Original Research

Grassland Ecosystems in the Varied Hydrological and Ecological Conditions of the Kulawa River Valley

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Abstract

Grasslands in the Kulawa river valley (ca. 10 ha) were subject to land improvement in the 19th century, and remnants of the hydrotechnical system and overgrown ditches are still present. This study aims to:
(1) evaluate the present meadow ecosystems;
(2) predict their changes under the influence of the planned restoration of the hydrotechnical system and
(3) compare results of various methods: phytoindication, phytosociological, floristic, and principal component analysis.

The applied methods complemented one another. The devastation of the hydrotechnical system and the lack of utilization of the grasslands have led to either drying or waterlogging of the soil, and to changes in vegetation. The plant communities that have developed there represent the intermediate stage of regressive succession, and belong to the orders *Arrhenatheretalia, Molinietalia*, and the class *Phragmitetea*. Particularly the patches growing on relatively dry, strongly decomposed peaty soil have lost the characteristics of damp meadows. Meadow species have declined there, and nitrophilous species have replaced them. Only a local depression without outflow, which was earlier drained, is now waterlogged again, with a mosaic of calcareous fen, meadow, and marsh vegetation, including large populations of 11 species that are rare, protected, or listed as indicator species for the Natura 2000 habitat 7210*. Results of this study indicate that the present conditions in the waterlogged depression should be preserved. In contrast, the dry patches should be irrigated and subject to extensive farming.

Keywords: biodiversity, Natura 2000, meadow protection, drainage

Introduction

The first records of meadows near the village of Laska are found in its endowment document, dating back from the year 1400 [1]. Gradual development of settlements resulted in forest clearance and farming in open habitats, mostly along rivers, where water retention was enhanced by the construction of, e.g., ponds. Regulation of water conditions in river valleys enabled the elimination of periods of water excess (unfavourable for farmland) separated by periods of water deficits [2]. This disturbed natural hydrological processes and often, due to excessive drainage, negatively

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affected biodiversity [3]. Currently it is believed that regulation of water conditions should serve both productive and ecological purposes [4]. However, the ecological role is certainly of primary importance in the case of river valleys located within protected areas, which (e.g., the Kulawa river valley) are characterized by habitat diversity and richness in both flora and fauna [5].

The Kulawa river valley, because of its high conservation value, has long been studied by botanists, e.g. by Lucas [6], Lisowski et al. [7, 8], Boiński [9], Prajs and Antkowiak [10]. In the Przymuszewo Forest District in 2006, a plan was formulated to restore the local system of water retention thanks to support from the Polish EcoFund (Ekofundusz). In relation to this, it has become necessary to evaluate the vegetation of the ecosystems associated with the river valley. During field research, special attention was paid to, e.g., the meadows where the reconstruction was planned [5]. An analysis of their current state forms the basis both for the decision whether it is advisable to reconstruct the historical water conditions, and for monitoring the effects of these protective measures.

Objectives of this study were:

(1) to record and identify meadow communities in the Kulawa river valley;

(2) to predict their dynamics after restoration of optimum water conditions in those habitats and return to grassland management; and

(3) to compare the usefulness of various research methods for assessment of the condition of the studied ecosystems.

Material and Methods

Study Area

The Kulawa river valley (Fig. 1) is situated in the western part of protected areas: Special Protection Area PLB220001 'Wielki Sandr Brdy,' and the Zaborski Landscape Park. The Kulawa, which is about 7.5 km long, runs along the bottom of a meridional postglacial valley, and feeds the Zbrzyca river near the village of Laska. The river valley cuts the outwash plain to a depth of 25-30 m, and is up to ca. 300 m wide. The broader sections of the river form three throughflow lakes: Głuche Duże, Głuche Małe, and Sieczonek. The valley section where the studied grasslands are located is highly varied morphologically, lithologically, and hydrologically (Fig. 1). The numerous depressions and kettle holes are separated by rock steps and surrounded by steep slopes and terraces [11]. The valley, in the bottom of a former lake, is composed of accumulated glacial sediments, covered with a layer of carbonate-rich lake marl (chalk) [12]. The soils, mostly post-lake rendzinas [13], are modified depending on land relief and water conditions. Local depressions, characterized by a high moisture level or even permanently flooded by carbonate-rich water flowing down the slopes, are filled with accumulated biogenic sediments of various depths. On the plains along the river, peaty soils and mud-peaty soils have developed. Elevations, terraces and ledges are usually covered by clay soils and sandy soils. In many places, chalk deposits have been exposed due to erosion.

Hydrological conditions in the habitats located within the valley are shaped mostly by waters of the river and lakes, water seepage from dissected aquifers, precipitation level, and soil type. The landscape is dominated by non-forest ecosystems, e.g. old fields, mires, and meadows. On maps from the late 19th century, several irregular ditches are marked in the area of the meadows. Probably already before that time, below Lake Głuche Małe, some hydrotechnical structures were built: a weir raising the water level, an irrigation canal, ditches with sluices, and a culvert under a road. They served to optimize the water conditions, mainly to irrigate or, to a lesser extent, to drain the area, where the river itself plays a draining role, and both the sloping valley and gyttja in the substrate do not support water retention in the soil.

Research Plots

Field research was conducted in 3 grasslands. Grasslands A and B are located in flat parts of the bottom of the valley, elevated about 3 m above the river water level (Fig. 1). Even in periods of high water level in spring, they are not flooded by the river. They are flooded by precipitation and surface runoff from the steep slopes, directed

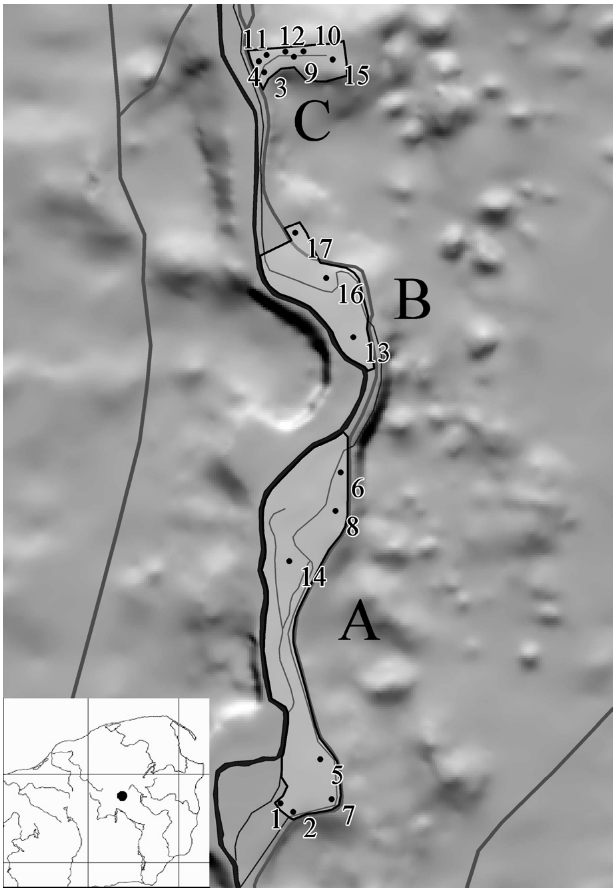

Fig. 1. Localization of study area: A, B, C – grasslands in the Kulawa river valley; ● research plots.

towards the river bed, so they can be classified as soligenous mires with area water supply, where water flow is perched by hardly permeable deposits of gyttja [14].

Grassland A covers 8.32 ha, with a gentle slope (0.3-4º) directed towards the river bed. The grassland is characterized by varied soil conditions. Peaty and muck soils are located near the river, while in the more elevated fragments, sandy and loamy soils are found.

Grassland B covers 3.18 ha, and is characterized by varying slope angle (0.2-6°) directed towards the river bed. The grassland (Fig. 1) developed on peaty soils, which are now subject to decomposition. In spring this meadow is distinguished by a high groundwater level, dependent on precipitation and the water level in the river. During the growing season, the water level declines markedly, which causes, e.g., drying of the soil and intensification of peat decomposition.

Grassland C is located in a wet local depression, covering 0.84 ha, far away from the river (Fig. 1). The centre of the depression was dissected by a drainage ditch, linked by means of a culvert with a system of ditches located between the road and the river (Fig. 1). The blocked culvert has caused stagnation of the water, which resulted in permanent waterlogging of the central part, lined with gyttja covered with a peat layer (ca. 30 cm thick).

Methods

Field research lasted from early spring till autumn 2006. It was necessary to make a comprehensive assessment of the condition of sites and vegetation in a relatively short time, so various methods of research were used. In individual patches of meadows, phytosociological relevés were made according to the classic Braun-Blanquet method, to document the protected plant communities.

Because of the lack of information on environmental conditions in the past and the strong transformation of meadow communities, particular attention was paid to the participation of indicator plants, according to the phytoindication method for site moisture assessment developed by Oświt [15], as well as to soil type and structure. In one of the depressions a sampling well was drilled, and basic hydrochemical parameters of the water were analyzed.

To present the condition of the best-preserved meadow communities, in the phytosociological table we compiled 12 relevés out of 17 relevés of 50 m^2 each. Floristic diversity of individual plots was compared, taking into account the phytosociological classification of species (i.e. socioecological groups). Species diversity of the plant communities (Fig. 3), determined quantitatively and qualitatively with respect to species number on plots and mean moisture numbers, was subject to principal component analysis (PCA, using Statistica 8 package). For this purpose, total cover-abundance of species in relevés (according to the Braun-Blanquet scale) was log-transformed [16]. In the diagram, degraded or partly-developed communities were also taken into account, although they were omitted in the phytosociological table. Laboratory work included site analysis with the use of a model of the terrain, prepared on the basis of topographic map 1: 10,000, in the TNTmips software module. The plant names used here follow Mirek et al. [17], while names of plant communities follow Matuszkiewicz [18].

Results

The three grassland areas in the Kulawa valley differ in site conditions (mostly in moisture content and soil type) as well as vegetation. Only small areas are covered by patch-

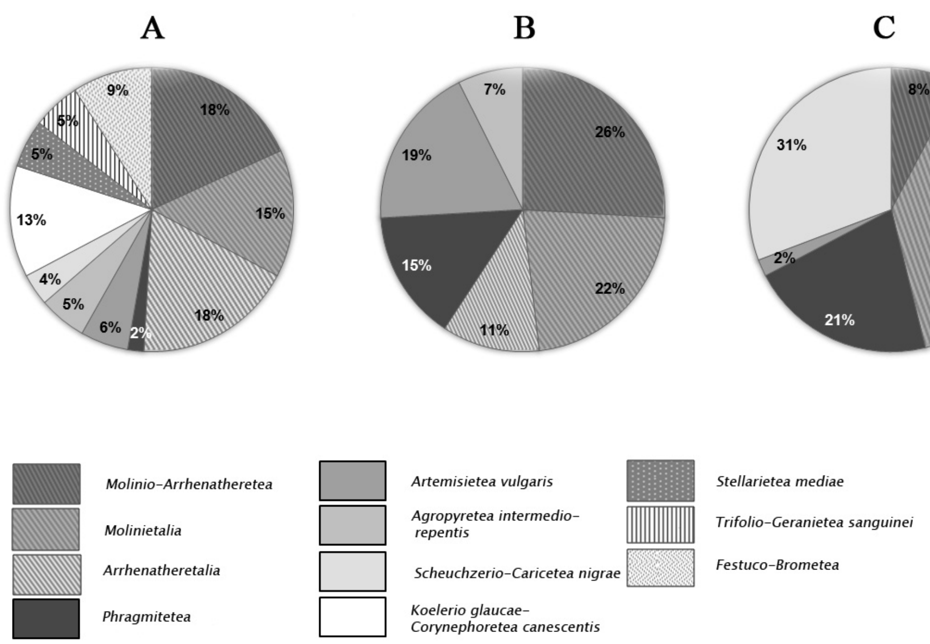

Fig. 2. Contributions of species of various socioecological groups in studied grasslands A, B, C.

Table 1. The meadow plant communities of the Kulawa River valley.

1	2	3	4	5	6	7	8	9	10	11	12	13
Successive No. of relevé	1	2	3	4	5	6	7	8	9	10	11	12
Relevé No.	3	4	1	2	9	10	11	12	6	5	7	8
No. plots (Fig. 1)	3	3	1	1	3	3	3	3	1	1	1	1
Type of soil	peat	peat	peat	peat	peat	peat	peat	peat	min.	min.	min.	min.
Date [06. 2006]	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Plat cover [%]	100	100	100	80	100	100	100	80	80	80	90	100
Area of relevé [m^2]	50	50	50	50	50	50	50	50	50	50	50	50
Number of species	28	27	21	22	26	20	14	9	14	9	15	16
Ch. O. *Molinietalia caerulae*												
Crepis paludosa	1	1	+	+	1	+						
Myosotis palustris	+	+	1	+	+		1					
Dactylorhiza majalis	+	+			1	1	+	+				
Lotus uliginosus	+	+			+	1	1	+				
Galium uliginosum	+	1		+	1	+						
Cirsium palustre	+	+			+		+	+				
Cirsium oleraceum	3	2	2	1								
Polygonum bistorta	1	1	1	+								
Lychnis flos-cuculi	+	1	+	+			+					
Filipendula ulmaria	1	1		+			1					
Ophioglossum vulgatum	1	+			+		1					
Epilobium palustre		+		+			+	1				
Molinia caerulea							4	3				
Deschampsia caespitosa							+	1				
Ch. O. *Arrhenatheretalia elatioris*												
Achillea millefolium									+	+	+	+
Arrhenatherum elatius									3	3		
Dactylis glomerata									1	2		
Leucanthemum vulgare									1	1		
Campanula patula									1	+		
Daucus carota									+	1		
Heracleum sibiricum									+	+		
Ch. Cl. *Molinio-Arrhenatheretea*												
Holcus lanatus	+	1	1	1	+	1						
Festuca rubra	+		+	1					2	1		
Poa pratensis			+	+	1				1	1		
Poa trivialis	1	+	3	1								
Festuca pratensis	+		1	1			+					
Plantago lanceolata	+	+	1	+								
Phleum pratense		1	1	+								
Rumex acetosa	+	1	+									
Ranunculus acris	+	+	+			+						
Festuca ovina											1	1
Taraxacum officinalis	+	+										

Table 1. Continued.

1	2	3	4	5	6	7	8	9	10	11	12	13
Ch. Cl. *Scheuchzerio-Caricetea nigrae*												
Carex nigra	2	2	1	1	2	2	+	+				
Viola palustris	+	+	+		1	+						
Valeriana dioica					4	4						
Carex flava					3	1						
Hydrocotyle vulgaris					1	2						
Epipactis palustris	1				1	1						
Agrostis canina					1	1						
Comarum palustre					1	+						
Carex limosa					+	+						
Carex dioica					+	+						
Ch. Cl. *Koelerio glaucae-Corynephoretea canescentis*												
Hieracium pilosella											4	3
Rumex acetosella											1	2
Viola tricolor											1	1
Helichrysum arenarium											1	1
Sedum acre											+	2
Teesdalea nudicaulis											+	+
Others												
Geum rivale	1	1	+	+	+	+						
Briza media		1	+	+			1	1				
Anthoxanthum odoratum	+	+	+	1		+						
Veronica chamaedrys	+	+	+	+								
Urtica dioica	+	1						+				
Carex vesicaria	1	+										
Equisetum fluviatile					+	1						
Equisetum arvense			1	+								
Geranium pusillum											+	1
Echium vulgare									+		1	
Hypericum perforatum									+		+	
Linaria vulgaris									+			+
Galium verum											+	+

Sporadic species:
Ch.O. *Molinietalia caerulae: Dactylorhiza incarnata* 3(1); *Valeriana officinalis* 11;
Ch.O. *Arrhenatheretalia elatioris*: *Geranium pretense* 6;
Ch.Cl. *Scheuchzerio-Caricetea nigrae*: *Eriophorum angustifolium* 9(1); *Carex canescens* 9; *Triglochin palustre* 9; *Ranunculus flammula* 10; *Stellaria palustris* 9;
Ch.Cl. *Koelerio glaucae-Corynephoretea canescentis: Sedum sexangulare* 7(1); *Cerastium semidecandrum* 8; *Festuco-Brometea: Ranunculus bulbosus* 8; *Pimpinella saxifraga* 7; *Verbascum lychnitis* 8;
Others: *Carex panicea* 6; *Carex gracilis* 9; *Calamagrostis epigeios* 7; *Arabidopsis thaliana* 8(1); *Anchusa arvensis* 8; *Carex hirta* 2.

es of plant communities that can be unambiguously classified phytosociologically (Table 1).

On grassland A (Fig. 1), diverse microhabitats have been formed, which have been colonized by plant communities that vary greatly in soil and moisture requirements. At the southern and southwestern edges of the area, (which are lower), mud-peaty soils have developed and are covered by patches of *Angelico-Cirsietum oleracei* (=*Cirsio-Polygonetum*) (Table 1, rel. 1, 2). The vegetation of mineral-rich islands and elevations along the road is dominated by communities of strongly degraded fresh meadows (order *Arrhenateretalia*), usually species-poor phytocoenoses of *Poo-Festucetum rubrae*, which are a stage of degeneration of *Arrhenatheretum elatioris*. Species-poor patches of *Arrhenatheretum elatioris*, and patches dominated by *Arrhenatherum elatius* are relatively rare. Many of the species recorded there are characteristic of sandy grassland (class *Koelerio-Corynephoretea*), e.g. *Hieracium pilosella, Rumex acetosella* and *Viola tricolor*. The last species often forms clumps with *Geranium pusillum, Cardaminopsis arenosa*, and *Calamagrostis epigeios*.

Neglected irrigation ditches are located in the central part and along the road. They are covered by a dense growth of *Caricetum vesicariae*. In the spaces between ditches, where the process of peat decomposition is easily noticeable, expansion of *Agropyron repens* and other nitrophilous species can be observed.

The floristic analysis of this grassland reflects the substantial transformation of vegetation on both mineral and peaty soils. Out of the 65 vascular plant species recorded, 28 are assigned to various units within the class *Molinio-Arrhenatheretea* (Fig. 2). The former character of this site, i.e. damp meadow, is now evidenced by single stands of, e.g., *Dactylorhiza majalis*, situated in local depressions, while the severe drying of the more elevated areas is reflected in the large contribution of plants characteristic of sandy grassland, including *Elymus arenarius*, as well as xerothermic calcicoles, e.g. *Carex praecox* and *Verbascum lychnitis.*

The applied phytoindication method [15] enabled us to distinguish the following site types:

- dry and dry but periodically moistened: 32 species with moisture numbers 2-5, but mostly with numbers 4-5;
- very moist and wet: 16 species with moisture numbers 6-10, but mostly with number 8.

Grassland B (Fig. 1) is covered by transitional, partly developed phytocoenoses, which because of the lack of characteristic species or of a characteristic combination of species, can mostly be assigned only to the higher phytosociological units.

Near the river and the ditch, *Phalaris arundinacea* dominates, with large contributions of *Agropyron repens, Holcus lanatus*, and *Urtica dioica*. The more moist local depressions and ditches are covered by patches of *Caricetum gracilis* and *Caricetum vesicariae,* with admixture of species characteristic of damp meadows, e.g., *Cirsium oleraceum, Lysimachia vulgaris* and *Deschampsia caespitosa* (order *Molinietalia*). In the remaining area, grassland communities are found, composed of, e.g., *Dactylis glomerata, Poa pratensis, Alopecurus pratenis, Festuca pratensis*, and species of the classes *Artemisietea* and *Agropyretea*. In respect of phytosociological affiliation, out of the 27 plant species recorded, 16 belong to the class *Molinio-Arrhenatheretea*. The high degree of transformation of the flora of this study is evidenced by the lack of typical meadow communities and the conspicuous presence of plants of the class *Artemisietea vulgaris* (Fig. 2). Considering the moisture requirements of plants, the moisture numbers of species recorded there range from 5 to 10, with high proportions of taxa with numbers 5 and 7. This classifies sites of this area as fresh meadows or moist meadows drying periodically [15].

Based on the current species composition, we predict that if irrigation and proper management (i.e. extensive farming) are applied in grasslands A and B, the dynamics of vegetation will depend on soil type. On peat, patches of *Angelico-Cirsietum oleracei* will develop, while on mineral soils, *Arrhenatheretum elatioris* (Fig. 4).

On grassland C, a mosaic of plant communities has developed: peatland, meadow, and marsh vegetation of the alliance *Magnocaricion*. The elevated edges of the depression, mostly on its western and northern sides, small patches of various communities are found: *Caricetum paniculatae, Molinietum caerulae,* and fragments of *Angelico-Cirsietum oleracei,* with a high contribution of *Ophioglossum vulgatum* and orchids: *Dactylorhiza majalis, D. incarnata,* and *Epipactis palustris*. In the wet, central part of this moss-rich site, a patch of *Cladietum marisci* is located. This is a calciphilous community dominated by the great fen-sedge. It is surrounded by a mossy meadow, whose greatest part is covered by the community *Valeriana dioica - Carex flava*.

On grassland C, within the depression, rare peatland species are found, e.g. *Eriophorum latifolium* and *Carex*

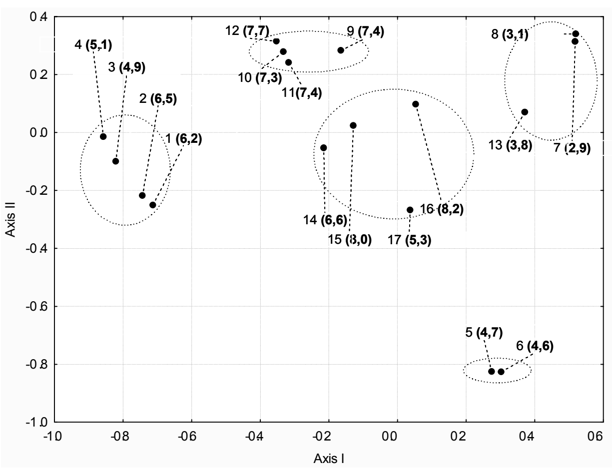

Fig. 3. Distribution of plots along the first two principal component axes (i.e. species number on the plot and total cover-abundance). Labels include plot number and (in brackets) arithmetic mean of moisture numbers of species on the plot.

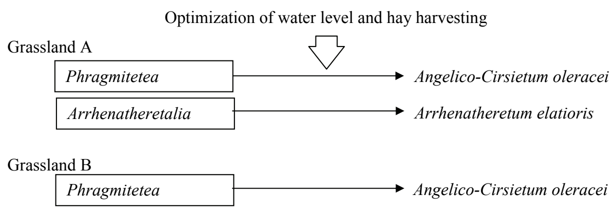

Fig. 4. Anticipated trends of meadows vegetation in the Kulawa river valley.

limosa, but also *C. davalliana, C. lepidocarpa, C. diandra, C. panicea, Triglochin palustre*, as well as a relict moss species, *Paludella squarrosa*. This site is dominated by plant species with moisture numbers 8 and 9. These include many taxa of the phytosociological class *Scheuzcherio-Caricetea nigrae,* which is composed of communities of intermediate mires (Fig. 2). The chemical analysis of water collected there showed that it is strongly alkaline: 4.30 mEq/l and pH 7.70. Also nutrient levels are low there: phosphates 0.27 mg/l, nitrate nitrogen 0.03 mg/l, and ammonium nitrogen 0.29 mg/l.

The plant communities developed as a result of intensive saturation of the soil with the water flowing down the slopes can be regarded as some of the most valuable elements of the vegetation in the Kulawa valley. They included 11 plant species protected by law, or classified as rare and endangered, and most of them are indicator species for ecosystems included in the Habitat Directive (calcareous fens, site code 7210*).

The distribution of plots along the first two principal component axes shows variation in vegetation in relation to environmental factors: soil type (mineral vs. organic) and its moisture content (Fig. 3). Five groups of communities can be distinguished on the diagram. On its right-hand side, plots with mineral soils (sandy or loamy) are found. They are covered by communities of fresh meadows of the order *Arrhenatheretalia* (plots 5 and 6) and communities of the class *Koelerio glaucae-Corynephoretea canescentis* (plots 8 and 7). The impoverished community on plot 13 seems to be closely related to *Koelerio glaucae-Corynephoretea canescentis*. Peaty plots are aggregated in the left part of the diagram and its upper central part. Two groups can be clearly distinguished there: 4 patches of *Angelico-Cirsietum oleracei* (1, 2, 3, 4) and 4 plots with patches of *Molinietum caerulae* (11, 12) and with *Valeriana dioica-Carex flava* (9, 10). The location of plot 9 on the diagram is probably due to the influence of yet another factor (or factors), e.g. to $CaCO_3$ content of the soil. Vegetation on dry peat and on partly decomposed peat is represented by plots 14 17. The somewhat separate location of plot 17 reflects the presence of nitrophilous plants (e.g. *Urtica dioica, Cirsium arvense,* and *Antriscus sylvestris*), which are expansive on degraded peaty soils.

Discussion and Conclusions

Meadow ecosystems in northern Europe, especially meadows in river valleys, which were earlier colonized by people, have been shaped by many ages of human economics. At present, all over Europe they tend to disappear, which is one of the major threats to biodiversity, at the level of genes as well as landscape [19]. To enable their effective protection, it is important to assess the condition of sites and to evaluate their vegetation [29]. Many publications present methods for studying relationships, e.g. between plant distribution, biodiversity of ecosystems, and variation in abiotic factors, both on the continental scale [21] and locally [22]. Research conducted by Zelnik and Čarny [23] showed that the major environmental factors that determine, e.g., distribution of plant communities in the river valley, as well as their floristic richness, include groundwater level fluctuations. This is confirmed by observations of meadow vegetation in the Kulawa valley. Meadows are specific habitat islands in the wooded landscape, and their conservation value depends mainly on local factors, e.g. hydrological and soil conditions and land use [24, 25], but also, as noted by Bruun [26], on the possibility of gene exchange. Since no data were available on seasonal and long-term variation in water level in the soil, as well as on the farming practices applied in the past, various methods of research were used. The phytoindication method, as emphasized by Oświt [15], allows a simple, although generalized, separation of various moisture types of meadows. The application of properly calibrated bioindicators is relatively common [26, 27] as they are of great practical value. Floristic analysis in respect of socioecological groups not only reflects the floristic richness of the studied meadow patches, but is also of diagnostic importance. The presence of species that are characteristic of other habitats indicates the directions of transformations leading to the development of some other, non-meadow ecosystems [3]. Phytosociological description of vegetation by the Braun-Blanquet method is possible if the communities can be unambiguously classified phytosociologically on the basis of syntaxonomic criteria. In the study area, only some phytocoenoses met those criteria, so in the phytosociological table we included only 12 relevés, from grasslands A and C. They can be used as comparative material for monitoring of the condition of protected communities [28]. In contrast, the spatial variation of communities presented by using PCA, gives a synthetic image of similarities and differences in species composition between the studied patches in relation to environmental factors. The application of statistical analysis for research on relationships between wet meadow communities of the order *Molinietalia* and gradients of environmental factors, e.g. concentrations of nutrients in the soil, pH, and weather conditions, is presented in an interesting study conducted in Slovenia [30]. Knowledge of these relationships is also of practical importance. It allows, e.g., selection of a suitable protection strategy, taking into account the heterogeneity of site conditions. The applied research methods were proven to complement one another. They enabled a comprehensive description of the study area, and form the basis for comparisons during monitoring in the future.

Meadows in the Kulawa river valley, since the 19^{th} century, have been irrigated and subject to traditional management. In the 1990s, for economic reasons, many grasslands were abandoned [29], and due to devastation of the hydrotechnical system, water conditions changed there. This often results in drying and decomposition of peat, which is gradually invaded by expansive nitrophilous species, or waterlogging of mud-peaty soils, and their colonization by alders and willows [33]. Processes of degradation, of varied origin and intensity, take place also on two of the three studied grasslands. The negative effects of drying of the soil have been recently aggravated due to the lowering of the groundwater level, and low precipitation [30]. In this situation, the reconstruction of the local system of water retention and irrigation of the two grasslands located near the river, although necessary to stop the regressive succession of vegetation, is not sufficient to restore the floristic richness characteristic of damp meadows. Our field observations and results reported by, e.g., Pałczyński [31] and Jasnowska et al. [32], indicate that when the moisture content of the soil is high, then species-poor patches of marsh vegetation of the alliance *Phragmition* and sedge communities of the alliance *Magnocaricion* develop on peaty soils, together with tall herb communities of the alliance *Filipendulion*. They are characterized by a low biodiversity and a relatively low faunistic value. Lack of their management leads to the expansion of woody species, which eliminates many protected species, including the animal species associated with open habitats [33]. For development and survival of meadow communities of the order *Molinietalia*, it is necessary to apply properly planned extensive farming, aimed at preserving their floristic richness [25, 36, 37]. Experiments on the influence of hay harvesting on diversity of semi-natural grasslands showed that the frequency and timing of hay cutting are of great significance. It is particularly favourable to apply periodical but very late hay cutting, which enables seed production and enrichment of the soil seed bank [38].

Meadows in valleys of small rivers play an important ecological role, but partly because of their relatively small areas, they are classified as biocoenotic systems with high dynamics [35]. This is particularly conspicuous in grassland C in the Kulawa valley. It constitutes a separate hydroecological type, isolated from groundwater by gyttja deposits, and fed by rainwater and carbonate-rich surface runoff from the slopes surrounding the depression. The mosaic of habitats that have developed in those conditions is an example of plant succession towards carbonate-rich moss communities and intermediate mires. They are secondary in relation to the communities of damp meadows, which were probably present there in the past, when the moisture level was lower. However, now they are some of the most valuable ecosystems, protected because they are very rare in Poland and have nearly completely disappeared in other parts of Europe [20, 35]. This excludes any attempts to drain that area, and additionally makes it necessary to monitor plant succession there and to counteract any possible unfavourable transformations.

The grasslands in the Kulawa valley are seminatural habitats, which because of their small areas are of little economic value, but in the wooded landscape they play an important ecological and landscape-shaping role. The variation in site conditions and in land use are major factors affecting the potentially high conservation value of the ecosystems. Both habitat heterogeneity and management type are factors that strongly affect the potential floristic diversity of those ecosystems, also the size of populations of protected, rare, vulnerable, and endangered species. Optimization of water conditions, as well as return to traditional management, should enable restoration or preservation of their natural value. This strategy is consistent with the principles of management of environmentally sensitive areas [36], which include Natura 2000 sites.

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