	+	r	r	+	r	+	+	.	.	.	.	.	.	.	.	.
Rhinanthus angustifolius	.	.	+	.	.	.	.	.	.	.	.	.	+	1	+	.	.	.	.	.	.
Rumex acetosa	+	+	1	1	1	2	.	+	2	.	+	2	.	.	.	.	+	+	.	.	+
Trifolium pratense	.	.	.	.	.	.	r	.	.	r	+	+	.	.	.	.	.	.	.	.	.

Explanations as in Table 1

Other species often occur: *Anthoxanthum odoratum* + (4abc, 6bc), 1 (1bc, 2a), 2 (2bc, 3bc), 3 (3a); *Cardaminopsis arenosa* r (1a, 2a), + (1bc, 2c, 3bc), 1 (3a); *Carex hirta* r (1a, 5a), + (1bc, 5bc), 1 (2abc); *Cirsium rivulare* r (4a, 7a), + (1c, 4b, 6ab, 7bc), 1 (4c, 6c); *Filipendula ulmaria* + (1abc); *Geum rivale* + (2bc, 3b, 6bc, 7c), 1 (1abc, 2a, 3ac); *Lythrum salicaria* + (6c, 7bc), 1 (4abc, 6ab, 7a); *Mentha arvensis* + (6c, 7bc), 1 (4abc, 6ab, 7a); *Phragmites australis* r (3a, 4a, 7a), + (3bc, 4b, 6b), 1 (4c, 6c, 7bc).

Other species rarely occur: *Achillea millefolium* 1 (5abc); *Carex gracilis* + (1abc, 2c); *Comarum palustre* r (6a); *Conyza canadensis* + (5abc); *Dactylis glomerata* + (1c); *Dactylorhiza incarnata* r (3a, 4a); *Dactylorhiza majalis* r (7a), + (4ab, 6bc), 1 (6a); *Equisetum arvense* + (1bc, 2b), 1 (2c); *Galium mollugo* + (1abc, 5abc); *Galium verum* + (1ab, 2c), 1 (1c); *Heracleum sphondylium* + (7a); *Hypericum perforatum* + (5a); *Knautia arvensis* + (1b, 2c), 1 (1c); *Leucanthemum vulgare* r (4a), + (1b), 1 (1ac); *Linaria vulgaris* r (3a), + (3bc); *Luzula campestris* r (7a), + (1c, 2c, 3abc, 4abc); *Lycopus europaeus* + (4abc); *Lysimachia vulgaris* + (1b, 6bc, 7abc), 1 (1c); *Polygonum bistorta* r (3a, 7a), + (6ab, 7b), 1 (6c, 7c); *Potentilla anserina* + (2bc, 3ac), 1 (2a, 3b); *Scutellaria galericulata* + (4c, 6a); *Silene vulgaris* + (1c, 2c, 5b), 1 (5ac); *Taraxacum officinale* r (1a), + (1bc); *Thalictrum lucidum* + (1bc); *Thymus pulegioides* 1 (5abc); *Trifolium dubium* r (1ab, 2a, 4a), + (1c); *Urtica dioica* + (1c, 2a); *Veronica chamaedrys* r (1a, 2a, 4a), + (1c, 5abc); *Vicia hirsuta* + (1abc)

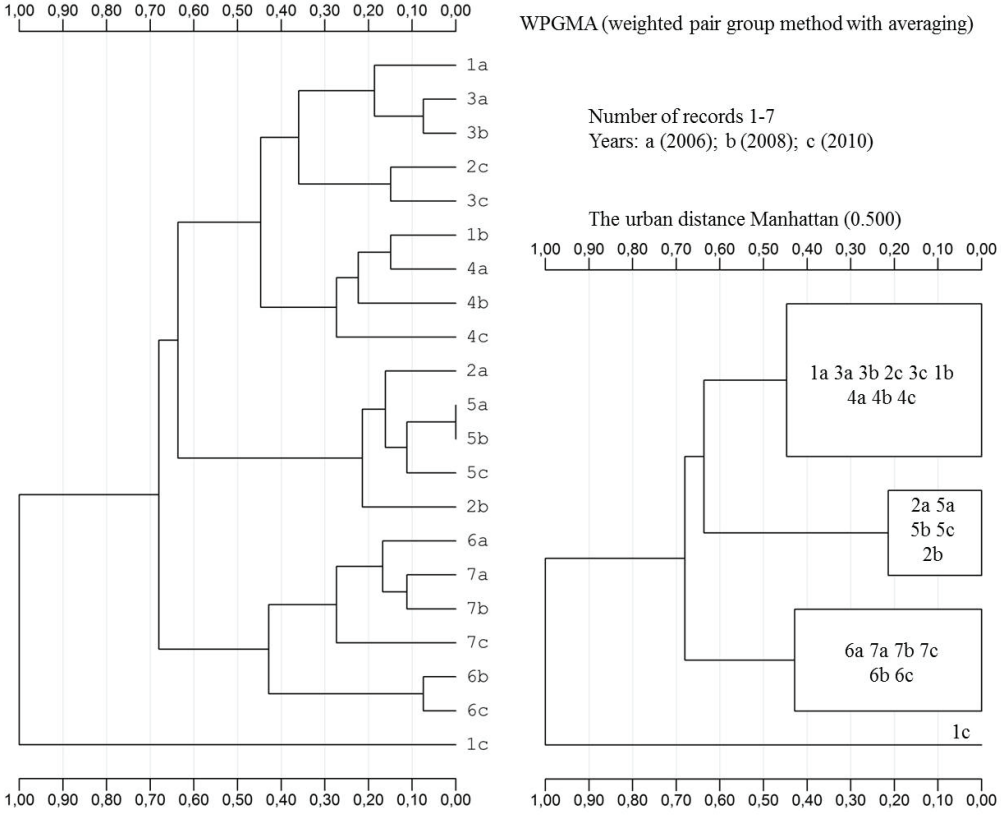

Fig. 2. Cluster analysis of phytosociological records.

Table 3. Mean ecological indicator values according to Ellenberg et al. [25] and chemical properties of soil in 2006.

Objects	Ecological indicator			Chemical properties				
	F	R	N	pH	OM	P	K	Mg
				1n KCl	%	mg·100·g^{-1}		
1	5.78	6.92	3.81	6.96	22.27	85.8	13.5	29.5
2	6.34	6.09	3.96	-	-	-	-	-
3	6.66	5.77	3.52	5.34	75.92	15.2	17.5	31.5
4	7.17	5.99	3.03					
5	5.23	7.04	3.83	7.46	14.43	16.2	5.0	6.4
6	7.63	5.36	2.42	5.04	74.64	10.7	16.5	51.5
7	7.95	4.92	2.60					

F – soil moisture value, R – soil acidity value, N – nitrogen content value, OM – organic matter content

ing study years while some of them (*Dianthus superbus*, *Succisa pratensis*, and *Selinum carvifolia*) were not observed in 2010 in some researching objects (Table 2). Many such complexes have been abandoned and invaded by *Molinia caerulea* [15-18, 24], while the tested meadows were characterized by the dominance of that species but with a smaller abundance. Fall in the abundance of *M. caerulea* was observed (Table 2), also in meadow that was additionally used for grazing. That grass is very sensitive for grazing and early cutting, and most studies confirm the decrease of *M. caerulea* cover after such treatments [15, 17]. On the other hand, an increased abundance was observed for species characteristic of the *Molinio-Arrhenatheretea* class, particularly *Holcus lanatus* and *Deschampsia caespitosa* of the *Molinietalia caerulea* order. The above-mentioned inappropriate methods of use caused the transformation of the typical structure of *Selino-Molinietum* meadow. In the meadow that was cut in June, numerous species of the *Molinio-Arrhenatheretea* class and *Molinietalia caerulea* order were observed. The cut meadow that was additionally used for grazing exhibited a lower share of characteristic species of the *Selino-Molinietum* association and a larger share of species of the *Molinio-Arrhenatheretea* class. Due to extensive alterations to the water regime and intensification of agriculture, many of these meadows in European countries have been replaced by species-poor meadows or agricultural fields [3, 6, 10, 33]. The number of tree and shrub species and their abundance increased only in the unused meadow. When no cutting was carried out, the initial succession of forest associations, with a large share of *Salix rosmarinifolia* and *Betula pubescens*, was observed (Table 1). After cutting is discontinued, *Molinia* meadows undergo succession and are transformed into unvaried associations dominated by willow and alder thickets [1, 4, 5, 10, 17, 22, 23]. Some subassociation of *Molinia* meadows can be transformed into herb communities (*Filipendulion*), scrubs (*Salicetum pentandro-cinerea*), riparian (*Fraxino-Alnetum*), or oak-hornbeam-spruce forests (*Tilio-Carpinetum*) [3]. Furthermore, the absence of mowing causes the aggravation of habitat conditions and reduction of biodiversity [42]. The results of the study did not confirm a decrease in biodiversity because 10 years had passed since the meadow ceased to be used and it was an initial stage of succession, while an increase in the number of species was mainly linked with the appearing tree species. Sienkiewicz-Paderewska et al. [4] also confirm the presented tendency. Interestingly, in 2010 one of the abandoned meadows was characterized by the highest share of the characteristic species (4 pcs) of the *Selino-Molinietum* association. The inappropriate use of *Molinia* meadows poses a greater risk than no use at all. Alarming is the number of protected species in meadow swards that have decreased in study years. In 2006 the occurrence of 5 protected species was found, but in 2010 their number fell to 3. In 2008 and 2010 *Betula humilis* and *Dactylorhiza incarnata* were not observed in the meadow sward. The abundance of other protected species (*Dactylorhiza majalis*, *Dianthus superbus*, and *Gentiana pneumonanthe*) was considerably lower (Table 2). The smallest disturbances in phytocenosis were observed in the abandoned meadow (A) and additionally grazing (P), where the same number of protected species were noted in following years (Table 1).

A botanical-weight analysis also showed a significantly higher share of the *Molinio-Arrhenatheretea* class species and a significantly lower share of the *Selino-Molinietum* association species in 2010 as compared with 2006 (Fig. 1). Irrespective of the study year, the *Selino-Molinietum* species had the significantly highest share in the unused meadow (37.8%), while the *Molinio-Arrhenatheretea* species was in the meadow that was additionally grazed (47.7%). The abandoned meadow was characterized by the significantly highest share of characteristic and differential species of *Molinia* meadow (Fig. 1). Interestingly, that meadow that was additionally used for grazing (P) was characterized by the significantly lower share of species characteristic of the *Selino-Molinietum* association (Fig. 1), while the number of that species was similar to the other researching objects (Table 1). That was the driest part of the meadow, which was confirmed by soil moisture values

Table 4. Mean values of biodiversity indices and the Disturbance Index for study years.

Use method	No. of record	Years	Indexes and trends									
			Richness		Shannon		Eveness		Simpson		Disturbance	
M	1	2006	24	↓	2.40	↓	0.75	↓	0.83	↓	2.30	↷
		2008	30		2.74		0.80		0.86		1.50	
		2010	39		3.37		0.92		0.95		2.68	
	2	2006	17	↷	2.09	↷	0.74	↓	0.79	↓	1.34	↷
		2008	15		2.08		0.77		0.81		1.42	
		2010	25		2.58		0.80		0.86		1.38	
	3	2006	21	↓	2.03	↓	0.67	↓	0.77	↓	2.77	↑
		2008	21		2.32		0.76		0.82		2.20	
		2010	25		2.43		0.76		0.85		2.17	
	4	2006	31	↷	2.61	↓	0.76	↷	0.85	↓	4.87	↑
		2008	27		3.12		0.95		0.94		4.27	
		2010	31		3.19		0.93		0.94		2.35	
P	5	2006	17	↑	2.19	↷	0.77	↷	0.81	↷	2.02	↑
		2008	17		2.49		0.88		0.89		1.92	
		2010	16		2.40		0.87		0.88		1.83	
A	6	2006	21	↓	1.79	↓	0.64	↓	0.68	↓	4.24	↓
		2008	26		2.58		0.79		0.87		4.38	
		2010	27		2.70		0.82		0.87		18.13	
	7	2006	20	↷	2.18	↓	0.73	↓	0.80	↓	9.87	↓
		2008	19		2.56		0.87		0.89		16.13	
		2010	22		2.75		0.90		0.91		23.05	

Straight arrows indicate unidirectional tendency, wavy one – fluctuating
Explanations like in Table 1.

according to Ellenberg et al. [40]. Drier vegetation grasslands that are subject to higher grazing pressure have undergone a greater degree of change than wetter mire vegetation, which appears to be more resistant to change [43]. These meadows constitute impermanent secondary communities whose dynamics and flora diversity primarily depend on the use method and habitat they occupy. A greater frequency of cutting, land drainage, and fertilizing leads to the transformation of *Molinia* meadows into communities with a lower flora diversity, while inadequate use results in communities with *Deschampsia caespitosa* [1, 5, 10].

A cluster analysis at the distance level of $\alpha = 0.5$ (alpha-scale) produced 3 groups of relevés. The most distinctive group was constituted by records taken in the abandoned meadow in every year of the study (Fig. 2). This indicates the smallest changes in the number of a group's species (tree and shrub, Ch.Ass. and D.Ass. *Selino-Molinietum* as well as Ch.Cl. *Molinio-Arrhenatheretea*) taken into account in the particular years of the studies. Also, records 3 and 4 (I group) as well as 5 belonged to the same groups. Records 1 and 2 were found to be the most distant study areas, especially record 1c (2010), which was not classified in any group. These were the driest parts of the cut meadow, where the greatest changes in the species composition were observed. Changes in meadows depend not only on land management, but also on meteorological conditions as well as edaphic and moisture conditions of the habitats [44].

Biodiversity increased considerably in the study period, which resulted from the emergence of species, primarily belonging to the *Molinio-Arrhenatheretea* class (meadow and meadow + grazing), as well as tree and shrub species (abandoned meadow). All calculated indices (Richness-index, Shannon-index, Eveness-index, and Simpson-index) characterized by a systematic increase in study years (Table 4). The exception was a slightly reduced Richness-index and small fluctuations of other indices, especially in the meadow that was additionally used for grazing. In general, 77 plant species were found to occur in the area under study. The number of these species is very low in comparison with the typical, non-degraded *Molinia* meadows that are usually characterized by high biodiversity [2].

Alongside the use type, changes in habitat humidity, which have a significant impact on vegetation abundance, may account for the low biodiversity and small number of characteristic species [44]. The smallest disturbances in the community were observed in the unused meadow where the greatest number of characteristic *Selino-Molinietum* species occurred. Undisturbed systems are a sanctuary for many rare and dying plant and animal species. The inadequate use of *Molinia* meadows poses a greater risk than no use at all. An unused meadow can be cleared and restored to its previous extensive use. This trend is not confirmed by the Disturbance Index calculated for all relevés made during the study years. Objects where the greatest changes in the species were observed showed the lowest values – closest to the value of 1. It should be added that the values of this index for these objects were decreasing during the study years. This resulted from the increasing share of species of the *Molinio-Arrhenatheretea* class. The unused meadow, on the other hand, was characterized by the highest values of this index, with a growing trend, during the study years. This means that species other than those mentioned above, i.e. trees and shrubs, have a stronger impact on the increase of this index. In Kącki and Michalska-Hejduk [2] studies, all of the indices analyzed were negatively correlated with the Disturbance Index. In the present studies, only the wet part of the meadow (3 and 4 records) was characterized by that tendency (Table 4).

The chemical properties of the soil in the particular sections of the meadow varied, which also influenced the growth and development of the vegetation. The reaction of soil in the complex under study ranged from slightly acidic – 5.04 (A) to slightly alkaline – 7.46 (P). Moreover, slightly alkaline soil was characterized by the low content of organic matter 14.43 (P) – 22.27 (M). In this part of the meadow, advanced process of the organic matter mineralization is also connected with lower ground water level and less humidity. Habitat factors, especially ground water level significantly influenced the formation of vegetation [44-47]. However, soil of the other part of the cutting meadow as well as abandoned meadow was characterized by the higher content of organic matter (74.64-75.92). It is connected with a better humidification that stops the moorsh forming process in organic soils [45]. The reaction of soil is similar to adequate ecological indicators according to Ellenberg et al. [40]. soil acidity value (R) ranged from 4.92 to 7.04, indicating that the soil is moderately acidic to neutral, while nitrogen content value (N) ranged from 2.42 to 3.96, indicating that soil is mineral-humic to rich in organic matter (Table 3). Furthermore, the soil in the complex under study exhibited a low or medium content of the basic macroelements, with the exception of the drier part of the cutting meadow, where high phosphorus content was observed. Very important is soil moisture value (F), ranging from 5.23 to 7.95 (relevés 5<1<2<3<4<6<7). This indicates that soil under cutting meadow was varied from fresh to moist while the abandoned one was characterized by very moist soil (7.63-7.95) [40]. Periodically higher humidity of the habitat was one of the reasons why farmers stopped cutting this part of the meadow.

Conclusions

1. Significant flora changes were observed in 2006-10: the number of trees and shrubs as well as species characteristic of the *Molinio-Arrhenatheretea* class and differential of *Selino-Molinietum* association increased, while the number of species characteristic of the *Selino-Molinietum* association and protected one decreased. All above-mentioned inappropriate methods of use (early 1-cut meadow, early 1-cut meadow with grazing, and abandonment) caused the transformation of the typical structure of *Selino-Molinietum* meadows.
2. The number of tree and shrub species and their abundance increased only in the unused meadow. The initial succession of forest associations, with a large share of *Salix rosmarinifolia* and *Betula pubescens*, was observed, but abandoned meadow characterized by the highest share of the characteristic species of the *Selino-Molinietum* association. A cluster analysis also indicates the smallest changes in that meadow with a number of group's species taken into account. Intensive use of *Molinia* meadows poses a greater risk than no use at all.
3. An early cut meadow as well as meadow that was additionally used for grazing exhibited a smaller share of characteristics and differential species of the *Selino-Molinietum* association and a larger share of species of the *Molinio-Arrhenatheretea* class.
4. Biodiversity increased considerably in the study period, which resulted from the emergence of species, primarily belonging to the *Molinio-Arrhenatheretea* class (meadow and meadow + grazing) as well as tree and shrub species (abandoned meadow). All calculated indices Richness-index, Shannon-index, Evenness-index, and Simpson-index were characterized by a systematic increase in study years.
5. Efforts are being made to include this meadow in an agri-environmental scheme in order to restore its proper structure. The problem lies with the absence of biological indicator species required by the methodology for preparing environmental documentation, except for the unused meadow, which met these requirements in 2006. Proper use of these meadows in the future, particularly concerning the optimum time of cutting without grazing, will require further research.

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