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ORIGINAL RESEARCH ARTICLE

Floristic and habitat diversity of the dunes in the Narew River Valley

Robert Czubaszek*, Ewa Walentynowicz

Białystok University of Technology, Faculty of Civil and Environmental Engineering,
Department of Environmental Protection and Management, ul. Wiejska 45 A, 15–351 Białystok, Poland.

Tel. +48 79 799 5952; e-mail: r.czubaszek@pb.edu.pl

Abstract. The aim of the research presented here was to determine and compare the habitat conditions of the two adjacent dune areas in the Narew River Valley. For the comparative studies we used the ecological indicator value method and the index of forest soil trophism (*ITGL*), both of which revealed differences between the investigated habitats. Values of *ITGL* indicate that in the case of the Uroczysko Serwańce dune, which is covered by a mixed coniferous forest (*Serratulo-Piceetum*), the habitat is oligotrophic, while the habitat on the Ławki Małe dune is dominated by a not yet fully developed *Tilio-Carpinetum* plant community which displays a mesotrophic character. Similar differences were observed using ecological indicator values. Soil indices calculated for the oak-hornbeam stand on the Ławki Małe dune indicate the presence of fresh, mesotrophic, humus-mineral soils made of sandy loam or silt substrate with a near-neutral pH. From these results we can deduce that climatic conditions, affected by peatlands, have a greater impact on the development of vegetation on inpeatland dunes than relatively poor soils.

Key words: inpeatland dunes, ecological indicator values, forest soil trophism index

1. Introduction

Sand dunes are commonly encountered in the Biebrza Basin and Narew River Valley. They can occur as relatively large dune fields or take the form of several metre-high hills, jutting out of peatlands and situated on the peatland mineral substrate (Banaszuk 2004). These forms, the main elements diversifying the terrain of river valleys, act as environmental islands in the landscape. Most of the species inhabiting the dunes must have arrived as a result of propagule dispersion, most likely from areas beyond the valley's bottom (Wołkowycki 2004). Such isolated patches of habitats, especially forests, are of particular importance in shaping the biodiversity and enabling the exchange of species, energy and matter in the landscape. Forested dunes, occurring in the monotonous area of peatlands, not only increase the mosaic of the land, but can also provide an important refugial environment for many plant and animal species (Dąbrowska-Prot 1998).

Inpeatland dunes are relatively poorly explored elements of the Biebrza Basin and Narew River Valley. Although the Eolian relief of the Basin has been the subject of interest for many authors, their studies primarily focused on the problem of the origin and age of the dune fields (Mycielska-Dowgiałło 1982; Grzybowski 1982; Banaszuk, Banaszuk 1992). More detailed studies on soil cover, albeit for the dune fields outside of the Narew floodplain valley, near Tykocin, were conducted by Banaszuk (1979). In contrast, soils on dunes were researched in the broader context of their association with vegetation by Czerwiński (1981) who led a study, among others, at the Grzędy reserve of the Central Biebrza Basin. In turn, the effect of habitat conditions on nutrient cycle in the coniferous forest communities of the dunes in the Szelągówka reserve, located in the

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southern part of the Biebrza Basin, was the subject of a doctoral dissertation by Banaszuk (1997). Much less research in the literature is devoted to inpeatland dunes. Soils developed at such sites were primarily studied by Czubaszek (2006, 2008) who led a research on the rate of the decomposition of organic material on inpeatland dunes (Czubaszek, Iwanek 2012). The diversity of the soils belonging to different types that developed on the inpeatland dunes of the Biebrza Basin and Narew Valley is one of their characteristic features. Based on the content of various forms of iron and aluminium, the soils of the 'Biebrza' dunes should be considered as rusty, while those developed at the 'Narew' dunes are podzolic, with their eluvial horizon eliminated (masked) during their previous use as cropland (Czubaszek 2006; Czubaszek 2008). Łotowska's study (2008) conducted on the Ławki Małe and Uroczysko Serwańce dunes showed that different soil types exist in the dune areas within the Narew Valley, where podzols occur at the former while rusty soils are found at the latter site.

There are relatively few studies of the vegetation on inpeatland dunes. Only Wołkowycki (2006), in addition to Czubaszek (2011), presented the results of research on the floristic composition of the inpeatland dunes of the Narew Valley, while Brzosko and Wróblewska (2003) described the genetic diversity of one species of orchids (*Listera ovata*) at one of the Biebrza Basin dunes. All of the authors mentioned emphasise the unusual relationship of soil, vegetation, which can be observed at most of the inpeatland dunes. This is primarily the result of the development of relatively rich vegetation on the seemingly nutritionally poor dune sand. The studied objects, maintained in their natural or near-natural state, can be an excellent testing ground for studies on the proper management of dune areas (Czubaszek 2007).

The main component of the forest ecosystem is soil. Its functions include, among others, the storage of humus, water retention and meeting the nutritional requirements of plants. Its specific properties, such as particle size distribution, pH and humus content, determine its potential fertility and the ability of specific plant communities to develop. That is why soil is a basic element in the diagnosis of forest habitat (Brożek 2001). Therefore, because conducting a direct comparison of the analytical data on soil chemistry is frequently cumbersome and time-consuming, numerical indicators of trophism are often used in habitat defining. The aim of the work presented in this study was to determine and compare the habitat conditions prevailing at neighbouring dune areas of the Narew Valley that differ in vegetation cover using numerical trophism indicators. In this paper, comparative research was performed using ecological indicator values (Zarzycki et al. 2002) and a method known as the forest soil trophism index (ITGL) (Brożek 2001).

2. Study subject and methods

The study was conducted at two adjacent inpeatland dunes located in a reclaimed section of the Narew River Valley (N 53° 12', E 22° 5'). The first, Uroczysko Serwańce, is about 1.5 km in length and about 300 m wide and given its size, it is often treated as a dune field. It has been planted with pine stands, but also has some more natural vegetation, also of a coniferous character. The second studied dune, Ławki Małe, is a 260-meter long hill, approximately 60 m wide and about 4 m high. It is a sort of bridge between Uroczysko Serwańce and another dune field, situated on a terrace above the floodplain of the Narew River – Kępa Lipnicka. The plant community found here has been described as not fully developed *Tilio-Carpinetum* Tracz 1962 (Czubaszek 2011).

In order to assess habitat conditions using the ecological indicator values (Zarzycki et al. 2002), 12 phytosociological relevés (six for each study object) of 400 m^2 in size were prepared of the study sites. The relevés were done using the 11-point Londo abundance scale, which was recalculated to the 6-point Braun-Blanquet scale. The names of vascular plant species were taken from Mirek et al. (2002), and the names of bryophytes from Ochyra et al. (2003). Plant communities were identified according to the phytosociological system of Matuszkiewicz (2001). Qualitative and quantitative comparisons of the floristic composition of the surveyed plant communities were based on the number of synthetic characteristics counted (Pawłowski 1972). Individual species were assigned corresponding values from the list of ecological indicator values. The synthetic index for each habitat characteristic was calculated as a weighted average of the indicators and cover coefficients.

In order to calculate the forest soil trophism index (Brożek 2001) on the studied dunes, a total of six pits were dug, three at the Ławki Małe dune and three at Uroczysko Serwańce. The pits were located within the areas where the phytosociological relevés were performed. The genetic horizons were distinguished in the exposed profiles, then their thickness was measured and

colour determined in their natural state based on the Munsell atlas (Revised Standard ... 1997) and remaining morphological features were described. The symbols for soil horizons of the new Systematics of Polish Soils (2011) were used in the description of the soil profile. Soil samples were taken from each horizon for further study in the laboratory. In order to determine the bulk density, soil was collected in metal cylinders in a manner preserving its structure. The soil samples were used to determine:

– particle size distribution, using the Bouyoucos areometric method with the modifications of Casagrande and Prószyński,

– organic carbon, using the Tiurin method, total nitrogen by direct nesslerisation after dissolving the sample in a mixture of sulphuric acid and hydrogen peroxide using a Hach mineralisation column,

– pH of the soils, using the potentiometric method with an aqueous extract and 1-mole solution of KCl,

– sum of base cations, using the Kappen method,

– bulk density, using dry weight by drying the material at 105°C.

The analyses were aimed at determining the properties of the substrate from which the studied soils developed, as well as calculating the forest soil trophism index. For this purpose, the results were replaced with indicators of the specific properties of the soils (Table 1). In case of sum of base cations obtained in mass unit the results were recalculated as a unit of volume using the following formula:

$$D = 1.3773 \cdot e^{-0,0547 \cdot x},$$

where:

D – bulk density in g·cm^{-3},

x – organic carbon content (%).

This made it possible to obtain comparable samples with widely differing bulk densities (Brożek, Zwydak 2003).

Then, we used the formula:

$$ITGL = (I_{pył} + I_{czs} + I_{pH} + I_{kat} + I_{C:N}) - I_{szk},$$

where:

$I_{pył}$ – indicator of silt content,

I_{czs} – indicator of clay content,

I_{pH} – indicator of reaction,

I_{kat} – indicator of the exchangeable alkali,

$I_{C:N}$ – indicator of the degree of organic matter decomposition,

I_{szk} – indicator of the skeleton content.

The index was calculated for specific soil horizons. In order to calculate the ITGL index for the entire studied profile, a weighted average was calculated with the measure of horizon thickness expressed in centimetres (Brożek, Zwydak 2003). The indicator of organic matter was described only for the upper horizons of the soil.

Table 1. Ranges of soil properties and corresponding indicators (I) (Brożek, Zwydak 2003)

Soil particle size groups						pH_{H2O}		Sum of exchangeable alkali (S)		Soil organic matter	
>1.0 mm		0.1–0.02 mm		<0.02 mm							
%	I_{szk}	%	$I_{pył}$	%	I_{czs}	pH	I_{pH}	content in cmol(+)·dm^3	I_{kat}	C:N	$I_{C:N}$
0–30	0	0–1	1	0–1	1	≤ 3.5	1	0.1	1	>30.0	1
31–40	1	2	2	2	2	3.6–3.7	2	0.2	2	25.1–30.0	2
41–50	2	3	3	3	3	3.8–4.0	3	0.3–0.4	3	22.1–25.0	3
51–60	3	4–5	4	4–5	4	4.1–4.4	4	0.5–0.6	4	20.1–22.0	4
61–80	4	6–7	5	6–7	5	4.5–4.9	5	0.7–1.0	5	18.1–20.0	5
81–100	5	8–10	6	8–10	6	5.0–5.5	6	1.1–2.0	6	16.1–18.0	6
		11–15	7	11–15	7	5.6–6.2	7	2.1–5.0	7	14.1–16.0	7
		16–25	8	16–25	8	6.3–7.0	8	5.1–10.0	8	12.1–14.0	8
		26–50	9	26–50	9	7.1–7.9	9	10.1–20.1	9	10.1–12.0	9
		>50	10	>50	10	≥ 8.0	10	>20.0	10	≤ 10.0	10

Explanation: $I_{pył}$ – indicator of silt content, I_{czs} – indicator of clay content, I_{pH} – indicator of reaction, I_{kat} – indicator of sum of the exchangeable alkali, $I_{C:N}$ – indicator of degree of organic matter decomposition, I_{szk} – indicator of skeleton content

3. Study results

Profile structure and properties of the soils

Despite the diverse systematic classification of the soils that developed on the dunes of Ławki Małe and Uroczysko Serwańce, they had a similar profile structure. The studied soils differed in the structure of the upper part of profile. In the case of Ławki Małe, both the organic horizon as well as the underlying humus and enrichment horizons had greater thickness than the analogous horizons of the soil at Uroczysko Serwańce.

All the studied soils evolved from poor dune deposits. The sand fraction strongly dominated in the mineral part of the soil, with a negligible clay content that did not exceed 5%. The difference in the soils of dunes was

Table 2. Selected soil properties

Object	Horizon	Depth [cm]	Percentage of soil fractions [mm]			C [%]	N [%]	C:N	pH		S [cmol·kg^{-1}]
			1–0.1	0.1–0.02	< 0.02				H_2O	KCl	
Serwańce 1	A	0–21	88	9	3	0.94	0.06	16	4.1	3.6	0.57
	Bv	21–34	91	7	2	0.52	0.05	10	4.4	4.0	0.31
	BC	34–47	93	5	2	0.30	0.05	6	4.6	4.1	0.28
	C1	47–77	92	7	1	0.17	0.05	3	4.8	4.3	0.38
	C2	77–150	94	3	3	0.11	0.03	4	5.0	4.3	0.40
Serwańce 2	A	0–7	90	7	3	0.72	0.07	10	4.7	4.1	0.62
	Bv	7–19	94	4	2	0.21	0.04	5	4.8	4.5	0.41
	C1	19–89	95	4	1	0.15	0.02	8	4.8	4.6	0.39
	C2	89–150	86	13	1	0.10	0.01	10	4.8	4.6	0.24
Serwańce 3	A	0–8	86	9	5	2.21	0.07	32	4.0	3.4	0.64
	AB	8–18	91	7	2	1.42	0.06	24	4.4	4.0	0.41
	Bv	18–30	91	7	2	0.83	0.05	17	4.7	4.4	0.37
	BC	30–73	96	3	1	0.38	0.03	13	5.1	4.5	0.30
	C	73–150	94	5	1	0.21	0.02	11	5.2	4.6	0.39
Ławki Małe 1	A	0–15	84	13	3	1.93	0.09	21	4.2	3.6	0.63
	AEs	15–40	85	13	2	0.82	0.07	12	4.4	4.1	0.58
	Bs	40–65	86	13	1	0.53	0.03	18	4.6	4.2	0.43
	BC	65–88	89	9	2	0.42	0.03	14	4.7	4.4	0.32
	C	88–150	90	8	2	0.20	0.05	4	4.9	4.4	0.40
Ławki Małe 2	A	0–22	83	14	3	2.50	0.09	28	3.5	3.0	0.72
	AEs	22–37	88	9	3	0.58	0.08	7	3.8	3.3	0.15
	Bs	37–62	86	12	2	0.78	0.12	7	4.4	3.9	0.37
	BC	62–82	87	12	1	0.48	0.06	8	4.7	4.2	0.40
	C	82–150	86	13	1	0.25	0.05	5	5.2	4.5	0.39
Ławki Małe 3	AEs	0–22	78	20	2	1.56	0.09	17	4.0	3.5	0.62
	Bs	22–39	84	14	2	0.89	0.08	11	4.6	3.9	0.42
	BC1	39–55	84	15	1	0.60	0.06	10	4.8	4.1	0.36
	BC2	55–67	87	10	3	0.41	0.03	14	4.9	4.2	0.41
	C1	67–112	89	10	1	0.25	0.03	8	5.1	4.4	0.28
	C2	112–150	86	12	2	0.14	0.04	4	5.4	4.5	0.42

a slightly higher silt fraction in the soils of Ławki Małe dune (Table 2). Only minor differences were observed between the profiles among the selected chemical properties of the soils analysed for the purposes of this study. This was the case, for example, in the slightly higher content of organic carbon in the soils of Ławki Małe dune and in the profile of the Serwańce 3 site, with a similar nitrogen content that also resulted in slightly higher ratios of C:N in these profiles. The degree of acidification of the soils was similar. All were characterised as strongly acidic or, in some cases, acidic and have relatively low content of basic cations (Table 2).

The diversity of the vegetation at the studied dunes

The plant community of the Ławki Małe dune can be defined as a not fully developed *Tilio-Carpinetum* Tracz 1962 deciduous forest (Czubaszek 2011). The basis for this determination was the floristic composition. Aside from accompanying species, the area is dominated by deciduous-eutrophic species of the *Fagetalia* order and mesotrophic of the *Querco-Fagetea* class (Table 3). The average tree cover was about 40%. This was dominated by pedunculate oak (*Quercus robur*) with a smaller proportions of Norway maple (*Acer platanoides*), European hornbeam (*Carpinus betulus*), silver birch (*Betula pendula*) and Wych elm (*Ulmus glabra*). The average shrub cover slightly exceeded 40%. In addition to the tree species already mentioned, the shrub layer is made up of euonymus (*Euonymus verrucosus*), common hazel (*Corylus avellana*), rowan (*Sorbus aucuparia*) and alder buckthorn (*Frangula alnus*). The herb layer of the described community covered almost 100% of the area. Mainly deciduous species prevailed. Of all the species, the greatest coverage and stability were achieved by yellow archangel (*Galeobdolon luteum*), wood millet (*Milium effusum*) and mountain melick (*Melica nutans*), considered to be an indicator species of eutrophic habitats. No layer of moss was found in the studied area. Although rich in species composition, a significant number of species characteristic for *Querco-Fagetea* were lacking. The relatively high proportion of associated species and the presence of species from other classes, especially those related to human activity, indicated that the described community represented a not fully developed deciduous forest. The basis for such a finding was the significant share of meadow and pasture species of the *Molinio-Arrhenatheretea* class, for example, tufted hair grass (*Deschampsia caespitosa*) and red fescue (*Festuca rubra*) as well as the species of ruderal xerothermic communities of the *Agropyretea* class, quackgrass (*Agropyron repens*) (Table 3).

Table 3. Differentiation of the synthetic properties of plant communities

Syngenetic groups	Not fully developed *Tilio-Carpinetum* Ławki Małe			*Serratulo-Piceetum* Uroczysko Serwańce		
	S	G	D	S	G	D
Cl. Querco-Fagetea	60.00	33.65	20.19	56.67	10.56	5.98
Cl. Molinio-Arrhenatheretea	47.62	9.35	4.45	16.67	4.97	0.83
Cl. Trifolio-Geranietea sanguinei	66.67	5.61	3.74	66.67	2.48	1.66
Cl. Nardo-Callunetea	58.33	3.27	1.91	53.33	4.35	5.30
Cl. Epilobietea angustifolii	33.33	0.93	0.31	58.33	4.35	2.54
Cl. Vaccinio-Piceetea	33.33	0.93	0.31	78.57	20.50	16.10
Cl. Artemisietea vulgaris	66.67	3.74	2.49	-	-	-
Cl. Stellarietea mediae	25.00	1.40	0.35	-	-	-
Cl. Agropyretea	66.67	1.87	1.25	-	-	-
Cl. Rhamno-Prunetea	38.89	3.27	1.27	-	-	-
Cl. Koelerio-Corynephoretea	-	-	-	66.67	2.48	1.66
Accompanying species	64.17	35.98	23.09	50.69	45.34	22.99

Explanation: S – average group constancy, G – group share, D – systematical value of species group

The plant community developed at Uroczysko Serwańce had a completely different character than at Ławki Małe. Analysing the floristic composition helped to establish it as *Serratulo–Piceetum* Sokol 1968, a multi-species mixed forest. As in the case of Ławki Małe, the species composition was dominated by accompanying species, with the next largest share held by *Vaccino-Piceetea* species related to coniferous forests. The *Querco-Fagetea* class was present to a much lesser degree here, while the share of heath species from the *Nardo-Callunetea* class significantly increased (Table 3). The tree coverage of Uroczysko Serwańce averaged 50%. It was comprised primarily of Scots pine (*Pinus sylvestris*) and, to a lesser degree, pedunculate oak (*Quercus robur*). The shrub layer was mainly made up of pine saplings. In addition, large shares of the area were covered by common hazel (*Corylus avellana*), common juniper (*Juniperus communis*) and silver birch (*Betula pendula*), accompanied by single individuals of pedunculate oak (*Quercus robur*) and rowan (*Sorbus aucuparia*). The average coverage of this layer was approximately 50%. The herbaceous layer was mainly comprised of wood small-reed (*Calamagrostis epigejos*). A large share of this layer also included sheep's fescue (*Festuca ovina*), common bent (*Agrostis capillaris*) and red fescue (*Festuca rubra*). In addition, there were also tree and shrub seedlings: oak, juniper as well as single individuals of spruce and rowan. The average coverage of the herb layer was estimated to be 40%. There was a rich layer of mosses and lichens in the mixed coniferous forest. The average coverage was approximately 60%. Red-stemmed feather moss (*Pleurozium schreberi*) dominated this layer, accompanied mostly by juniper haircap moss (*Polytrichum juniperinum*) and rugose fork-moss (*Dicranum polysetum*). There were also single individuals of such species as *Eurhynchium angustirete*, *cypress-leaved plait-moss* (*Hypnum cupressiforme*) and broom fork-moss (*Dicranum scoparium*).

Determining habitat conditions on inpeatland dunes using the ecological indicator values method

The ecological indicator values method enables two groups of indicators to be determined: climatic and edaphic (Table 4).

The close proximity of the studied sites resulted in similar values of temperature and continentality (Table 4). Larger differences between the sites occurred in the case of the light value. The value obtained at the Ławki Małe dune indicated semi-shaded conditions, while moderate or full light was observed at Uroczysko Serwańce.

The soil indicators calculated at the studied dunes on one hand confirmed their specific properties described earlier, but on the other hand, 'differentiated' the dunes to a large extent. The values for moisture content and organic matter content were similar. The values of these indicators at both Ławki Małe and Uroczysko Serwańce pointed to a fresh habitat and humus-mineral soil. As for the other features, they indicate that the soils at Ławki Małe developed from sandy clays or silt deposits, had a neutral pH, and the habitat could be described as mesotrophic or eutrophic, while the soils at Uroczysko Serwańce evolved from sand deposits, had a moderately acidic pH and developed an oligotrophic or mesotrophic habitat.

Determining habitat conditions on inpeatland dunes using the forest soil trophism index

Calculated on the basis of selected soil properties, the habitat quality indicators clearly differentiated the dunes under study. The ITGL value for the Uroczysko Serwańce dune had a range of 14.92–16.05, while in the case of Ławki Małe, it was 18.20–18.96 (Table 5).

Two elements were mainly responsible for these differences. The first was the higher fraction of silt in soils developed at Ławki Małe dune, which resulted in

Table 4. Habitat quality indicators determined by the ecological indicator values method

Object	Climatic indicators			Edaphic indicators				
	L	T	K	W	Tr	R	D	H
Ławki Małe	3.23	3.63	3.00	3.15	3.40	3.77	4.02	2.01
Serwańce	4.20	3.53	3.01	2.99	2.68	3.24	3.49	1.76

Explanation: L – light value, T – temperature value, K – continentality value, W – soil moisture value, Tr – trophism value, R – soil acidity value, D – soil granulometric value, H – organic matter content value

Table 5. Indicator values assigned to soil properties to determine the forest soil trophism index (*ITGL*)

Object	Horizon	Depth [cm]	$I_{pył}$	I_{czs}	$I_{C:N}$	I_{pH}	I_{kat}	Thickness [cm]		I_{Σ}	*ITGL*
								horizon	profile		
Serwańce 1	A	0–21	6	3	7	4	5	21	150	25	16.05
	Bv	21–34	5	1		4	3	13		13	
	BC	34–47	4	1		5	3	13		13	
	C1	47–77	5	1		5	4	30		15	
	C2	77–150	3	2		6	4	73		15	
Serwańce 2	A	0–7	5	3	9	5	5	7	150	27	15.50
	Bv	7–19	4	2		5	4	12		15	
	C1	19–89	4	1		5	4	70		14	
	C2	89–150	7	1		5	3	61		16	
Serwańce 3	A	0–8	6	4	1	3	5	8	150	19	14.92
	AB	8–18	5	2	3	4	4	10		15	
	Bv	18–30	5	2		5	4	12		16	
	BC	30–73	3	1		6	3	43		13	
	C	73–150	4	1		6	4	77		15	
Ławki Małe 1	A	0–15	7	3	4	4	5	15	150	23	18.96
	AEs	15–40	7	2	9	4	5	25		18	
	Bs	40–65	7	1		5	4	25		17	
	BC	65–88	5	2		5	3	23		15	
	C	88–150	6	2		5	4	62		17	
Ławki Małe 2	A	0–22	7	3	2	1	5	22	150	18	18.20
	AEs	22–37	6	3	10	2	2	15		23	
	Bs	37–62	7	2		4	4	25		17	
	BC	62–82	7	1		5	4	20		17	
	C	82–150	7	1		6	4	68		18	
Ławki Małe 3	AEs	0–22	8	2	6	3	5	22	150	24	18.43
	Bs	22–39	7	2		5	4	17		18	
	BC1	39–55	7	1		5	4	16		17	
	BC2	55–67	6	3		5	4	12		18	
	C1	67–112	6	1		6	3	45		16	
	C2	112–150	7	2		6	4	38		19	

Explanation: $I_{pył}$ – indicator of silt content, I_{czs} – indicator of clay content, I_{pH} – indicator of reaction, I_{kat} – indicator of sum of the exchangeable alkali, $I_{C:N}$ – indicator of degree of organic matter decomposition, I_{szk} – indicator of skeleton content

a higher indicator value. The second factor influencing the higher ITGL values obtained for Ławki Małe was the much greater thickness of the humus horizon of the soil. The weighted average calculated for this parameter clearly increased the index value for the entire studied profile.

4. Discussion

The results confirmed both a diverse habitat in adjacent dune areas of the Narew River Valley, as well as their specificity. Compatibility was confirmed between

habitat and vegetation at Uroczysko Serwańce with its mixed forest community functioning on relatively poor rusty soils, whereas the Ławki Małe dune has a system that can be considered unusual, where soils with chemical properties indicating an ongoing process of podzolisation developed under deciduous vegetation. The fact that, in some cases, rich deciduous forests developed on inpeatland dunes is due to their specific location, surrounded by peatlands. On the one hand, peatlands create a climate of rapidly decomposing organic matter, thereby accelerating the recirculation of elements. On the other hand, they provide plants with nutrients taken up by the root systems of trees growing at dune edges. The nutrients taken up by the plants return to the soil when the plant dies back. This plant matter is then very rapidly mineralised, making it possible to reuse the elements (Prusinkiewicz et al. 1974; Prusinkiewicz, Biały 1976).

The construction of the soil profile of inpeatland dunes located in the Narew River Valley, and especially the observed system of their genetic horizons, in conjunction with the deposits from which they are built, is characteristic of rusty soils (Systematics ... 2011). What differentiates the studied soils, especially those developed at Ławki Małe, from others of this type is a well-developed layer of humus, distinctly cut off from the adjacent layer below. Both of these features may be the result of agricultural activity conducted here in the past, which also masked the morphological manifestations of the podzolisation process.

The results of research conducted by the Archaeological Photographs of Poland indicated the activity of humans in the Biebrza Valley in all archaeological epochs: from the Paleolithic through the Mesolithic, Neolithic, Bronze Age, the so-called 'Early Iron Age', the Middle Ages to modern times (Pietrowski, Balcerzak 2000). Czerwiński (1983) wrote about the possibility of the soils of inpeatland sand dunes being farmed in the sixteenth century. The author emphasised that this was primitive cultivation, and could have contributed to the resumption of Eolian processes, as evidenced by the presence of palaeosolic soil horizons. As a result of succession, oak forests developed on the exposed surfaces. Jentsch and Beyschlag (2003) and Lawesson and Wind (2002) presented a similar model of vegetation succession on inland dunes. In time, inpeatland dunes were mainly used as pasture, which greatly distorted the plant communities occurring there. Moreover, the dunes continue to be managed as pasture to this day. Burning stubble in the spring is also related to pasturing cattle, which resulted in the abundant development of grasses (Czerwiński 1995). This is evidenced by the numerous wood coals in the genetic horizons of the studied dune soils.

The specified climatic indicators for the studied inpeatland dunes exhibit little variation. The results indicate generally moderately cool and moderately warm climatic conditions characteristic of most of the lowlands, with a particular focus on its northern part. The continentality index value indicates the dominance of species neutral to these climate conditions, and thus able to tolerate both low and high temperatures, as well as moist and dry air (Zarzycki et al. 2002). A slightly greater variation in the light indicator value at Ławki Małe dune is probably caused by the higher amount of tree and shrub cover there.

The soil indicators calculated for the studied dunes point to much more favourable habitat conditions than can be inferred from the deposits building these landforms. According to the analysis of the grain size composition, one of the basic characteristics of the soil, which bear on a number of other properties, all of the tested soils were formed of loose sandy deposits (Table 2). Such soils are generally characterised by low moisture, acidity, low organic matter content and little nutrient content for plants. The observed discrepancy between the calculated moisture indicator, indicating a fresh habitat, and the character of the deposits from which the studied inpeatland dunes are built was also described by other authors. According to Roo-Zielińska (2004), the dry but nutrient-rich soils can provide plants with enough nutrients, despite their limited transpiration. Thus, they can be colonised by species that are assigned to higher moisture indicator values. The slightly higher value of this index at Ławki Małe dune may be due to a higher content of silt, which improves the moisture properties of sandy deposits, enabling richer vegetation to develop, which provides a great amount of organic debris that raises the trophism of the habitat. The difference in the trophism indicators calculated for the studied dunes is primarily caused by the high cover ratios obtained for the deciduous *Querco-Fagetea* class at Ławki Małe. At Uroczysko Serwańce, a coniferous species the Scots pine dominates, which does not have high trophism demands.

When comparing the obtained trophism index values of forest soils with the ranges provided by the Atlas of Polish Forest Soils (Brożek, Zwydak 2003) for different types of soils, it can be concluded that they overlap with the ranges defined for lowland podzolic and rusty soils. According to soil trophism categories, the soils developed on the Uroczysko Serwańce should be treated as oligotrophic, and the soils developed on Ławki Małe dune as mesotrophic. The authors of the above-mentioned atlas attempted to use the forest soil trophism

index to diagnose lowland and upland forest habitats. As a result of analyses undertaken for this purpose in various regions of Poland, several types of habitats were distinguished, which can be categorised in the following manner based on their ITGL value:

ITGL ≤ 10.0	coniferous habitats,
ITGL 10.1–16.0	mixed coniferous habitats,
ITGL 16.1–26.0	mixed deciduous forest habitats,
ITGL > 26.0	deciduous forest habitats.

Given the above classification, we can conclude that Uroczysko Serwańce has a mixed coniferous habitat, while Ławki Małe has a mixed deciduous habitat. These results coincide with the results of the floristic analysis carried out at the study sites. This consistency indicates the usefulness of the ITGL method to determine habitat conditions on dunes surrounded by peatlands despite the fact that, as stated by Brożek et al. (2010) in concluding his research, the numerical indicators of trophism are especially suitable for use in forests with a tree species composition similar to a natural state, where the climate does not differentiate the living conditions of the trees.

5. Conclusions

Based on the research conducted, the following conclusions can be formulated:

1. The basic factors conditioning the development and influencing the functioning of the relatively rich plant associations on the inpeatland dunes of the Narew River Valley are their location, surrounded by peatlands, as well as the activity of humans, both in the past as well as in the present-day.

2. Despite their proximity and nearly identical soil substrate, which in both cases are loose dune sands, plant communities differing by their floristic composition developed on neighbouring dune areas in the Narew River Valley. A deciduous forest community developed at Ławki Małe, while Uroczysko Serwańce has a mixed coniferous forest community.

3. The methods of assessing habitat conditions used in the work showed diverse compliance in the ecological systems observed at the inpeatland dunes. The ecological index values indicated convergence between the plant association and the soils developed at Uroczysko Serwańce, while the results obtained for Ławki Małe indicate a much richer material in its substrate. The assessment of soil trophism conditions conducted by using the forest soil trophism index agreed in both cases with the forest communities actually occurring at the studied dunes.

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Contributions

R.C. – development of the concept of the article, interpretation of results, literature review and preparation of the manuscript

E. K. – preparation of research results for analysis and literature review

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