BIAŁOWIEŻA FOREST (NE-POLAND) AND VALDAY NP (NW-RUSSIA) – BIOGEOGRAPHICAL CHARACTERISTICS OF EUTROPHIC DECIDUOUS FORESTS

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Abstract: During geobotanical studies in the north-eastern border of hemi-boreal zone, in Valday (NW Russia), rare eutrophic deciduous forests dominated by oak *Quercus robur* were observed. A comparison of these forests with the model of European deciduous forest in Białowieża National Park (NE-Poland) indicates a great similarity. Therefore, eutrophic deciduous forests in Valday can be classified to the *Querco-Fagetea* class, the *Fagetalia sylvaticae* order and to the *Capinion betuli* alliance, despite the absence of hornbeam *Carpinus betulus* in the region. Rarity of eutrophic deciduous forests in Valday region results probably from strong anthropogenic pressure in the past.

Key words: hemiboreal and nemoral eutrophic deciduous forests; biogeographical characteristic

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Introduction

The role of eutrophic deciduous forests in a transition zone between boreal coniferous (Northern Europe) and deciduous forests (Western Europe) has not been explained sufficiently so far. Eutrophic deciduous forests belong to the *Querco-Fagetea* class and the *Fagetalia sylvaticae* order. On the one hand, they are thought to have minor significance in rich habitats of the hemiboreal zone compared to spruce forests (Ahti et al. 1968, Lavrenko 1980, Korotkov 1991), on the other they are important type of potential natural vegetation and their present rarity results from long, sustained human activity (Lavrenko 1980, Dyrenkov, Avdeev 1989).

The aim of this study was to quantify the phytosociological and biogeographical differences and similarities in plant species composition across two regional forms of eutrophic deciduous forests. The first one is found in the centre of European deciduous forests range (Białowieża Forest – BF) and constitutes a reference area, the second is found in its peripheral zone (Valday

National Park – V). The differences were related to the climatic conditions of the studied regions.

Study objects

The study was conducted in two forest complexes in Poland and in Russia, situated at the distance of ~ 830 km (Fig. 1). Białowieża Forest (52°42′ N; 23°51′ E) constituted a reference area for the forest complex in Valday National Park (57°58′ N; 33°17′ E). The studied forests were classified, according to Braun-Blanquet's method (Westhoff, van der Maarel 1978, Mueller–Dombois, Ellenberg 2003) as two regional forms of eutrophic deciduous forest belonging to the *Querco-Fagetea* class and the *Fagetalia sylvaticae* order. Generally, eutrophic deciduous forests encompass a very broad spatial range in Europe. It covers the area from Atlantic Ocean in the west to Ural Mountains in the east and from the southern border of boreal coniferous forests in the north to Mediterranean and steppe zones in the south. Eutrophic deciduous forests play an important role

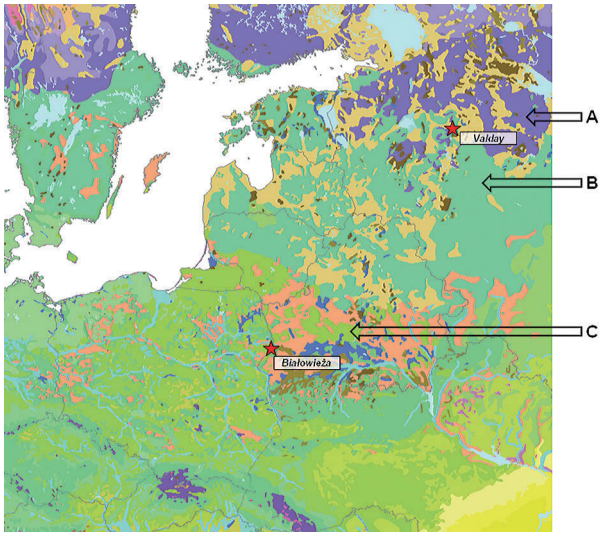

Fig. 1. Location of the studied forest complexes: Białowieża Forest and Valday National Park on the Map of the Natural Vegetation of Europe (2004)
A – Southern boreal coniferous and mixed broad-leaved-coniferous forests; Scandinavian-east European spruce forests partly with *Tilia cordata* and *Corylus avellana*, with herbs, dwarf shrubs and mosses.
B – Hemiboreal spruce forests with broad-leaved trees; Baltic-northwest Sarmatian herb-rich mixed broad-leaved-spruce forests (*Picea abies*, *Tilia cordata*, *Acer platanoides*, *Quercus robur*) with *Corylus avellana*, *Euonymus verrucosa*, *Galeobdolon luteum*, *Stellaria holostea.*
C – Mesophytic deciduous broad-leaved and mixed coniferous-broad-leaved forests; Mixed oak-hornbeam forests (*Carpinus betulus*, *Quercus robur*, *Q. petraea*, *Tilia cordata*)

in the vegetation of central Europe and of Poland as well. They have zonal character and constitute a climax type of natural community (potential natural vegetation). However, in Eastern Europe, especially in hemi-boreal zone they are not widespread, mainly due to human pressure.

Białowieża Forest is a complex of ancient forest (Peterken 1977, Rackham 1980). It has not been deforested since ages due to game objectives, especially in the area of Białowieski National Park. Białowieża Forest is regarded as nearly natural community with primeval forest characteristics. The lime-oak-hornbeam forest of *Tilio-Carpinetum* association belonging to the *Carpinion betuli* alliance (o. *Fagetalia sylvaticae,* c. *Querco-Fagetea)* is the most common type of natural community in Białowieża Forest. Almost all species characteristic of the alliance with hornbeam *Carpinus betulus* ahead can be found there. The lime-oak-hornbeam forests in BF have been phytosociologically and ecologically examined in detail. It is probably the best known type of lowland forest in Europe and can serve as a benchmark for the similar forest communities in the continent. First research of the lime-oak-hornbeam forests was carried out in 1920s by Józef Paczoski (pioneer of Polish phytosociology), then in 1940s by Matuszkiewicz (1952) and later by others: Sokołowski (1993), Faliński (1995), Matuszkiewicz et al. (2007). They left a very rich collection of phytosociological relevés. The *Tilio-Carpinetum* association in BF shows a great habitat diversity and therefore can be divided into several subassociations. The most important are: *Tilio-Carpinetum calamagrostietosum* on poor sandy-clay soils, *T.-C. typicum* on rich, fresh clay soils, *T.-C. stachyetosum* on moist clay soils and *T.-C. melittetosum* with significant share of light-demanding species. First three mentioned subassociations have been quite stable for last 50 years (Matuszkiewicz 2007, 2011) that indicates their natural character and a lack of human impacts. Instead, the subassociation with *Melittis melissophyllum* has been declined since 1960s and is very rare at present. The thinned stand with pine and light-demanding species from grasslands and oak forests in the herb layer clearly indicate anthropogenic or zoo-anthropogenic origin.

Contrary to BF, the forests ecosystems in Valday National Park (Russia) have been not care-

fully examined. They are located on the north-east edge of hemi-boreal spruce forests with broad-leaved trees (*Quercus robur* L., *Tilia cordata* Mill., *Ulmus glabra* Huds., *Acer platanoides* L.) bordering on the east with southern boreal type of mesophytic and hygromesophytic coniferous and mixed broad-leaved-coniferous forests (Map of the natural vegetation of Europe, 2004). They are located far away from the east border of hornbeam range therefore can hardly be classified to the *Carpinion betuli* alliance. Moreover, they have been put under intense human pressure inter alia selective tree cutting (valuable species like oak and lime; Korotkov 1991, Nikonov 2003; Tishkov 2014). The forest stands situated on clay soils of end moraines are dominated by oak with other species in addition. Similarly to BF, oak forests in Valday show habitat diversity and can be divided into three types: poor with *Calamagrostis arundinacea, Vaccinium myrtillus* and other acidophilus species, typical on rich habitats and moist type. Their species richness is also comparable: about 40 herbs and ground moss species. The oak forests in Valday can be classified as a phytocenon belonging to the *Querco-Fagetea* class and the *Fagetalia sylvaticae* order but their affiliation to an alliance or an association is ambiguous. It can be ascertain that they represent East European association of *Trollio-Quercetum* described by Korotkov (1991) belonging to *Querco-Fagetea.* The studied forest complex is moderately deformed with thinned stand and open habitat species. It is uncommon in Valday region dominated by spruce communities.

Materials and methods

The analysis of plant species composition was based on phytosociological relevés collected in accordance with the Braun-Blanquet methodology (1964). The data set consisted of 503 relevés from BF, situated in the national park (Matuszkiewicz 1952, Sokołowski 1993, Faliński 1995, Matuszkiewicz 2007). The 6 relevés from Valday National Park (Russia) were collected in July 2013, in plots situated within a radius of 1–2 km, in the west part of the park. Their characteristics, therefore, can be a bit accidental.

To explore differences in plant species composition across the studied forest complexes, species frequency was calculated for the indentified forest associations. In BF, forests were divided into 4 subassociations or were calculated together like in Valday NP. To compensate the great discrepancy in the number of relevés between the forest complexes, all species absent in Valday NP and present in less than 1/6 of relevés in BF were skipped.

The species affiliation to syntaxonomic units (acc. to Matuszkiewicz 2001, Zając, Zając 2009) and geographical elements (Zając, Zając 2009) was determined. The species presence in the regions was ascertained with the floristic sources (BF – Zając, Zając 2001; V – Morozova et al. 2010). The analysis concerned only vascular plant species; moss species were skipped because they are not classified regarding geographical elements.

The calculations of the species frequency in groups characteristic of various syntaxonomic units provided results of so-called systematic group values for:

- typical lime-oak-hornbeam forests of *Carpinion betuli* alliance,
- other eutrophic deciduous forests of *Querco-Fagetea* class,
- pine forests of *Vaccinio-Piceetea* class, and
- other syntaxonomic units.

Biogeographical analysis was carried out on plant species lists in two forest complexes (BF – all subassociations together) without taking into account species frequency. The share of geographical elements and sub-elements (Zając, Zając 2009) was calculated in the forest plant composition.

The climatic conditions of the studied regions were investigated comparing thermal (mean month temperature) and pluvial (total month precipitation) data, according to Chomicz (1977) and Spravochnik po klimatu SSSR (1965; 1968). To quantify climate influence on deciduous forest vegetation two pluvio-thermal indicators were calculated, proposed by Ellenberg (1978) – (1) and Matuszkiewicz (2001) – (2):

$$\text{PTI-E} = t_{VII}/P_{ann} \times 1000 \quad (1)$$

where t_{VII} is mean temperature in July, P_{ann} mean annual precipitation,

$$PTI\text{-}M = (P_V/3 - t_V)+(P_{VI}/3 - t_{VI})\ (P_{VII}/3 - t_{VII})\ (P_{VIII}/3 - t_{VIII})\ (P_{IX}/3 - t_{IX}) \quad (2)$$

where $P_{V..IX}$ is total mean precipitation in May to September, $t_{V...IX}$ mean temperature in May to September.

Originally, they were applied to indicate the climate conditions favourable for beech in Central Europe. This is fulfilled when *PTI-E* is lower than 30 and *PTI-M* is higher than 35.

Results

Analysis of differences in characteristic species frequency

The frequency of vascular plant species characteristic of the respective syntaxonomic units is presented in Table 1. The most important for the studied forest complexes are two classes aggregating eutrophic deciduous forests – *Querco-Fagetea* class and coniferous forests – *Vaccinio-Piceetea* class. A significant part of the plant composition in the studied forests consists of species characteristic of the *Querco-Fagetea* class. Their total frequency in BF in subassociations of *Tilio-Carpinetum calamagrostietosum* and *T.-C. melittetosum* amounts about 45% and in *T.-C. typicum* and *T.-C. stachyetosum* 67–68%. In Valday total frequency of these species is only slightly lower than in the poorer subassociations of BF.

The share of species characteristic of the whole *Querco-Fagetea* class is similar in BF (in all subassociations) and Valday and amounts 15–20% of the species composition (Fig. 2). The species characteristic of the *Fagetalia sylvaticae* order are more diverse. In poorer subassociations of BF these species amount 12–16% and even 30% in rich subassociations. Comparing BF and Valday NP, this difference is smaller, a few percent in favour of BF.

The obtained results confirm that the forests complex in Valday NP can be classified to the *Querco-Fagetea* class and the *Fagetalia sylvaticae* order despite distant border of the beech *Fagus sylvatica* range which name is included in the class and order names.

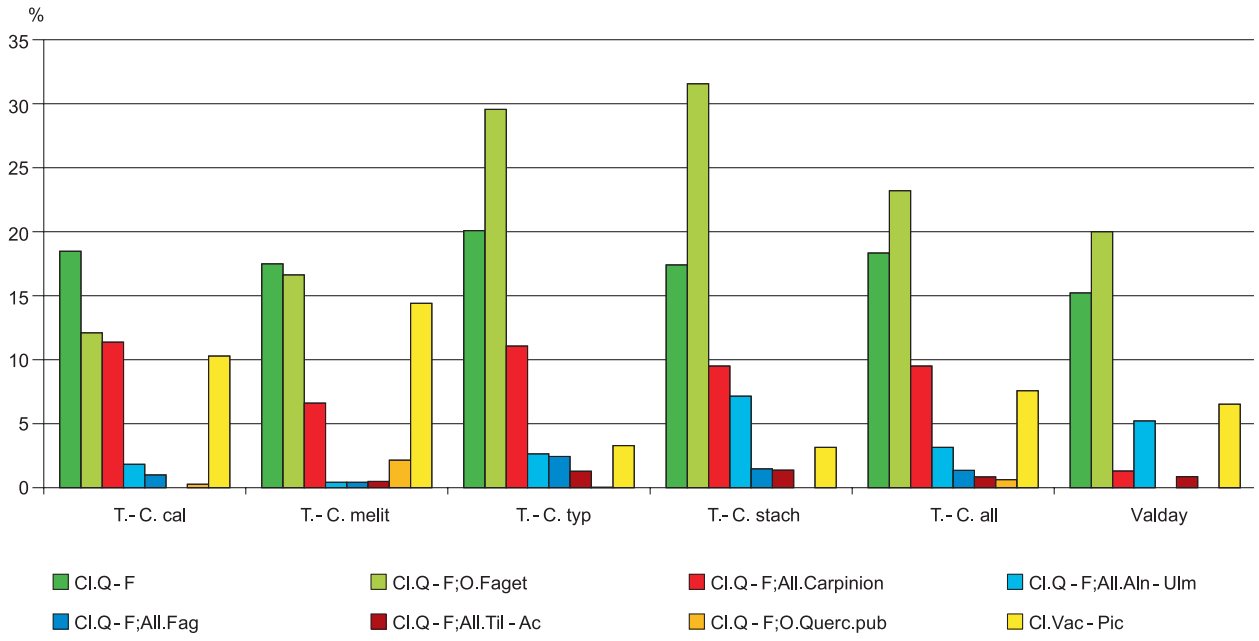

Fig. 2. Total frequency of vascular species characteristic of two phytosociological classes in the studied forest complexes
Cl.Q-F – species characteristic of *Querco-Fagetea* class
Cl.Q-F;O.Faget – species characteristic of *Fagetalia sylvatici* order
Cl.Q-F;All.Carpinion – species characteristic of *Carpinion betuli* alliance
Cl.Q-F;All.Aln-Ulm – species characteristic of *Alno-Ulmion* alliance
Cl.Q-F;All.Fag – species characteristic of *Fagion* alliance
Cl.Q-F;All.Til-Ac – species characteristic of *Tilio-Acerion* alliance
Cl.Q-F;O.Querc.pub – species characteristic of *Quercetalia pubescenti* order
Cl.Vac-Pic – species characteristic of *Vaccinio-Piceetea* class

Only one from four species characteristic of the *Carpinion betuli* alliance frequent in BF was noticed in Valday, namely: *Stellaria holostea.* The *Tilia cordata* and *Carex pilosa* although present in the region, were not observed in the studied forests, probably because of anthropogenic pressure. The *Carpinus betulus* is not present in the regional flora of Valday NP. The absence of this species raises doubts if forests in Valday NP can be classified like in BF to the *Carpinion betuli* alliance. The Figure 2 shows that the share of species characteristic of this alliance is there definitely smaller than in Białowieża Forest.

Species characteristic of other syntaxonomic units, included in the *Querco-Fagetea* class are less important. However, there is a significant share of species characteristic of *Alno-Ulmion* alliance in Valday NP forests. They resemble moist subassociations in BF. There is also a slight share of species characteristic of *Fagion* alliance in BF that are not recorded in Valday.

Differences in the share of species characteristic of the *Vaccinio-Piceetea* class divide poor and rich subassociations in BF (bigger and smaller share respectively). There is not such a difference between BF and Valday although the forest complex in Valday NP is located near the boreal coniferous forest zone.

Based on the obtained results the forest complex in Valday cannot be unambiguously classified to the *Carpinion betuli* alliance but it cannot be precluded. Furthermore, it seems there is not an alternative possibility – another alliance. In that case, forests in Valday should be classified as a borderland form of eutrophic deciduous forests of the *Carpinion betuli* alliance. The absence of *Carpinus betulus* is not so important alike in case of *Fagus sylvatica* absence for the classification of the *Querco-Fagetea* class and the *Fagetalia sylvaticae* order.

The share of species characteristic of open habitats amounts 6–7% in BF and three times as much (over 22%) in Valday NP (Fig. 3). In the BF, the species characteristic of *Epilobietea angustifoliae* (clearings communities), *Artemisietea* (ruderal and forest fringe communities), and *Trifolio-Geranietea* (thermophilous tall herbs communities) are the most frequent. All these species groups are integrally related to forest habitats. Their presence is associated with forest ageing and occur-

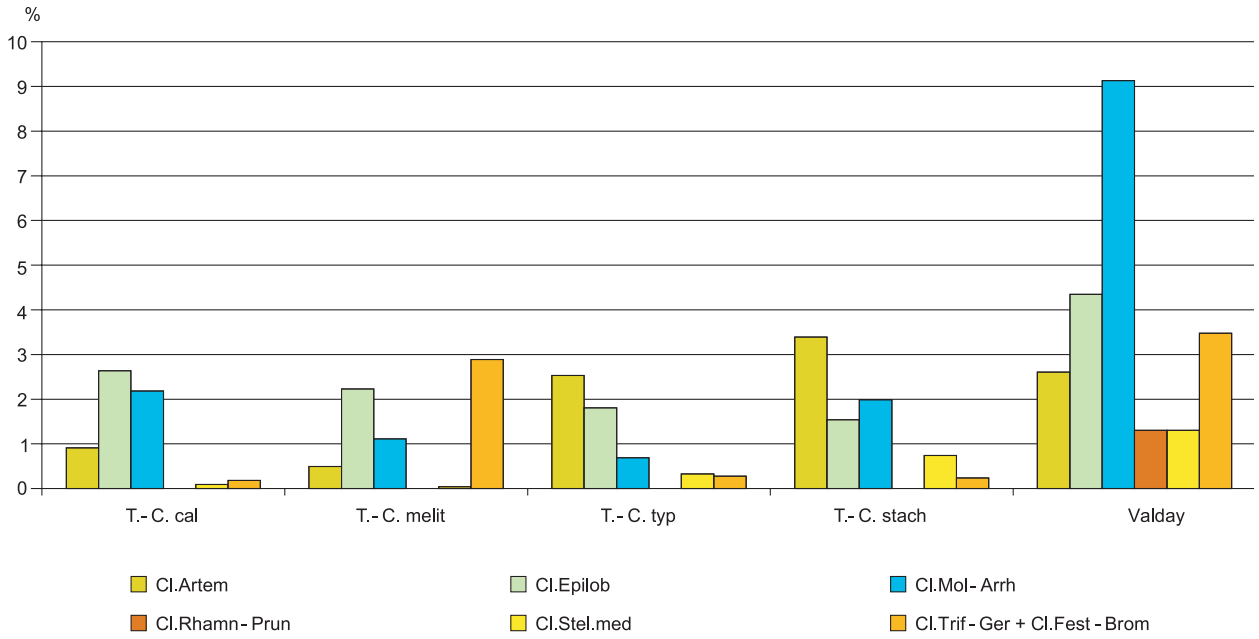

Fig. 3. Total frequency of vascular species characteristic of open habitats in the studied forest complexes
Cl.Artem – species characteristic of *Artemisietea* class (ruderal and forest fringe communities)
Cl.Epilob – species characteristic of *Epilobietea angustifolii* class (clearings communities)
Cl.Mol-Arrh – species characteristic of *Molinio-Arrhenatheretea* class (grassland communities)
Cl.Rhamn-Prun – species characteristic of *Rhamno-Prunetea* class (shrub communities)
Cl.Stel.med – species characteristic of *Stellarietea mediae* class (segetal and ruderal communities)
Cl.Trif-Ger + Cl.Fest-Brom – species characteristic of *Trifolio-Geranietea* and *Festuco-Brometea* classes (thermophilous tall herbs and grassland communities)

Table 1. The comparison of vascular plant species composition of eutrophic deciduous forests in Białowieża Forest and Valday; all species absent in Valday and present in less than 1/6 of relevés in BF were skipped

Species name	Syntaxonomical affiliation	Geographical element	Species presence in the flora of NE Poland	Species presence in the flora of Valday	Białowieża T.-C. calamagrostietosum [f%]	Białowieża T.-C. melitetosum [f%]	Białowieża T.-C. typicum [f%]	Białowieża T.-C. stachyetosum [f%]	Białowieża T.-C. all subassociations [f%]	Valday – Ass. ? (calamagrostietosum – typicum – stachyetosum)
Species characteristic of Carpinion betuli alliance										
Stellaria holostea	Cl.Q-F;All.Carpinion	sa-ES(w)-M(n, e)	+	+	82.2	37.3	95.7	92.4	76.9	50.0
Tilia cordata	Cl.Q-F;All.Carpinion	sa-ES(w)	+	+	71.1	73.3	81.1	89.4	78.7	
Carex pilosa	Cl.Q-F;All.Carpinion	CE	+	+	31.1	5.3	71.4	47.0	38.7	
Carpinus betulus	Cl.Q-F;All.Carpinion	CE-M(n)	+		93.3	97.3	99.5	95.5	96.4	
Species characteristic of Querco-Fagetea class										
Viola reichenbachiana	Cl.Q-F;O.Faget	CE(w)-M(n)	+		26.7	74.7	78.4	76.8	64.1	
Ranunculus lanuginosus	Cl.Q-F;O.Faget	CE-M(n)	+		2.2	12.0	53.5	65.2	33.2	
Dentaria bulbifera	Cl.Q-F;All.Fag	CE: ce-b	+		6.7	10.7	54.1	41.4	28.2	
Carex remota	Cl.Q-F;All.Aln-Ulm	sa-CE-M-IR(m)	+		15.6		19.5	51.0	21.5	
Sanicula europaea	Cl.Q-F;O.Faget	CE-M-IR(w)	+			17.3	28.1	34.3	19.9	
Melittis melissophyllum	Cl.Q-F;O.Querc.pub	CE(s, w)-M(n)	+		6.7	69.3	1.1	0.0	19.3	
Festuca altissima	Cl.Q-F;All.Fag	CE: a-ne	+		17.8	2.7	22.7	8.6	12.9	
Isopyrum thalictroides	Cl.Q-F;O.Faget	CE	+				5.4	27.3	8.2	
Circaea lutetiana	Cl.Q-F;All.Aln-Ulm	sa-CE-M-IR(w, m)	+				2.2	21.7	6.0	
Galium odoratum	Cl.Q-F;O.Faget	sa-ES(d)-M(n)-IR(w)	+	+	26.7	60.0	83.2	74.2	61.0	
Fraxinus excelsior	Cl.Q-F	sa-CE-M(n)-IR(w)	+	+	40.0	30.7	55.7	61.6	47.0	
Mycelis muralis	Cl.Q-F;O.Faget *	CE	+	+	24.4	29.3	24.3	16.2	23.6	
Stellaria nemorum	Cl.Q-F;All.Aln-Ulm	CE-M(n)	+	+	4.4	2.7	22.7	56.6	21.6	
Lilium martagon	Cl.Q-F;O.Faget	ES	+	+	11.1	29.3	1.1	0.0	10.4	
Ulmus glabra	Cl.Q-F;All.Til-Ac	sa-CE-M(n)	+	+		13.3	27.0	39.9	20.1	
Adoxa moschatellina	Cl.Q-F;O.Faget	CB(d)	+	+			9.7	25.3	8.7	
Lathraea squamaria	Cl.Q-F	CE	+	+	4.4		22.7	22.7	12.5	
Corydalis solida	Cl.Q-F;O.Faget	ES-M(n)	+	+			5.9	17.7	5.9	
Ficaria verna	Cl.Q-F;O.Faget	sa-CE-M(?)	+	+			10.3	44.9	13.8	
Anemone ranunculoides	Cl.Q-F;O.Faget	CE	+	+			1.6	17.2	4.7	
Chrysosplenium alternifolium	Cl.Q-F;All.Aln-Ulm	ES	+	+			4.9	26.8	7.9	
Gagea lutea	Cl.Q-F;All.Aln-Ulm	ES(d)	+	+			2.7	22.2	6.2	
Carex digitata	Cl.Q-F	ES(w)	+	+	48.9	88.0	62.7	47.0	61.6	16.7
Polygonatum multiflorum	Cl.Q-F;O.Faget	sa-CE-M(n)-IR(m)	+	+	15.6	5.3	67.0	63.6	37.9	16.7
Milium effusum	Cl.Q-F;O.Faget	CB(d)	+	+	53.3	78.7	82.7	79.3	73.5	33.3

Species name	Syntaxonomical affiliation	Geographical element	Species presence in the flora of NE Poland	Species presence in the flora of Valday	Białowieża T.-C. calamagrostietosum [f%]	Białowieża T.-C. melitetosum [f%]	Białowieża T.-C. typicum [f%]	Białowieża T.-C. stachyetosum [f%]	Białowieża T.-C. all subassociations [f%]	Valday – Ass. ? (calamagrostietosum – typicum – stachyetosum)
Melica nutans	Cl.Q-F	ES(d)	+	+	13.3	64.0	4.9	3.0	21.3	16.7
Anemone nemorosa	Cl.Q-F	sa-ES(d)	+	+	95.6	57.3	81.6	77.3	77.9	50.0
Acer platanoides	Cl.Q-F	CE-M(m)	+	+	82.2	80.0	85.9	90.4	84.6	50.0
Lathyrus vernus	Cl.Q-F;O.Faget	ES	+	+	6.7	49.3	54.6	50.5	40.3	16.7
Impatiens noli-tangere	Cl.Q-F;O.Faget	CB(d)	+	+	24.4		41.1	53.0	29.6	16.7
Galeobdolon luteum	Cl.Q-F;O.Faget	CE: ece	+	+	33.3	30.7	94.1	97.5	63.9	66.7
Athyrium filix-femina	Cl.Q-F;O.Faget *	CB	+	+	31.1	12.0	45.9	74.2	40.8	50.0
Festuca gigantea	Cl.Q-F;All.Aln-Ulm	sa-ES(w)-IR(m)	+	+	4.4	6.7	17.8	39.9	17.2	16.7
Dryopteris filix-mas	Cl.Q-F;O.Faget	CB(d)	+	+	2.2	6.7	46.5	52.0	26.8	33.3
Moehringia trinervia	Cl.Q-F *	sa-ES-M(n)-IR(m)	+	+	48.9	42.7	37.8	39.4	42.2	33.3
Corylus avellana	Cl.Q-F	sa-CE-M(n)-IR(w)	+	+	68.9	52.0	81.6	74.2	69.2	66.7
Ajuga reptans	Cl.Q-F *	sa-CE-M(n)	+	+	15.6	76.0	42.2	44.9	44.7	66.7
Circaea alpina	Cl.Q-F;All.Aln-Ulm	CB: c-b-w	+	+	20.0	4.0	13.0	22.2	14.8	16.7
Paris quadrifolia	Cl.Q-F;O.Faget	sa-ES	+	+	2.2	16.0	51.4	47.0	29.1	50.0
Daphne mezereum	Cl.Q-F;O.Faget	ES(w)	+	+	15.6	82.7	37.8	18.7	38.7	83.3
Hepatica nobilis	Cl.Q-F	ES(d)	+	+	22.2	70.7	76.8	61.1	57.7	83.3
Carex sylvatica	Cl.Q-F;O.Faget	sa-CE-M(n)	+	+		2.7	8.1	26.3	9.3	33.3
Aegopodium podagraria	Cl.Q-F	sa-ES(w)	+	+	6.7	4.0	75.1	68.7	38.6	83.3
Stachys sylvatica	Cl.Q-F;O.Faget	sa-ES(w)-M(n)-IR(n)	+	+			18.4	38.9	14.3	50.0
Poa nemoralis	Cl.Q-F	sa-ES-M-IR	+	+	4.4		3.2	1.0	2.2	16.7
Campanula trachelium	Cl.Q-F	sa-ES(w)-M	+	+			1.1	2.0	0.8	16.7
Actaea spicata	Cl.Q-F;All.Til-Ac	CE	+	+		2.7	13.5	7.1	5.8	33.3
Asarum europaeum	Cl.Q-F;O.Faget	CE-M(n)	+	+			42.2	39.4	20.4	66.7
Ranunculus cassubicus	Cl.Q-F;O.Faget	CE(e)	+	+			2.2	13.6	3.9	50.0
Viola riviniana	Cl.Q-F;O.Faget *	sa-CE-M	+	+	17.8	25.3	14.1	0.5	14.4	66.7
Pulmonaria obscura	Cl.Q-F;O.Faget	CE	+	+	2.2	4.0	19.5	13.6	9.8	66.7
Mercurialis perennis	Cl.Q-F;O.Faget	za-CE-M(n)	+	+		1.3	1.6	8.6	2.9	66.7
Padus avium	Cl.Q-F;All.Aln-Ulm	ES	+	+			0.5	3.0	0.9	100.0
Lonicera xylosteum	Cl.Q-F	ES(w)	+	+						83.3
Ulmus laevis	Cl.Q-F;All.Aln-Ulm *	CE: c(e)-b	+	+						33.3
Alnus incana	Cl.Q-F;All.Aln-Ulm	A-A: a-a-es		+						33.3
Species characteristic of Vaccinio-Piceetea class										
Picea abies	Cl.Vac-Pic	CE: a-ne	+	+	100.0	98.7	92.4	97.0	97.0	83.3

Species name	Syntaxonomical affiliation	Geographical element	Species presence in the flora of NE Poland	Species presence in the flora of Valday	Białowieża T.-C. calamagrostietosum [f%]	Białowieża T.-C. melitetosum [f%]	Białowieża T.-C. typicum [f%]	Białowieża T.-C. stachyetosum [f%]	Białowieża T.-C. all subassociations [f%]	Valday – Ass. ? (calamagrostietosum – typicum – stachyetosum)
Vaccinium myrtillus	Cl.Vac-Pic	sa-ES	+	+	66.7	92.0	1.1	3.0	40.7	33.3
Trientalis europaea	Cl.Vac-Pic	ES	+	+	68.9	60.0	5.9	5.1	35.0	33.3
Pinus sylvestris	Cl.Vac-Pic	ES	+	+	8.9	72.0	0.5	0.0	20.4	16.7
Orthilia secunda	Cl.Vac-Pic	CB	+	+	4.4	61.3		2.0	16.9	16.7
Vaccinium vitis-idaea	Cl.Vac-Pic	CB	+	+	2.2	33.3			8.9	33.3
Pyrola rotundifolia	Cl.Vac-Pic	CB(d)	+	+		9.3			2.3	16.7
Melampyrum pratense	Cl.Vac-Pic	sa-ES(w)	+	+		1.3			0.3	16.7
Goodyera repens	Cl.Vac-Pic	CB: c-b-w	+	+		17.3			4.3	
Monotropa hypopitys	Cl.Vac-Pic	CB(d)	+			20.0	3.2		5.8	
		Other species								
Carex montana		CE: ce(e)-b	+			38.7			9.7	
Serratula tinctoria	Cl.Mol-Arrh	sa-CE-M(n)	+			20.0			5.0	
Dryopteris dilatata		sa-CE	+		37.8		18.9	11.6	17.1	
Veronica officinalis	Cl.Nard-Cal	ES	+	+		28.0	2.2	1.5	7.9	
Gymnocarpium dryopteris		CB	+	+	46.7	6.7	62.2	60.1	43.9	
Glechoma hederacea	Cl.Artem	sa-ES-M(n, w)	+	+			7.0	18.7	6.4	
Polygonatum odoratum	Cl.Trif-Ger	ES	+	+		45.3	1.1	0.0	11.6	
Lapsana communis	Cl.Stel.med	sa-CE-M(n)	+	+	2.2	1.3	9.7	21.2	8.6	
Equisetum pratense		CB	+	+	4.4		56.8	68.7	32.5	
Geranium robertianum		sa-CE-M-IR	+	+	6.7	9.3	32.4	51.5	25.0	
Rubus saxatilis		ES	+	+	33.3	90.7	34.1	13.6	42.9	66.7
Pteridium aquilinum		cosmop	+	+	24.4	53.3	2.7	0.0	20.1	33.3
Convallaria majalis		sa-ES(d, w)	+	+	24.4	84.0	9.2	0.5	29.5	66.7
Luzula pilosa		sa-ES	+	+	40.0	84.0	27.6	26.8	44.6	66.7
Betula pendula		sa-ES	+	+	8.9	66.7	9.2	7.1	23.0	66.7
Veronica chamaedrys	Cl.Trif-Ger *	sa-ES-M(n)	+	+	2.2	33.3	7.0	7.1	12.4	50.0
Malus sylvestris		sa-CE-M	+	+	15.6	25.3	5.9	6.6	13.4	50.0
Vicia sepium	Cl.Trif-Ger	sa-ES-IR(m)	+	+	2.2	14.7	0.5	1.0	4.6	50.0
Fragaria vesca	Cl.Epilob	CB	+	+		37.3	13.0	6.1	14.1	100.0
Maianthemum bifolium		ES	+	+	93.3	98.7	97.3	88.4	94.4	16.7
Calamagrostis arundinacea		ES	+	+	95.6	100.0	42.7	26.3	66.1	33.3
Oxalis acetosella		sa-ES	+	+	100.0	96.0	96.2	96.5	97.2	33.3
Dryopteris carthusiana		CB(d)	+	+	93.3	48.0	80.0	88.9	77.6	50.0

Species name	Syntaxonomical affiliation	Geographical element	Species presence in the flora of NE Poland	Species presence in the flora of Valday	Białowieża T.-C. calamagrostietosum [f%]	Białowieża T.-C. melitetosum [f%]	Białowieża T.-C. typicum [f%]	Białowieża T.-C. stachyetosum [f%]	Białowieża T.-C. all subassociations [f%]	Valday – Ass. ? (calamagrostietosum – typicum – stachyetosum)
Urtica dioica	Cl.Artem	ES-M-IR-Asia E	+	+	22.2	16.0	53.0	60.6	38.0	33.3
Quercus robur		sa-CE-M(n)	+	+	82.2	89.3	66.5	52.0	72.5	66.7
Rubus idaeus	Cl.Epilob	CB	+	+	64.4	34.7	43.8	46.5	47.3	66.7
Sorbus aucuparia		sa-CE	+	+	97.8	76.0	51.9	44.9	67.7	100.0
Deschampsia caespitosa	Cl.Mol-Arrh	ES-IR-Asia SE	+	+	22.2	2.7	15.7	47.5	22.0	50.0
Solidago virgaurea		sa-ES	+	+	28.9	44.0	5.4	5.1	20.8	50.0
Molinia caerulea	Cl.Mol-Arrh	sa-CE	+	+	4.4	5.3		0.5	2.6	16.7
Dactylis glomerata	Cl.Mol-Arrh	sa-ES(d)-M-IR	+	+	2.2	1.3	3.8	3.0	2.6	16.7
Agrostis capillaris	Cl.Mol-Arrh *	sa-ES-M(n)	+	+		2.7			0.7	16.7
Populus tremula		sa-ES-M-IR-Azja E	+	+	35.6	52.0	12.4	9.6	27.4	66.7
Trollius europaeus	Cl.Mol-Arrh	ES(w)	+	+		1.3			0.3	16.7
Frangula alnus		sa-ES(w)	+	+	11.1	17.3	3.2	2.0	8.4	33.3
Crepis paludosa	Cl.Mol-Arrh	CE	+	+			1.6	10.1	2.9	33.3
Geum urbanum	Cl.Artem	sa-ES(w)-M-IR(m)	+	+			19.5	36.4	14.0	66.7
Equisetum sylvaticum		CB	+	+	46.7		20.0	30.8	24.4	83.3
Lysimachia vulgaris	Cl.Mol-Arrh	sa-ES-M(n)-IR(m)	+	+	24.4		0.5	6.6	7.9	66.7
Stellaria media	Cl.Stel.med	cosmop	+	+			0.5	4.0	1.1	50.0
Melampyrum nemorosum		CE: ece	+	+	2.2	8.0		0.0	2.6	66.7
Galeopsis tetrahit		sa-CE	+	+	15.6	4.0	16.2	5.6	10.3	83.3
Angelica sylvestris	Cl.Mol-Arrh	sa-ES	+	+		2.7			0.7	83.3
Hypericum perforatum		sa-ES(w)-M-IR	+	+						33.3
Knautia arvensis	Cl.Mol-Arrh	sa-ES(w)-M	+	+						50.0
Dactylorhiza fuchsii		ES(w) [?]	+	+						16.7
Galium album ?	Cl.Fest-Brom	sa-CE-M(n)	?	+						33.3
Rosa majalis	Cl.Rhamn-Prun *	ES(w, n)		+						50.0
Aconitum septentrionale		?		+						16.7
Number of relevés					45	75	185	198		6
Average number of species in the relevé					31.2	39.7	36.2	40.5		40.2

rence of gaps caused by trees throw. Their slight share in forests corresponds with the model of natural deciduous forest. In Valday NP, besides above mentioned groups, species of *Molinio-Arrhenatheretea* class (grassland communities) are quite frequent. This indicates past anthropogenic pressure – livestock grazing resulting in grassland species dispersal. These effects are in line with the observations of many forests in Poland (Matuszkiewicz et al. 2007).

Analysis of biogeographical differences in plant species composition

Biogeographical characteristics of plant species composition in the studied forest complexes is presented in Figure 4. Geographical sub-elements were assigned to all vascular plant species. The majority of plant species composition in both complexes belongs to Holarctic element (58% in BF and 63% in Valday). A significant part of species constitutes connective Holarctic-Mediterranean or Holarctic Irano-Turanian elements. European-temperate sub-element and connective elements: European-temperate-Mediterranean and European-temperate-Mediterranean-Irano-Turanian are more frequent in BF (together 41% in BF and 27% in Valday), while Euro-Siberian sub-element and connective Euro-Siberian-Mediterranean-Irano-Turanian element are more frequent in Valday (54%). Circum-Boreal sub-element has similar share in both regions (15%) while cosmopolitan element is rare in both regions. The Arctic-Alpine sub-element is only present in Valday NP.

Summing up, both forest complexes are quite similar, although, due to forests location there are more European-temperate sub-elements in BF and Euro-Siberian sub-elements in Valday NP. Through their biogeographical similarity, the studied forests can be regarded as two vicarious units within *Carpinion betuli* alliance.

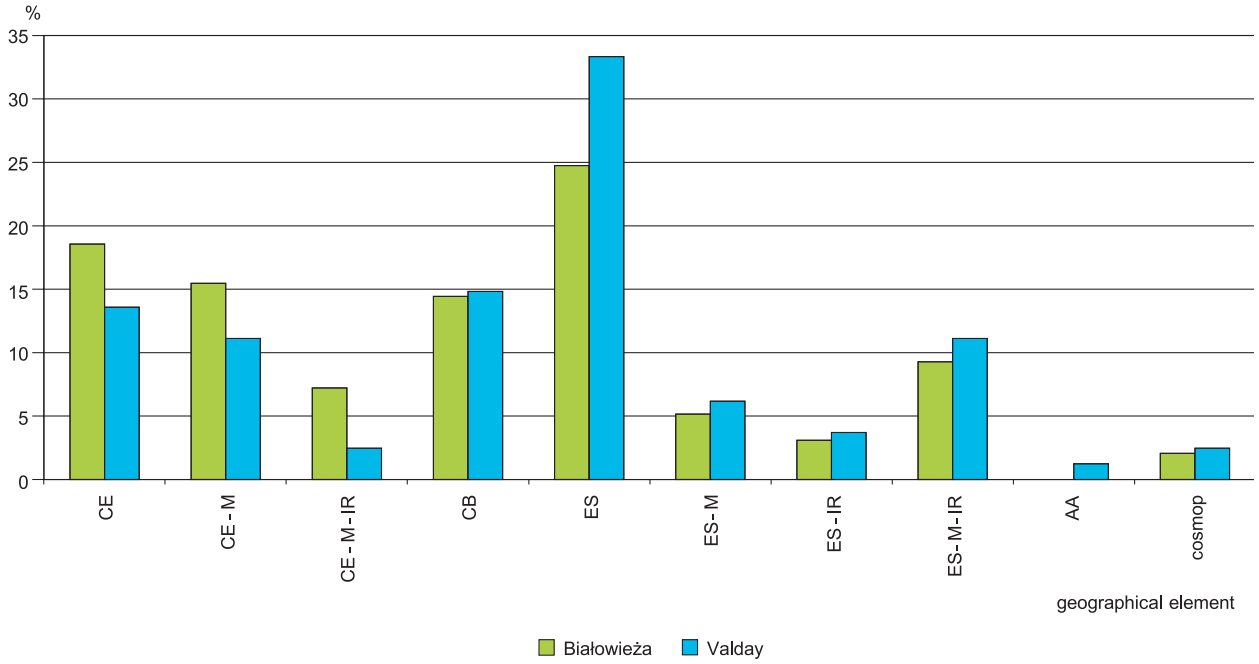

Fig. 4. Biogeographical characteristics of flora in studied forest complexes. Geographical elements and sub-elements acc. to Zając, Zając (2009)
CE – Holarctic element; European-temperate sub-element
CE-M – Conective element: European-temperate – Mediterranean
CE-M-IR – Conective element: European-temperate – Mediterranean – Irano-Turanian
CB – Holarctic element; Circum-Boreal sub-element
ES – Holarctic element; Euro-Siberian sub-element
ES-M – Conective element: Euro-Siberian – Mediterranean
ES-IR – Conective element: Euro-Siberian – Irano-Turanian
ES-M-IR – Conective element: Euro-Siberian – Mediterranean – Irano-Turanian
AA – Holarctic element; Arctic-Alpine sub-element
cosmop – Cosmopolitan element

Analysis of differences in climatic conditions

The differences between the studied regions are highly visible in the climatic conditions (Table 2). Mean annual temperature in Valday NP is 3°C lower than in Białowieża Forest what is mainly caused by cooler winter months. The differences in mean month temperatures in winter exceed 5°C. In contrast, the mean temperatures of summer months are quite similar, the mean temperature in July is only 1°C lower in Valday NP than in Białowieża Forest. The annual temperature amplitude is significantly higher in Valday NP than in BF what indicates the climate continentality.

Annual precipitation is generally higher in Valday NP. Average month precipitation is about 30% higher in this region but it changes during a year. However, in May, mean month precipitation is higher in Białowieża.

The pluvio-thermal indicators show that climatic conditions are even more favourable for beech habitats in Valday NP than in Białowieża Forest. The question is how this species would adapt to thermal conditions of winter season. The actual range of beech is distant form Białowieża Forest and Valday NP but it seems that their climatic conditions are adequate for plant species adapted to temperate cool and humid climate.

The climate conditions of Valday are more severe and continental in temperature but also

Table 2. The climatic conditions of the studied regions

Name of the station		Białowieża	Valday	Difference (V-B)
Latitude		52° 42′	57° 58′	5° 16′
Longitude		23° 51′	33° 17′	9° 26′
Altitude m a.s.l.		164	201	37
Mean month precipitation	annual	600	828	228
	I	34	56	22
	II	36	49	13
	III	31	52	21
	IV	45	55	10
	V	62	58	–4
	VI	70	85	15
	VII	70	92	22
	VIII	68	89	21
	IX	52	85	33
	X	42	72	30
	XI	50	71	21
	XII	40	64	24
	average	50	69	19
Mean month temperature	annual	6.4	3.2	–3.2
	I	–4.3	–9.6	–5.3
	II	–5.0	–9.4	–4.4
	III	–1.4	–5.0	–3.6
	IV	6.3	2.8	–3.5
	V	11.9	9.9	–2.0
	VI	16.5	14.2	–2.3
	VII	17.7	16.6	–1.1
	VIII	16.5	14.8	–1.7
	IX	12.0	9.6	–2.4
	X	7.1	3.4	–3.7
	XI	1.9	–2.2	–4.1
	XII	–2.0	–7.2	–5.2
	amplitude	22.7	26.2	3.5
Pluvio-thermal indicators	PTI-E	29.5	20.0	–9.5
	PTI-M	32.7	71.2	38.5

more humid than those in Białowieża Forest. However, the climatic differences during vegetation period, important for deciduous trees and many herbs, are significantly smaller. Therefore, similar vegetation communities can appear in both regions.

Conclusions

Eutrophic deciduous forests with plant species composition close to East-European forests of nemoral zone are also observed in hemi-boreal zone, even near its border with boreal coniferous forests. According to their geobotanical characteristics they can be classified to the *Querco-Fagetea* class and the *Fagetalia sylvaticae* order or even with some restrictions to the *Capinion betuli* alliance. This is possible due to similar (to Central European) climatic conditions in summer, despite considerable differences in winter season.

Rarity of eutrophic deciduous forests in Valday NP results probably from their stands degradation and deforestation, especially during strong agricultural pressure in the past. If this hypothesis proves to be true, the studied forest type can be important type of potential natural vegetation in the region.

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