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ORIGINAL PAPER

MEADOW PLANTS AND THEIR CHEMICAL COMPOSITION UNDER THE HABITAT CONDITIONS PREVAILING IN THE PASŁĘKA RIVER VALLEY NATURA 2000 SITE*

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Abstract

The aim of the study was to assess the diversity of meadow ecosystems and the chemical composition of the meadow flora in a Natura 2000 site called the Pasłeka River Valley, depending on the habitat conditions and management. Physical and chemical properties of the selected habitat components were studied and compared with the calculated bioindicators. Taking into account the dynamics of mursh formation in the organic soil's topmost layer and the habitat conditions in which such soils occur, grassland growing in areas with different land use was selected for the study. One meadow, lying about 50 m from the Pasłęka River, was cut occassionaly. Another meadow, approx. 150 m from the river bank, was cut once, and yet another sampling site situated at a distance of *ca* 300 m from the river consisted of a meadow used intensively for hay-growing and as a pasture. The poorest floral composition was found on the wettest soil, i.e. on the occasionally cut meadow located in the nearest vicinity to the river. The available phosphorus content in soil, same as total nitrogen, decreased as the distance from the river increased. At a larger distance from the river, the available phosphorus content of the groundwater decreased and the available potassium content increased. The N-NO_3 content in water drawn from the river was more than 2– to 4-fold higher than its content in the groundwater collected under the meadows. The highest content of macro and micronutrients was determined in the plant material from the meadow nearest to the river. The results prove that the developed bioindicators for plants do not always reflect the properties of a habitat.

Keywords: fen peatland soils, floral composition, macro- and micronutrients.

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INTRODUCTION

Grassland growing on organic soils in river valleys is a valuable type of habitat owing to its biodiversity (Laidlaw, Šebek 2012, Żyszkowska 2007). Meadows are important in European landscape, having been used for centuries as pastures and hay-growing grassland (Hejcman et al. 2013). Moreover, peat meadows provide essential services in ecosystems, such as prevention of soil erosion, absorption of atmospheric CO_2 by plants and its further accumulation in soil, but also as areas for leisure and recreation (Hopkins, Holz 2006, Zlinszky et al. 2014). Meadows are often included in nature conservation programmes of international importance e.g. Natura 2000 (Maiorano et al. 2007, Verhoeven 2014). The integration of these valuable ecosystems into the Natura 2000 network is often the only way to prevent biodiversity loss (Żmihorski et al. 2016). Intensive grassland management plays a crucial role as a potential protective factor (Franke et al. 2012). Natural grasslands located on organic soils adjacent to rivers and in land depressions are areas susceptible to the impact of external factors. Deterioration of hydrological conditions (water level on site) is considered as the major contributor to organic soil degradation (Glina et al. 2019), which in consequence decreases the moisture content of organic soil (Grzywna, Urban 2008) and leads to its progressive disappearance due to mursh formation. Changes in physical and chemical properties of organic soils may result from their use. When choosing a land use for areas located in river valleys, the impact on the ecosystem's structure and functioning should be predicted (Ibisate et al. 2011). Rational use of meadows is often the only way to preserve the natural values of such areas (Żyszkowska, Paszkiewicz-Jasińska 2010). Plant communities on organic soils are very sensitive to changeable water conditions (Miatkowski, Turbiak 2016). The floral composition and usefulness of meadow communities as well as the direction of succession are mainly determined by the soil moisture and trophic status (Grzywna, Urban 2008). Permanent grassland plays an important role as forage and nutrient sources for animals (Jankowska-Huflejt et al. 2011). The use of permanent grassland may significantly improve the circulation of macro- and micronutrients in nature. Meadow plants as a source of nutrients may also reflect the habitat conditions prevailing in a particular area, and be a useful tool for both land management and protection (Szydłowska 2010).

The aim of the study was to assess the diversity of meadow ecosystems and the chemical composition of the meadow flora depending on the habitat conditions and the land use type. The study was conducted in the Pasłęka River Valley, a site included in the Natura 2000 network. Physical and chemical properties of the main habitat components were studied and compared with the calculated bioindicators.

MATERIAL AND METHODS

The phytosociological study on meadow plants and their chemical composition depending on the habitat conditions, particularly the physical and chemical properties of organic soils and chemical properties of groundwater, was established near the village Kiewry and conducted in 2014–2016. The research site belongs to Olsztyn Lakeland, and lies in the Province of Warmia and Mazury, north-eastern Poland. It belongs to the Natura 2000 network, and is called the Pasłęka River Valley site (Figure 1). The area

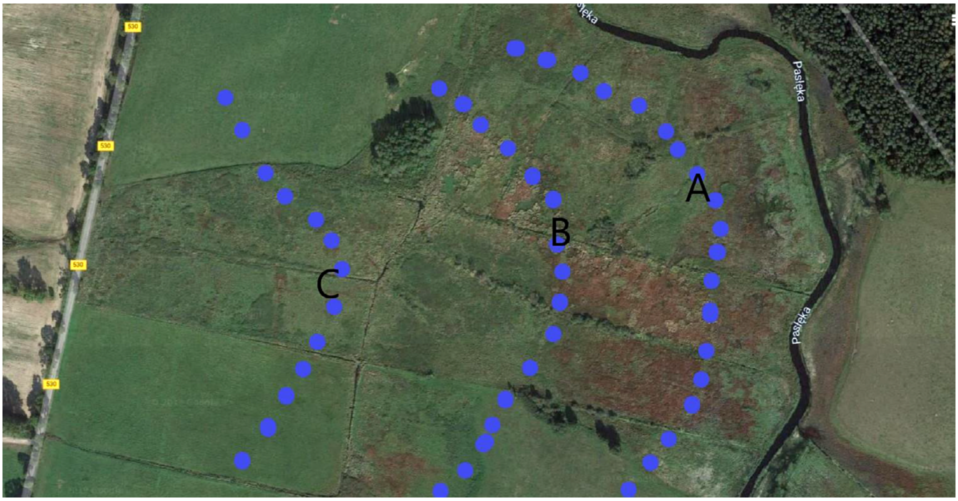

Fig. 1. The location of the permanent grassland under study in the Pasłęka River Valley Natura 2000 site: A – distance of 50 m, B – 150 m, C – 300 m from the river (www.google.pl/maps/place/Kiewry)

submitted to analysis contains 12 ha of grassland lying on fen peatland soils, characterised by various degrees of transformation. Taking into account the dynamics of mursh formation in the organic soil's topmost layer and the habitat conditions where these soils occur, three representative grassland areas with different type of land use were selected for the study.

The first study site was an occasionally cut meadow, about 50 m from the Pasłęka River. The second site, a meadow cut only once a year, was approximately 150 m from the river bank. The third research site was located *ca.* 300 m from the river, and consisted of a meadow intensively used for hay-growing and as a pasture.

In the spring of each year, 12 phytosociological relevés (a study area covered 12 ha, and each phytosociological relevé measured 25 m^2) taken from the study areas were composed of samples of sward from grasslands growing on peat and peat-mursh soils with low and medium organic matter transformation (Pawluczuk et al. 2019). To assess species composition, a seven-degree cover-abundance scale was used, following the Braun-Blanquet method (Braun-Blanquet, 1964). A table summarising the plant species was prepared, and the consistency of their occurrence and their surface coverage were calculated. The names of these plant species were identified according to Mirek et al. (2002).

On representative surfaces, three soil test pits were dug out to a depth up to 150 cm, and the organic formation types were identified within the pits (Figure 1). Morphological features of the genetic soil horizons, based on which the organic soil type was identified, were described in soil profiles (Pawluczuk et al. 2019). In order to determine the soil's physical and chemical properties, soil samples were collected from the soil test pits, on the same dates when the phytosociological survey of materials from the 5-10 and 35-40 cm layers undergoing the peat or mursh formation process was carried out. Given that organic soils were located on representative surfaces, the results for physical and chemical properties obtained in particular years were averaged.

The organic matter content was determined by loss on ignition (LOI) after placing dried samples in a muffle furnace at 550°C for five hours. Chemical analyses were conducted by methods commonly applied for organic soils: acidity in 1N KCl; total nitrogen by the Kjeldahl method; phosphorus and potassium content by the Egner-Riehm method (extraction with a buffered calcium lactate and lactic acid solution at pH 3.5); magnesium content by the Schachtschabel method (extraction with 0,0125 M $CaCl_2$); copper, zinc, manganese, boron and iron in extract 0.5 M HCl by the atomic absorption spectroscopy (AAS) method after mineralization of the sample in a mixture of acids (HNO_3, H_2SO_4 and $HClO_4$).

Aerial parts of plant material were collected for chemical analyses from an area of 1m^2 located on the sites from which phytosociological relevés were taken. Harvested plants dried naturally and were ground in a grinder. The content of nutrient in the plant material was determined using the generally accepted methods: nitrogen by the Kjeldahl method; phosphorus by the molybdovanadate method; potassium and calcium by the flame photometric method. The plant material was mineralised in a mixture of HNO_3, H_2SO_4 and $HClO_4$ acids (4:1), and the content of magnesium, copper, zinc, manganese and iron was determined by atomic absorption spectroscopy (AAS). Groundwater levels were measured in piezometers placed in the vicinity of the soil pits. NNO_3 was determined by the potentiometric method (ionometric method) in 0.03 M CH_3COOH. The pH in water was determined by the potentiometric method.

The results were statistically processed in Statistica 10.0 (StatSoft, Tulsa, Oklahoma, USA) using one-way ANOVA. Basic parameters and homogenous groups were determined by the Tukey's test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Biodiveristy

Less numerous floral composition was noted in phytosociological relevés from highly moist soils located in the vicinity of the river (50 m) – Table 1. On average, 19 plant species were noted there, and the dominant herbs and weeds were *Ranunculus repens* (L.), *Equisetum palustre* L., *Galium mollugo* L. and *Cirsium oleraceum* (L) Scop.. As regards grasses, identified the species, i.e. *Deschampsia caespitosa* (L.) P. Beauv., *Phragmites australis* (Cav.) Trin. ex Steud., *Poa trivialis* L., are of low value for animals. High soil moisture and an occasionally cut meadow resulted in the occurrence of less numerous plant species, with the dominant *Deschampsia caespitosa* (L.) P. Beauv. The same results were obtained by GAMRAT et al. (2010) and BARYŁA, KULIK (2011). On a representative area located 300 m from the river, the grassland was identified as being a fresh meadow, according to ZARZYCKI et al. (2002). The floral composition there comprised more species in comparison with the other analysed objects. Such soil properties as determined at that site are reflected in the species composition of the meadow flora (STOSIK 2014, GAMRAT et al. 2010). The cited researchers found that the community of *Deschampsia caespitosa* (L.) P. Beauv did not often occur in habitats that implicated desiccation. An average of 28 species were found in the phytosociological relevés sampled at this site. Valuable grasses (*Festuca rubra* L., *Festuca pratensis* Huds.) were often found in the phytocenose, although their share was insignificant. The following species were dominant in the sward: *Holcus lanatus* L., *Anthoxanthum odoratum* L., *Rumex acetosa* L., *Geum rivale*.

Lower soil moisture in the object located 300 m from the river helped to maintain legume plants in the sward (Table 1). Irrespective of the moisture content of the analysed objects, a high proportion of low-value grasses and weeds was observed, which, according to DUCKA and BARSZCZEWSKI (2012), may indicate progressive degradation of a habitat. Many plant species were found in more than one object. Such species as *Deschampsia caespitosa* (L.) P. Beauv., *Ranunculus repens* L.), *Festuca rubra* L., *Holcus lanatus* L., are frequent sward components of meadows located on organic soils with varying physical and chemical properties. The reason is the broad tolerance of these species to prevalent habitat conditions (ALBERSKI et al. 2012, MURAWSKI et al. 2017).

Physical and chemical properties of groundwater and soil

The pH of water sampled from the Pasłęka River and the groundwater under the meadows lying 50 and 300 m from the river was neutral, becoming slightly acidic at a distance of 150 m from the river (Table 2). The $N\text{-}NO_3$ content of water drawn from the river was more than 2- to 4-fold higher than its content in the groundwater drawn from the analysed objects. As the dis-

Table 1

Most frequent species of the Kiewry site in the Pasłęka River Valley

Species	Distance from the river (m)					
	50		150		300	
	S*	D**	S*	D**	S*	D**
Deschampsia caespitosa (L.) P.Beauv.	V	2375	V	3375	V	190
Ranunculus repens L.	V	1500	V	1000	IV	562.5
Equisetum palustre L.	V	437.5	II	10	IV	127.5
Galium mollugo L.	V	250	II	2.5	IV	67.5
Cirsium oleraceum (L.) Scop.	V	70	II	62.5	V	190
Poa trivialis L.	IV	437.5	V	625	IV	190
Alopecurus pratensis L.	IV	187.5	IV	187.5	III	125
Geum rivale	IV	127.5	IV	127.5	V	625
Lythrum salicaria L.	IV	127.5	III	65	II	5
Festuca rubra L. s. s.	IV	67.5	V	437.5	V	625
Lychnis flos-cuculi L.	IV	67.5	V	190	II	62.5
Phragmites australis (Cav.) Trin. ex Steud.	IV	67.5	III	65	-	-
Juncus effusus L.	IV	67.5	III	5	IV	7.5
Potentilla anserina L.	IV	67.5	II	62.5	IV	562.5
Polygonum bistorta L.	IV	67.5	II	62.5	-	-
Veronica chamaedrys L.	IV	7.5	III	5	II	5
Cirsium arvense (L.) Scop.	IV	7.5	II	62.5	IV	127.5
Cerastium holosteoides Fr. em. Hyl.	IV	7.5	II	62.5	IV	67.5
Ranunculus acris L. s. s.	III	125	III	5	III	65
Festuca pratensis Huds.	III	125	II	62.5	V	437.5
Glechoma hederacea L.	III	125	-	-	II	62.5
Lotus uliginosus Schk.	III	125	-	-	-	-
Rumex acetosa L.	III	65	II	62.5	V	940
Urtica dioica L.	III	65	-	-	-	-
Poa pratensis L.	III	5	V	10	IV	127.5
Phalaris arundinacea L.	II	875	II	437.5	IV	187.5
Carex gracilis Curtis	II	5	IV	937.5	IV	7.5
Cirsium palustre (L.) Scop.	II	5	III	65	-	-
Filipendula ulmaria (L.) Maxim	II	5	III	5	IV	187.5
Mentha arvensis L.	II	5	III	5	I	2.5
Cardamine pratensis L. s.s.	II	5	III	5	I	2.5
Scirpus silvaticus L.	II	5	-	-	-	-
Luzula campestris (L.) DC.	I	62.5	III	125	V	190
Stellaria media L.	I	2.5	III	5	V	190
Cardaminopsis arenosa (L.) Hayek	I	2.5	II	62.5	IV	7.5
Holcus lanatus L.	-	-	V	1375	V	2750
Ranunculus auricomus L. s. l.	-	-	IV	187.5	III	125
Anthoxanthum odoratum L.	-	-	III	125	V	625
Achillea millefolium L.	-	-	III	5	V	130
Agrostis gigantea Roth.	-	-	III	5	IV	127.5
Vicia cracca L.	-	-	III	5	IV	67.5
Taraxacum officinale F. H. Wigg.	-	-	II	2.5	II	5
Trifolium repens L.	-	-	-	-	V	130
Lathyrus pratensis L.	-	-	-	-	IV	7.5
Dactylis glomerata L.	-	-	-	-	III	125
Carex leporina L.	-	-	-	-	I	62.5
Mean number of plant species	19		22		28	

* S – constancy degree; ** D – cover coefficient

Table 2

Chemical properties of groundwater on the trial surfaces of the Kiewry site in the Pasłęka River Valley

Specification	Water from the river	Distance from the river (m)		
		50	150	300
pH in 1 mol KCl	7.13	$6.95^{ab} \pm 0.59$	$6.47^{b} \pm 1.11$	$7.18^{a} \pm 0.13$
$N\text{-}NO_3$ (mg dm^{-3})	4.64	$2.00^{a} \pm 0.81$	$1.00^{b} \pm 0.19$	$1.00^{b} \pm 0.33$
P (mg dm^{-3})	0.11	$1.24^{a} \pm 0.23$	$0.64^{ab} \pm 0.02$	$0.18^{b} \pm 0.01$
K (mg dm^{-3})	1.80	$0.80^{b} \pm 0.06$	$1.00^{ab} \pm 0.21$	$1.30^{a} \pm 0.04$
Mg (mg dm^{-3})	7.80	$3.00^{b} \pm 0.25$	$2.00^{b} \pm 0.08$	$16.0^{a} \pm 2.26$

a, *b*, *c*, … values with the same letter are not significantly different according to the Tukey's test ($P \leq 0.05$)

tance from the river increased, the phosphorus content of groundwater decreased while the potassium content increased. Water sampled from the object located 300 m from the river was characterised by the highest magnesium content.

The pH of organic soils of the analysed surfaces (depending on the distance from the river) in the 5-10 and 35-40 cm layers ranged from very acidic to slightly acidic (Table 3). The soil sampled from the object located 50 m from Pasłęka River was acidic, being very acidic at a distance of 150 m, slightly acidic pH was determined in soil sampled 300 m far from the river. According to Grzywna (2014), the nitrogen content in organic soils is determined by both the groundwater level and the intensity of use. As the distance from the river increased, the total nitrogen and organic matter content of the soil decreased, both in the topmost and deeper layers. However, these were not always statistically significant differences. The available phosphorus content varied the most among the macronutrients. In a study by Grzywna (2014), the content of available phosphorus in organic soil was also

Table 3

Chemical properties of soil on the trial surfaces of the Kiewry site in the Pasłęka River Valley

Specification	Layer (cm)	Distance from the river (m)		
		50	150	300
pH in 1 mol KCl	5-10	$4.92^{ab} \pm 0.37$	$4.45^{b} \pm 0.09$	$5.56^{a} \pm 0.03$
	35-40	$5.24^{a} \pm 0.28$	$4.46^{b} \pm 0.07$	$5.71^{a} \pm 0.13$
Organic matter (g kg^{-1})	5-10	$49.6^{a} \pm 5.11$	$44.8^{ab} \pm 3.23$	$42.4^{b} \pm 5.22$
	35-40	$45.1^{a} \pm 2.54$	$43.8^{ab} \pm 2.59$	$41.5^{b} \pm 1.98$
N-total (g kg^{-1})	5-10	$1.39^{a} \pm 0.14$	$1.27^{a} \pm 0.01$	$0.61^{b} \pm 0.01$
	35-40	$1.73^{a} \pm 0.29$	$1.15^{b} \pm 0.07$	$1.23^{b} \pm 0.81$

a, *b*, *c*, … values with the same letter are not significantly different according to the Tukey's test ($P \leq 0.05$)

Table 4

Content of macro- and microelements of soil on the trial surfaces of the Kiewry site in the Pasłęka River Valley

Specification	Layer (cm)	Distance from the river (m)		
		50	150	300
P- available (g kg^{-1})	5-10	2.124^{a} ± 0.05	0.494^{b} ± 0.00*	0.254^{c} ± 0.01
	35-40	0.969^{a} ± 0.06	0.448^{a} ± 0.00*	0.200^{a} ± 0.00*
K- available (g kg^{-1})	5-10	0.128^{a} ± 0.01	0.144^{a} ± 0.01	0.141^{a} ± 0.01
	35-40	0.101^{a} ± 0.01	0.125^{a} ± 0.00*	0.088^{a} ± 0.00*
Mg- available (g kg^{-1})	5-10	0.242^{b} ±0.02	0.217^{b} ± 0.00*	0.417^{a} ± 0.00*
	35-40	0.275^{ab} ± 0.05	0.169^{b} ± 0.01	0.497^{a} ± 0.01
B- available (mg kg^{-1})	5-10	6.84^{a} ± 0.29	0.63^{b} ± 0.05	0.69^{b} ± 0.06
	35-40	2.36^{a} ± 0.71	0.71^{a} ± 0.11	1.16^{a} ± 0.17
Mn- available (mg kg^{-1})	5-10	901^{a} ± 2.12	480^{b} ± 13.41	440^{c} ± 7.07
	35-40	564^{a} ± 17.10	450^{a} ± 28.3	495^{a} ± 7.07
Cu- available (mg kg^{-1})	5-10	191.0^{a} ± 11.32	55.8^{b} ± 1.13	30.0^{b} ± 0.71
	35-40	222.5^{a} ± 12.02	36.3^{a} ± 12.0	110.4^{a} ± 32.0
Zn- available (mg kg^{-1})	5-10	160.0^{a} ± 5.55	77.6^{b} ± 0.07	47.9^{c} ± 0.01
	35-40	183.0^{a} ± 32.5	46.5^{a} ± 8.98	88.7^{a} ± 18.1
Fe- available (mg kg^{-1})	5-10	31 000^{a} ± 169.8	14 400^{b} ± 70.7	12 150^{b} ± 38.2
	35-40	16 150^{a} ± 657.6	14 600^{a} ± 283.5	13 950^{a} ± 205.1

a, *b*, *c*, ... values with the same letter are not significantly different according to the Tukey's test ($P \leq 0.05$)
* data below 0.01

most strongly varied – from 20.7 to 584 mg 100 g^{-1} p.s.m. soil. The available phosphorus content is connected with the accumulation of organic matter (Sundström et al. 2000). The available phosphorus content of the soil, similarly to the total nitrogen content, decreased as the distance from the river increased (Table 4). In the soil located closest to the river (50 m), a very high available phosphorus content was noted, at a distance of 150 m, this content was high, while being low at a distance of 300 m. The available potassium content of the soil was very low and did not differ statistically between the objects. The soil sampled from the object located 300 m from the river was characterised by the highest available magnesium content.

Content of macro- and microelements of plant material

The highest macro- and micronutrient concentrations were noted in the plant material sampled from the object located closest to the river, i.e. at a distance of 50 m (Table 5). The lowest macronutrient content was noted in the sward collected from the object located 150 m from the river, and the lowest micronutrient content was determined in the plants collected

Table 5

Content of macro- and microelements of meadow sward of the Kiewry site in the Pasłęka River Valley

Specification	Distance from the river (m)		
	50	150	300
N (g kg^{-1})	25.3^{a} ± 1.31	12.7^{b} ± 0.42	21.6^{ab} ± 0.63
P (g kg^{-1})	4.10^{a} ± 0.33	1.50^{b} ± 0.11	3.30^{ab} ± 0.12
K (g kg^{-1})	7.85^{ab} ± 0.45	1.90^{b} ± 0.60	11.70^{a} ± 2.30
Mg (g kg^{-1})	2.50^{a} ± 0.19	1.05^{b} ± 0.12	1.80^{b} ± 0.10
Ca (g kg^{-1})	6.25^{a} ± 0.23	5.05^{a} ± 0.61	7.40^{a} ± 0.71
Cu (mg kg^{-1})	5.68^{a} ± 0.48	1.67^{b} ± 0.44	1.37^{b} ± 0.04
Fe (mg kg^{-1})	335^{a} ± 86.1	241^{ab} ± 29.6	140^{b} ± 11.6
Mn (mg kg^{-1})	274^{ab} ± 50.9	372^{a} ± 36.8	219^{b} ± 103.6
Zn (mg kg^{-1})	25.4^{a} ± 0.35	23.1^{ab} ± 0.99	15.1^{b} ± 0.42

a, *b*, *c*, … values with the same letter are not significantly different according to the Tukey's test ($P \leq 0.05$)

from the object located 300 m from the river. The fact that the highest total nitrogen content was found in the plant material from the site located in the nearest vicinity to the river may have been due to the high total nitrogen content in the soil and the highest $N\text{-}NO_3$ amount in the groundwater in this object. Similar trends were demonstrated for the phosphorus content. The highest total phosphorus content in the plant material from the site located closest to the river may have been due to the high available phosphorus content in the soil and the highest phosphorus amount in the groundwater in this object. The potassium content of the plant material was not proportional to its amount in the soil, and was only correlated with its content of the water. The lowest magnesium content was demonstrated in the plant material sampled from the object located 50 m from the river, which also corresponded to the lowest content of this element in the soil and water. The lowest micronutrient content was found in the soil of the site located at a distance of 300 m, which may have resulted in the lowest content of these elements in the plant material from the object. The macro- and micronutrient content of the plant material of the species occurring on eutrophic organic soils often coincides with the richness of these soils. A study conducted by Ławniczak (2011) of wetland phytocoenoses in areas with different trophic and moisture conditions showed a significant impact of moisture, soil pH and the ratio of nitrogen and phosphorus content in soil on the diversity of species composition of plants. High macro- and micronutrient concentrations in plant biomass result from the predominance of species that intensively take up nutrients from soil, and from the high competitive ability of fast-growing species that intensively absorb nutrients from soil (Venterink, Güsewell 2010).

Bioindicators

According to the determined physical properties, the wettest soil (90-94%) is found in the vicinity (50 m) of the river (Pawluczuk et al. 2019). Based on the standards developed by Zarzycki et al. (2002), it was concluded that the soil under the meadows located at a distance of 50 and 150 m from the river could be classified as moist soil, and the one located 300 m from the river represented fresh soil (Table 6). This coincided with the occurrence

Table 6

Bioindicators according to Zarzycki et al. (2002) depending on the distance from the river

Specification	Distance from the river (m)		
	50	150	300
Humidity (W)	$4.01^{a} \pm 0.07$	$3.90^{a} \pm 0.17$	$3.55^{b} \pm 0.07$
pH (R)	$4.09^{a} \pm 0.04$	$3.96^{a} \pm 0.02$	$3.95^{a} \pm 0.12$
The content of organic matter (H)	$2.34^{a} \pm 0.02$	$2.29^{ab} \pm 0.08$	$2.19^{b} \pm 0.02$
Trophism (Tr)	$3.86^{a} \pm 0.03$	$3.68^{a} \pm 0.09$	$3.69^{a} \pm 0.18$

a, *b*, *c*, … values with the same letter are not significantly different according to the Tukey's test ($P \leq 0.05$)

of species indicating the degree of moisture content of these soils (Table 1). *Lotus uliginosus* Schk. and *Scirpus silvaticus* L., which suggest a high moisture content of soil, were found only on the meadow closest to the river (50 m). Although some of the species indicating a higher moisture content (*Lythrum salicaria* L., *Cirsium arvense* (L.) Scop., *Equisetum palustre* L.) were also found on the other meadows, they occurred more frequently closest to the river. At a distance of 300 m from the river, *Festuca rubra* L. s. s., *Anthoxanthum odoratum* L. and *Vicia cracca* L., i.e. species typical of fresh habitats, and *Luzula campestris* (L.) DC. and *Cirsium arvense* (L.) Scop., typical of dry habitats, appear in high number in the meadow sward. Similarly to the soil moisture index, the organic matter content and trophism of the habitat slightly decreased as the distance from the river increased (Table 6).

Based on indicator plants occurring in all the analysed sites, it can be concluded that the substrate under the meadows was rich soil. This agrees with the assessment of the occurrence of these plants in the phytosociological relevés taken (Table 1). At a distance of 300 m from the river, species characteristic of poor habitats, such as *Achillea millefolium* L., *Cardaminopsis arenosa* (L.) Hayek, *Luzula campestris* (L.) DC., *Holcus lanatus* L. and *Anthoxanthum odoratum* L. occurred more frequently and in greater numbers. Based on the standards developed by Zarzycki et al. (2002), it was found that the plants determined on all the sites implicated a soil pH value close to neutral (Table 6).

CONCLUSIONS

The least numerous floristic composition was found on the highly moist soil, on an occasionally cut meadow located in the vicinity of the river. As the distance from the river increased, the air-water conditions of the soil improved and the floral composition richness increased. Under such habitat conditions, the meadow located 300 m from the river was an intensively managed hay-growing and pasture area. The habitat conditions and the use contributed to the floral diversity of this object. The available phosphorus content of the soil, similarly to the total nitrogen content, decreased as the distance from the river increased. As the distance from the river increased, the available phosphorus content of the groundwater decreased and the available potassium content increased. The $N\text{-}NO_3$ content in water drawn from the river was more than 2- to 4-fold higher than its content in the groundwater of the analysed objects. The highest macro and micronutrients content was determined in the plant material from the meadow located near the river. The study results confirm that the occasional use of meadows may cause the return of nutrients to the soil as a result of plant mass decomposition The lowest macronutrient content was noted in the sward collected from the object located 150 m from the river, and the lowest micronutrient content was found in the plant material collected from the object located 300 m from the river. The macro- and micronutrient content of the plant material of the species occurring on fen peatland soils often coincided with the richness of these soils.

Based on the developed bioindicators, it was found that the meadows located at a distance of 50 and 150 m from the river can be qualified growing on moist soil, and the one located 300 m from the river was underlain by fresh soil. This coincided with the occurrence of species indicating the degree of moisture content of these soils. Similarly to the moisture index, the organic matter content and trophism of each habitat slightly decreased as the distance from the river increased, which may be related to the biological activity of the soil and the processes occurring in it. Based on indicator plants occurring in the analysed objects, it can be concluded that the entire study area lies on rich soil. However, at a distance of 300 m from the river, species characteristic of less rich habitats occurred more frequently and in greater numbers. The study results prove that the developed bioindicators for plants do not always reflect the properties of a habitat. In the analysed objects, indicator plants suggested a soil pH value close to neutral, while laboratory tests showed that the soils had pH values ranging from slightly acidic to very acidic.

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