ORIGINAL RESEARCH ARTICLE

Vegetation diversity of the Scots pine stands in different forest sites in the Turawa Forest District

Ewa Stefańska-Krzaczek[1*], Paweł Pech[2]

University of Wrocław, Faculty of Biological Sciences, [1] Institute of Environmental Biology, Department of Botany, Laboratory of Vegetation Ecology, [2] Department of Ecology, Biogeochemistry and Environmental Protection, ul. Kanonia 6/8, 50–328 Wrocław, Poland.

*Tel. +48 71 3754084, e-mail: ewa.stefanska-krzaczek@uni.wroc.pl

Abstract. The utility of phytocenotic indices in the diagnosis and classification of forest sites might be limited because of vegetation degeneration in managed forests. However, even in secondary communities it may be possible to determine indicator species, although these may differ from typical and well known plant indicators.

The aim of this work was to assess the vegetation diversity of Scots pine stands in representative forest site types along a moisture and fertility gradient.

In total 120 sample plots from Turawa forests were included in the study. These plots represented young (21–40 years) and old (> 80 years) Scots-pine-dominated stands. The forest sites were categorised according to Polish site classification. Four site categories were studied: Bśw (very nutrient-poor and mesic sites), BMśw (nutrient-poor and mesic sites), BMw (nutrient-poor and moist sites), LMw (quite nutrient-rich and moist sites).

The species composition of the forest patches studied hardly differed among forest site types. Almost all of the vegetation in site Bśw was different from both moist site types (BMw and LMw). Sites Bśw and LMw had the exclusive species determined as site indicators. Moreover, young stands had their own site type indicator species which differed from old stands. Numerical classification showed that only two plant communities were widespread: *Leucobryo-Pinetum* in Bśw and BMśw, and the community of *Pinus sylvestris* and *Molinia caerulea* in BMśw, BMw, LMw. In secondary communities typical indicator species may not be useful, but it is possible to determinate species that are locally unique to forest site type. Despite the convergence in the composition of the plant community resulting from tree stand unification, plant communities have the capacity for a more diverse composition. Tree stand conversion can increase phytocenotic diversity.

Key words: forest typology, indicator species, secondary forest communities, *Pinus sylvestris*

1. Introduction

Species and plant communities are one of the criteria for identifying forest site types. Typological units are consistent with syntaxonomic division, which allows for indication of distinct species (Siedliskowe podstawy hodowli lasu 2004 [The Fundamentals of Site Silviculture 2004]). Although elementary associations are not a clear indicator of forest site types (Lasota et al. 2005;

Sikorska, Lasota 2007), it might be expected that habitats' differentiation on the basis of characteristics of phytocoenoses is realistic, taking into account syntaxa of lower position (Danielewicz et al. 2013). However, in the practice of diagnosis and classification of forest habitat, the possible use of vegetation is limited due to the forest distortion and secondary forest communities (Sikorska, Lasota 2007). Phytocoenoses of young stand or stand inconsistent with habitat usually have disturbed

or even completely altered species composition in relation to natural vegetation (Łaska 2006). Especially, simultaneous increase in the proportion of pine in the stand and unification of its composition and age give strong effect of distorting the structure of plant communities. In such situations, phytocoenotic elements in the diagnosis of habitats play a supporting role, and the main habitat evaluation criterion are soil factors (Brożek et al. 2007; Sikorska, Lasota 2007). However, taking into account the growing interest in the so-called close-to-nature forestry, as well as the need to protect the whole forest communities (Rutkowski 2009), recognition of the diversity and structure of the actual vegetation may be very helpful in specific decisions in the practice of silviculture (Rutkowski 2012). Even in distorted phytocoenoses, local indicator species are likely to occur (Stefańska 2007; Stefańska-Krzaczek 2011), which do not necessarily coincide with typical indicators (Siedliskowe podstawy hodowli lasu 2004 [The Fundamentals of Site Silviculture 2004]). It can be assumed that under the dominance of pine, floristic specificity of forest site types neighbouring in the typological grid will disappear first. However, owing to the complexity of factors influencing habitat conditions, at least the minimum vegetation variability of habitats should be maintained, even in the case of very high proportion of pine trees in the stand. This means that the analysis of vegetation, even heavily modified, may indicate a natural gradient of vegetation variability of the site and the direction of their possible reconstruction.

The aim of this study is to assess the degree of differentiation of forest communities of pine tree stands occurring on different types of forest habitat. The following detailed questions were asked: do the forest site types show floristic and structural distinctiveness despite the distortion of the tree stand and whether the preferences of species in the coniferous forests studied indicate differences in habitat conditions of forest site types, and also what is the diversity of plant communities against the typological diversity.

2. Profile of the studied area

According to the natural and forestry division into regions, Turawa Forest District (the Regional Directorate of State Forest in Katowice) is located in the Land of Silesia in Bory Stobrawskie Mesoregion (Zielony, Kliczkowska 2012). This area is poorly differentiated, vast areas are completely flat with small hills only, and the height does not exceed 200 m above sea level. Almost 82.6% of the forest land is covered by a Scots pine. The most common forest site types include: mixed coniferous forest of nutrient-poor and moist sites (BMw) that covers 35% of the Forest District, mixed broadleaved forest of quite nutrient-rich and moist sites (LMw, 21%), mixed coniferous forest of nutrient-poor and mesic sites (BMśw, 18%), and coniferous forest of very nutrient-poor and mesic sites (Bśw, 15%) (Pan Urządzenia Lasu 2007 [Forest Management Plan 2007]).

According to the survey of soils and habitats (Operat glebowo-siedliskowy 2007 [Survey of soils and habitats 2007]), the most common soils of the studied very nutrient-poor and mesic sites (Bśw) include podsolic soils and brown podsolic soils. These habitats represent the most a typical mesic variant (Bśw1) and partly also a well-moisturised variant (Bśw2), and in the majority are in the natural state (N1). The studied nutrient-poor and mesic sites (BMśw) are mainly related to podsolic soils and brown podsolic soils. The vast majority of the studied areas represent a well-moisturised variant (BMśw2) and the habitats are close-to-natural state (N2). The nutrient-poor and moist sites (BMw) are mostly related to mucky gley-podzol soils and gley muckous soils. These sites represent typical moist variant (BMw1) and close-to-natural state (N2). The quite nutrient-rich and moist sites (LMw) represent mainly pseudogley soils, podzolised, proper pseudogley soils, gley muckous soils and proper gley soils. Most habitats (LMw) represent typical moist variant (LMw1) and most of them are distorted as a result of improper forest management (Zb1).

3. Material and methods

The data were collected in Jełowa Sub-district (geometric centre coordinates: 18°3'48,328"E, 50°49'51,704"N) and Kuźnice Kluczborskie (18°1'25,912"E, 50°53'44,245"N), where site types include Bśw, BMśw, BMw and LMw and cover large and dense areas. Owing to a relatively new soil and habitat description (Operat glebowo-siedliskowy 2007 [Survey of soils and habitats 2007]) available for the Turawa Forest District, site data have not been verified, and forest site types have been assumed according to the valid document. Based on the review map (1:25 000) for each of the four site types (Bśw, BMśw, BMw and LMw), 30 forest sub-compartments were identified: 15 sub-compartments with stand between 21- and 40-years-old and 15 sub-compartments with stand more than 80-years-old. A total number of 120 sub-compartments were examined. They represented four groups of young stands and four groups of mature stands. In se-

lected sub-compartments, in the minimum distance of 50 m from the border of the sub-compartment, circular plots with a radius of 8 m each were founded (201 m²). Homogenous plots were selected, representative of the entire sub-compartment, while microhabitats and disturbed sites were excluded. On the plots, the percentage of the following layers was estimated: tree cover layer (divided into a1 and a2), shrub layer (divided into b1 – 3–8 m high ad b2 – 0.6–3 m high), undergrowth layer (c) and moss layer (d). For each layer all species were identified, and their coverage was determined according to a modified Braun-Blanqet scale (Faliński 2001; Mueller-Dombois, Ellenberg 2002): 5: species covers 75.1%–100% of the plot; 4: 50.1%–75%; 3: 25.1%–50%; 2: 10.1%–25%; 1: 1.1%–10% (± up to 1%); r: single specimen in the plot. The data collected were included into the Polish Vegetation Database (Kącki, Śliwiński 2012).

Floristic links of the studied plots against forest site types were analysed with the use of ordination method. In order to select the appropriate method for the data collected, a Detrended Correspondence Analysis was performed. The result of the above analysis is, among others, gradient length represented by the first ordination axis and measured in standard deviation (SD) (Piernik 2008). When the length of the gradient is less than 3 SD, a Principal Components Analysis (PCA) is recommended for further studies (Piernik 2008). As a result of the analysis of data used for this study, the gradient length of 2.298 SD was obtained, which allowed for the application of PCA method in further studies. The analyses were performed with the use of CANOCO software (Lepš, Šmilauer 2003). To emphasise the qualitative differences in species composition a quantitative scale was converted into the ordinal van der Maarel scale: 9, 8, 7, 5, 3, 2 and 1 (Dzwonko 2007).

In order to assess the degree of association of certain species to the forest habitat, fidelity and frequency of species in the forest site types (TSL) were calculated in JUICE software (Tichý 2002). Mature and young stands were separately analysed. As a measure of fidelity, phi coefficient was adopted. Calculations were made for binary data, and the value of fidelity equal to 0 was adopted for species with $p<0.05$ based on Fisher's exact test (Tichý et al. 2010).

Species richness, cover layers and stand quality were also compared. The mean number of species in each group of stands was calculated, the average cover of layer b (b1 and b2 in aggregate), c and d, and the average stand quality for the studied sub-compartments, taken from the stand survey description (Plan Urządzenia Lasu 2007 [Forest Management Plan 2007]). The significance of differenc-

es between the mean values was tested in Kruskal-Wallis test and multiple comparison tests with the use of STATISTICA software (StatSoft Inc. 2013). The comparison of stand layers cover was not carried out, as it directly depends on the tending operations performed.

For each of the studied plots, ecological indices were calculated, such as light index, soil moisture index, pH index and soil trophism index (L_{EIV}, F_{EIV}, R_{EIV}, N_{EIV}), with the use of ecological numbers for vascular plants (Ellenberg et al. 1992). Then, average values of indices for each stand group were calculated. The significance of differences between the mean values was tested in the Kruskal-Wallis test and multiple comparison tests in the STATISTICA software.

In order to determine plant communities against forest site types, data from the plots surveyed were classified according to Two Way Indicator Species Analysis. The analysis was performed in the JUICE software (TWINSPAN application). The groups of plots distinguished in the analysis were the basis for the identification of communities based on syntaxonomic association of species (Matuszkiewicz 2001).

4. Results

Eigenvalues of the PCA axes were low (axis PCA1 – 0.214; axis PCA2 – 0.097), which indicate a generally small variation of species composition in the studied gradient of sites. First of all, vegetation patches in very nutrient-poor and mesic sites (Bśw) differed from patches in moist sites (LMw and BMw) (Fig. 1). Species clearly related to Bśw are common heather *Calluna vulgaris,* rugose fork-moss *Dicranum polysetum,* red-stemmed feather-moss *Pleurozium schreberi* and lingonberry *Vaccinium vitis-idaea.* The opposite was a group of species included in moist sites (BMw and LMw): narrow buckler fern *Dryopteris carthusiana,* wood sorrel *Oxalis acetosella,* purple moor grass *Molinia caerulea,* bracken *Pteridium aquilinum*, pellucid four-tooth moss *Tetraphis pellucida* and May lily *Maianthemum bifolium.* Species associated with mature forest stands were also indicated: blue whortleberry *Vaccinium myrtillus,* glittering wood-moss *Hylocomium splendens*, neat feather-moss *Pseudoscleropodium purum*, as well as species of shrub layer. Wood small-reed *Calamagrostis epigeios* was related to young stands. In the case of young tree stands, a clearer distinction between mesic and moist sites was visible – patches representing Bśw and BMśw were more concentrated; likewise patches representing BMw and LMw (Fig. 1).
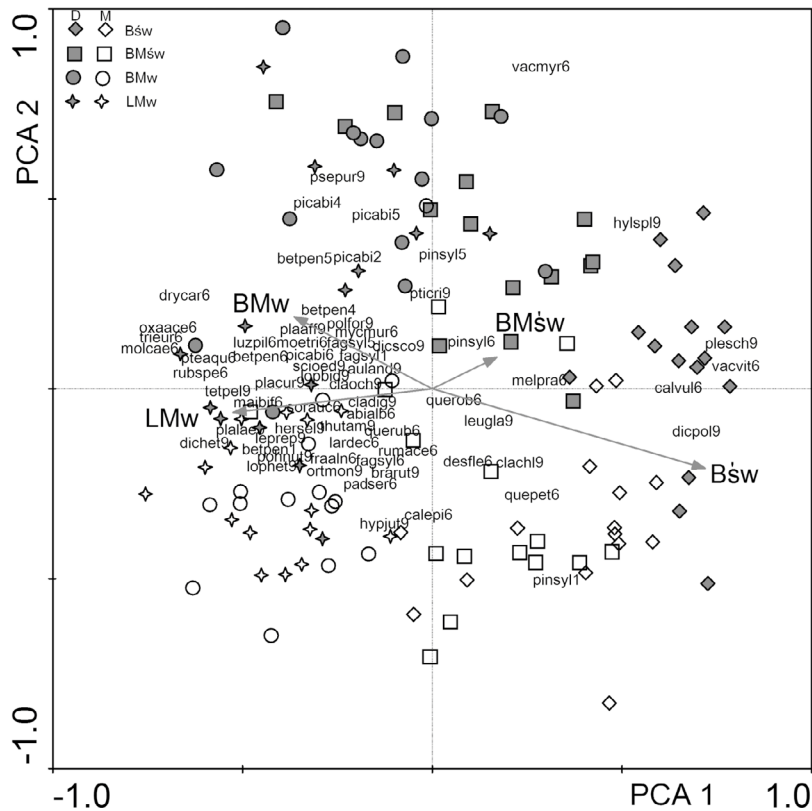
Figure 1. Vegetation diversity of the forest site types

Explanations: D – mature stands, M – young stands; species codes: abialb – *Abies alba*, auland – *Aulacomnium androgynum*, betpen – *Betula pendula*, brarut – *Brachythecium rutabulum*, calepi – *Calamagrostis epigeios*, calvul – *Calluna vulgaris*, clachl – *Cladonia chlorophaeae*, cladig – *Cladonia digitata*, claoch – *Cladonia ochrochlora*, desfle – *Deschampsia flexuosa*, dichet – *Dicranella heteromalla*, dicpol – *Dicranum polysetum*, dicsco – *Dicranum scoparium*, drycar – *Dryopteris carthusiana*, fagsyl – *Fagus sylvatica*, fraaln – *Frangula alnus*, hersel – *Herzogiella seligeri*, hylspl – *Hylocomium splendens*, hypjut – *Hypnum jutlandicum*, lardec – *Larix decidua*, leprep – *Lepidozia reptans*, leugla – *Leucobryum glaucum*, lopbid – *Lophocolea bidentata*, lophet – *Lophocolea heterophylla*, luzpil – *Luzula pilosa*, maibif – *Maianthemum bifolium*, melpra – *Melampyrum pratense*, moetri – *Moehringia trinervia*, molcae – *Molinia caerulea*, mycmur – *Mycelis muralis*, ortmon – *Orthodicranum montanum*, oxaace – *Oxalis acetosella*, picabi – *Picea abies*, pinsyl – *Pinus sylvestris*, plaaff – *Plagiomnium affine*, placur – *Plagiothecium curvifolium*, plalae – *Plagiothecium laetum*, plesch – *Pleurozium schreberi*, pohnut – *Pohlia nutans*, polfor – *Polytrichastrum formosum*, padser – *Padus serotina*, psepur – *Pseudoscleropodium purum*, pteaqu – *Pteridium aquilinum*, pticri – *Ptilium crista-castrensis*, quepet – *Quercus petraea*, querob – *Quercus robur*, querub – *Quercus rubra*, rubspe – *Rubus* species, rumace – *Rumex acetosella*, scioed – *Sciuro-hypnum oedipodium*, sorauc – *Sorbus aucuparia*, tetpel – *Tetraphis pellucida*, thutam – *Thuidium tamariscinum*, trieur – *Trientalis europaea*, vacmyr – *Vaccinium myrtillus*, vacvit – *Vaccinium vitis idaea*; 1 – layer a1, 2 – layer a2, 4 – layer b1, 5 – layer b2, 6 – layer c, 9 – layer d

Fidelity and frequency of species in groups of stands showed that Bśw and LMw had clear indicator species (Table 1). Some of the species selected for BMw was also associated with LMw, while a relationship with BMśw was found only for two species: variable-leaved crestwort *Lophocolea heterophylla* and broom fork-moss *Dicranum scoparium.* A certain number of species selected as indica-

tor species for communities with mature stands also played the role of an indicator for young stands, which, however, also had their own species differentiating forest sites. In the group of young stands, a tendency was visible to have indicator species of poorer sites on more fertile sites.

The lowest species richness both in the group of mature as well as young stands was found for Bśw and the highest

Table 1. Fidelity of indicative species of the forest site types in mature and young stands

Species	L	Mature stands				Young stands			
		Bśw	BMśw	BMw	LMw	Bśw	BMśw	BMw	LMw
Calluna vulgaris	c	59.9	.	.	.	.	.	.	.
Leucobryum glaucum	d	46.9	.	.	.	.	.	.	.
Dicranum polysetum	d	47.1	.	.	.	29	36.7	.	.
Vaccinium vitis-idaea	c	36.3	.	.	.	.	35.9	.	.
Lophocolea heterophylla	d	.	35	.	.	.	.	42.3	.
Dicranum scoparium	d	.	31.9	.	.	.	.	.	.
Dryopteris carthusiana	c	.	.	40.4	25	.	.	38.6	.
Betula pendula	b2	.	.	39.3	.	.	.	.	.
Trientalis europaea	c	.	.	35	27.2	.	.	48.1	.
Pseudoscleropodium purum	d	.	.	33.2	.	.	.	.	.
Oxalis acetosella	c	.	.	32.9	32.9	.	.	26.9	43.4
Molinia caerulea	c	.	.	30.9	38.6	.	.	27.8	36.3
Thuidium tamariscinum	d	.	.	.	62.9	.	.	.	.
Rubus sp.	c	.	.	.	50.5	.	.	.	.
Fagus sylvatica	b2	.	.	.	50.1	.	.	.	.
Pteridium aquilinum	c	.	.	.	40.8	.	.	.	49
Plagiothecium laetum	d	.	.	.	40.4	.	.	.	31.9
Cladonia ochrochlora	d	.	.	.	32.3	.	.	.	.
Luzula pilosa	c	.	.	.	31.9	.	.	.	.
Hypnum jutlandicum	d	.	.	.	30.9	.	.	.	.
Calamagrostis epigeios	c	.	.	.	.	51.9	.	.	.
Hylocomium splendens	d	.	.	.	.	49	.	.	.
Melampyrum pratense	c	.	.	.	.	.	46.5	.	.
Herzogiella seligeri	d	.	.	.	.	.	32.7	.	.
Orthodicranum montanum	d	.	.	.	.	.	30.9	.	.
Dicranella heteromalla	d	.	.	.	.	.	.	47.1	.
Betula pendula	c	.	.	.	.	.	.	40.4	.
Tetraphis pellucida	d	.	.	.	.	.	.	34.8	34.8
Plagiothecium curvifolium	d	.	.	.	.	.	.	32.9	.
Betula pendula	a1	.	.	.	.	.	.	.	51
Maianthemum bifolium	c	.	.	.	.	.	.	.	45.3

Explanations: L – layer: a1 – high tree layer, b2 – low shrub layer, c – herb layer, d – moss layer. Species with fidelity higher than 30 and frequency higher than 30% were presented

for LMw (Fig. 2). The differences were of statistical significance only when comparing these extreme sites and also Bśw and BMw. The differences between young and mature stands on the same sites were not statistically significant.

Layers b, c and d differentiated the studied sites only partially (Table 2). In phytocoenoses with mature stand, the cover of layer b was the lowest in sites of Bśw and differed significantly when compared with BMw and LMw. In phytocoenoses of young stands, this feature was not diversifying. The cover of layer c did not show statistically significant differences regardless of the group age. The cover of layer d was significantly higher
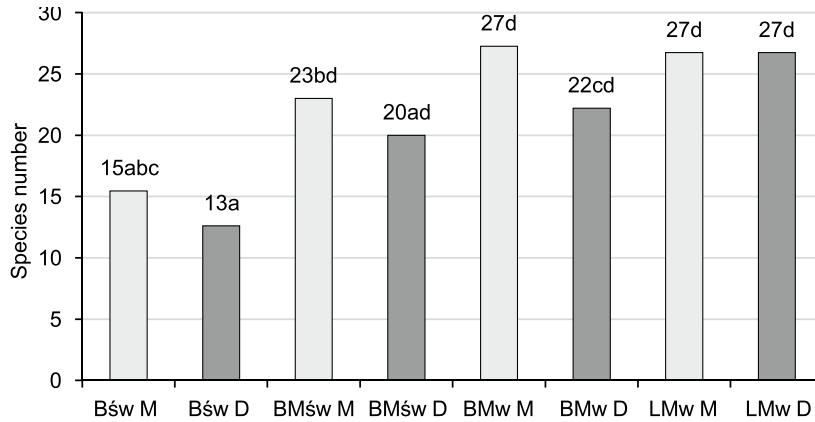
Figure 2. Species richness of the forest site types in mature and young stands

Explanations: D – mature stands (dark grey bars), M – young stands (light grey bars); values followed by the same letter are not significantly different according to the Kruskal-Wallis test at *p=0.05*

Table 2. Mean cover of layers in plant communities of mature and young stands occurring in the examined forest site types

Site type	Layers		
	b (b1+b2)	C	d
Bśw M	3[a]	20[a]	67[ab]
Bśw D	4[ab]	70[b]	77[a]
BMśw M	7[ab]	41[ac]	56[ac]
BMśw D	14[bcd]	61[bc]	67[ad]
BMw M	6[ab]	44[acd]	28[c]
BMw D	25[cd]	67[bd]	47[bcd]
LMw M	9[ac]	43[acd]	26[c]
LMw D	39[d]	58[bcd]	41[bcd]

Explanations: b – shrub layer, c – herb layer, d – moss layer; D – mature stands, M – young stands; values followed by the same letter are not significantly different according to the Kruskal-Wallis test at *p*=0.05
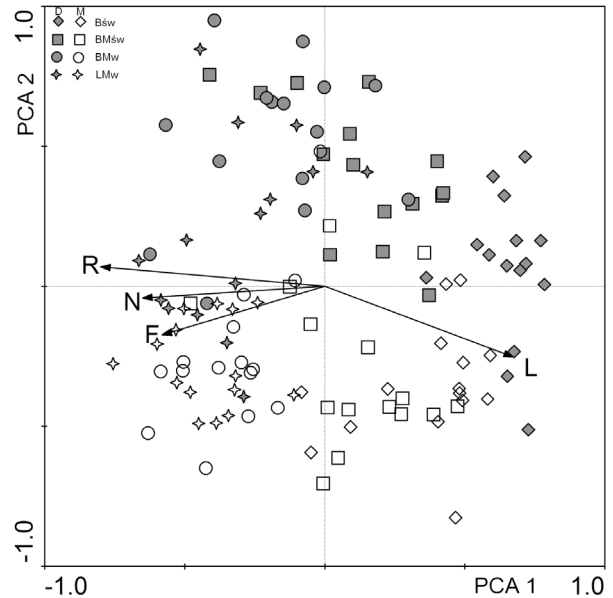

Figure 3. Gradient of site factors based on species preferences in relation to the forest site types

D – mature stands, M – young stands; L – light, F – ground moisture, R – ground reaction, N – ground trophism

on Bśw in comparison with BMw and LMw for mature and young stands. Differences between phytocoenoses of mature and young stands on the same sites were marked on Bśw as well as BMw and LMw. In young stands, the cover of layer c was significantly lower on Bśw, while the cover of layer b was significantly lower on BMw and LMw.

An average stand quality of young stands (Bśw I.4, BMśw I.4, BMw I.07, LMw I.03) did not differ significantly. Stand quality of mature stands (Bśw II.4, BMśw I.9, BMw I.8, LMw I.6) differed significantly (*p*=0.05)

when comparing Bśw with LMw and with BMw, as well as BMśw with LMw.

Ecological indices suggest differentiation of site conditions in the entire sites gradient (Fig. 3); however, as in the case of features analysed before, a clear line may be drawn mostly between Bśw and moist sites: BMw and LMw (Table 3). Sites of Bśw were characterised by

Table 3. Mean ecological indices for the forest site types in mature and young stands

Site type	L_{EIV}	F_{EIV}	R_{EIV}	N_{EIV}
Bśw M	6.1[a]	5.1[ab]	2.5[ab]	3.1[ab]
Bśw D	6.2[a]	4.4[a]	1.8[a]	1.8[c]
BMśw M	5.9[ab]	5.5[b]	2.7[abc]	2.4[ac]
BMśw D	5.8[ab]	5.1[ab]	2.7[ac]	2.5[acd]
BMw M	5.8[ab]	5.7[b]	3.1[bc]	3[ade]
BMw D	5.5[bc]	5.2[ab]	3.1[bc]	3[ae]
LMw M	5.4[bc]	5.6[b]	3.2[bc]	3.2[bde]
LMw D	5.3[c]	5.6[b]	3.4[c]	3.4[be]

Explanations: L_{EIV} – light index, F_{EIV} – moisture index, R_{EIV} – reaction index, N_{EIV} – trophism index; D – mature stands, M – young stands; values followed by the same letter are not significantly different according to the Kruskal-Wallis test at p=0.05

Table 4. Species constancy in the identified plant communities (shortened synoptic table)

	L	1	2	3	4
Plots number Bśw		12M, 15D	3M		
Plots number BMśw		3M, 7D	11M, 7D	2M, 1D	
Plots number BMw		1D	14M, 12D	1D	1M
Plots number LMw			12M, 11D		3M, 4D
Trees and shrubs					
Pinus sylvestris	a1	V	V	V	V
Betula pendula	a1		I		III
Picea abies	b1	I	III		II
Fagus sylvatica	b1		I	II	III
Picea abies	b2	III	III	II	IV
Fagus sylvatica	b2	I	I	II	IV
Quercus robur	b2	I	I	IV	I
Pinus sylvestris	C	V	V	II	III
Quercus robur	C	V	V	IV	IV
Quercus petraea	C	IV	III	II	IV
Picea abies	C	II	III	II	IV
Betula pendula	C	I	IV	II	IV
Sorbus aucuparia	C	II	III	III	II
ChCl. *Vaccinio-Piceetea*					
Vaccinium myrtillus	C	V	V	IV	V
Pleurozium schreberi	D	V	V	V	IV
Vaccinium vitis-idaea	C	V	III	V	
Hylocomium splendens	D	V	III	III	I
Dicranum scoparium	D	I	II	III	
Melampyrum pratense	C	II	I	IV	
Trientalis europaea	C		IV		III

	L	1	2	3	4
ChO. *Cladonio-Vaccinietalia**					
*Dicranum polysetum**	D	V	III	IV	
DSAll. *Dicrano-Pinenion*					
Luzula pilosa	C		II		IV
DAss. *Leucobryo-Pinetum*					
Deschampsia flexuosa	C	III	III	IV	I
Leucobryum glaucum	D	II	II		
Others					
Polytrichastrum formosum	D	V	V	IV	V
Hypnum jutlandicum	D	III	III	III	V
Calluna vulgaris	C	IV	I	III	
Molinia caerulea	C	I	V		V
Pohlia nutans	D	II	IV	V	III
Dryopteris carthusiana	C	I	IV		IV
Rubus sp	C	I	IV	II	V
Pteridium aquilinum	C	I	III	II	IV
Pseudoscleropodium purum	D	II	III	V	III
Sciuro-hypnum oedipodium	D	I	III		II
Dicranella heteromalla	D	I	III		III
Lophocolea heterophylla	D	I	III		II
Orthodicranum montanum	D	I	III	IV	II
Plagiothecium curvifolium	D	I	III	III	II
Oxalis acetosella	C		III		IV
Brachythecium rutabulum	D	I	I	III	I
Cladonia ochrochlora	D	I	I	III	II
Herzogiella seligeri	D	I	II	III	II
Plagiomnium affine	D	I	II	II	IV
Maianthemum bifolium	C		I		IV
Plagiothecium laetum	D		II		IV
Tetraphis pellucida	D	I	II		III
Thuidium tamariscinum	D		I		IV

Explanations: 1 – *Leucobryo-Pinetum*, 2 – community of *Pinus sylvestris* and *Molinia caerulea,* 3 – community of *Pinus sylvestris* and *Quercus* sp., 4 – community of *Pinus sylvestris* and *Fagus sylvatica*; L – layer: a1 – high tree layer, a2 – low tree layer, b1 – high shrub layer b2 – low shrub layer, c – herb layer, d – moss layer; D – mature stands, M – young stands; species with constancy of class I (=frequency lower than 20%) in all columns were deleted

higher light index and lower soil moisture, pH and soil trophism indices. The differences between mature and young stands on the same sites were mostly insignificant; only the value of soil trophism index was significantly higher for young tree stands.

Phytosociological diversity of studied vegetation patches was minor. Some of them, mainly on very nutrient-poor and mesic sites, might be included in the *Leucobryo-Pinetum* association (Table 4, column 1). Most of the studied patches, mainly on moist sites, represented secondary phytocoenoses determined as community of *Pinus sylvestris* and *Molinia caerulea* (Table 4, column 2). This community may be included in *Dicrano-Pinion* alliance, but it is difficult to classify it to a specific plant associa-

tion. Few patches with their species composition of undergrowth could be classified to *Leucobryo-Pinetum,* but they showed the participation of beech and oak in different community layers. They were determined as a community of *Pinus sylvestris* and *Quercus* sp. (Table 4, column 3). Also a group of patches on moist and locally most fertile sites was identified (Table 4, column 4), which related to *Pinus sylvestris* and *Molinia caerulea* community. In comparison with this community, of marginal importance were lingonberry *Vaccinium vitis-idaea,* broom fork-moss *Dicranum scoparium,* rugose fork-moss *D. polysetum* and glittering wood-moss *Hylocomium splendens.* In addition, in the shrub layer, more often than in *Pinus sylvestris* and *Molinia caerulea* community, there occurred beech and, rarely, hornbeam. Therefore, this group was interpreted as a community of *Pinus sylvestris* and *Fagus sylvatica.*

5. Discussion

The forest site types analysed in this study represent three trophic groups: coniferous forests, mixed coniferous forests and mixed forests. Therefore, it can be expected that the associated vegetation will show unique features. However, the studied sites constitute a spatial continuity resulting from the continuity of geological and topographical conditions on a local scale, and they do not differ significantly in moisture variant.

Stand quality might confirm the relative homogeneity of the sites. It differs only while comparing Bśw and LMw and BMśw and LMw. It may be expected that stand quality will differentiate between the pairs of forest site type (TSL) trophically different by definition; however, when soils are moist enough, differences in trophism may be secondary (Sewerniak 2013). Excessive participation of pine in the stand is an additional factor that unifies vegetation. The dominance of this species increases the production of acidic litter fall poor in nutrients (Jonczak 2012), which results in converging surface soil levels with upper levels of oligotrophic soils (Sewerniak 2011). Therefore, convergence of vegetation on floristic and structural terms occurs (Olaczek 1974; Łaska 2006). In the studied area, vegetation specificity of habitats that differ in soil trophism and moisture persists, as Bśw and LMw and Bśw and BMw. Therefore, as expected, in the case of high proportion of pine in tree stands and unification of their age and species composition in the first place, vegetation distinctiveness of forest site types neighbouring in the typological grid disappears, while diversity throughout the entire site gradient remains.

Despite the poor floristic distinctiveness of forest site types, indicator species of local scale were selected. It also applies to young tree stands. In addition, it was found that species occurring in mature stands are also present in young stands, but then in more fertile sites. Similar relationship was observed in very nutrient-poor and mesic sites in the Bory Dolnośląskie forest (Stefańska 2007; Stefańska-Krzaczek 2011). This confirms the usefulness of plant indicators in the site diagnosis even in the case of degenerated communities (Czerwiński 1999; Rutkowski 2012). Although the selected indicators of forest site types are the result of the synthesis of data from numerous plots, and some of them are tiny cryptogams, they provide an additional opportunity to assess the site conditions.

As a result of the distorted species composition of the stand and its simplified structure, the actual vegetation of the studied sites in the majority does not correspond to the potential vegetation. For Bśw, the potential vegetation is sub-Atlantic pine forest *Leucobryo-Pinetum* (Siedliskowe podstawy hodowli lasu 2004 [The Fundamentals of Site Silviculture 2004]; Sikorska, Lasota 2007) and it was found in these sites (Bśw). However, on other forest site types studied, secondary phytocoenoses occur. At BMw and LMw, community of *Pinus sylvestris* and *Molinia caerulea* was noted. This community may constitute a form of *Querco roboris-Pinetum molinietosum,* as well as *Molinio caerulae-Quercetum roboris,* both distorted by high proportion of pine. In addition, phytocoenoses of moist sites with participation of beech and hornbeam and reduced participation of coniferous forest species may indicate a stronger relationship with the poorest oak-hornbeam communities. Floristic relationship of studied phytocoenoses with *Querco roboris-Pinetum molinietosum, Molinio caerulae-Quercetum roboris* and oak-hornbeam forests are significant, because these units are selected as potential vegetation for studied sites. *Querco roboris-Pinetum,* including the sub-association of *molinietosum,* is quoted as a community associated with BMw (Sikorska, Lasota 2007), and *Molinio caerulae-Quercetum roboris* both with BMw and LMw (Siedliskowe podstawy hodowli lasu 2004 [The Fundamentals of Site Silviculture 2004]; Danielewicz et al. 2013). Also, oak-hornbeam forests are indicated as being related to LMw (Siedliskowe podstawy hodowli lasu 2004 [The Fundamentals of Site Silviculture 2004]; Sikorska, Lasota 2007; Danielewicz et al. 2013). The sites of BMśw are not homogenous in terms of vegetation. Some patches occurring on these sites represents *Leucobryo-Pinetum* association, which in the case of these sites is secondary community for *Calamagrostio arundinaceae-Quercetum petraeae* or for *Querco roboris-Pinetum,* which can constitute potential vegetation of BMśw (Sikorska, Lasota 2007; Danielewicz et al. 2013). In the case of patches

identified as *Leucobryo-Pinetum,* these would probably be *typicum* sub-associations for *Calamagrostio-Quercetum* and *Querco roboris-Pinetum* (Kasprowicz 2010). However, most of patches on BMśw were identified as the community of *Pinus sylvestris* and *Molinia caerulea.* This does not exclude the above-mentioned associations (*Calamagrostio arundinaceae-Quercetum petraeae* and *Querco roboris-Pinetum*) as potential vegetation. In this case, more probable would be moist sub-associations: *Calamagrostio arundinaceae-Quercetum petraeae molinietosum* and *Querco roboris Pinetum molinietosum* (Kasprowicz 2010). However, *Molinio caerulae-Quercetum roboris* cannot be excluded, although it is assigned to BMw or LMw (Sikorska, Lasota 2007; Danielewicz et al. 2013). Based on the current structure and species composition of phytocoenoses, potential vegetation cannot be clearly indicated for BMśw, BMw or LMw; however, phytocoenotic differences between the studied site types could be enhanced by stand conversion. Therefore, potential vegetation should be assumed in advance for each site, e.g. BMśw – *Calamagrostio arundinaceae-Quercetum petraeae,* BMw – Q*uerco roboris Pinetum* and LMw – *Tilio-Carpinetum.* This means stand conversion mainly with the use of sessile oak on nutrient-poor and mesic sites (BMśw), common oak on nutrient-poor and moist sites (BMw), and common oak, beech and hornbeam on quite nutrient-rich and moist sites (LMw).

6. Conclusions

In the case of secondary forest communities, typical indicator species may be useless; however, it is possible to identify locally differentiating species.

As a result of the simplified stand structure and composition, vegetation of different sites becomes homogenous. However, the species composition indicates that plant communities have a tendency to spontaneously form more diverse systems.

References

Brożek S., Zwydak M., Wanic T., Gruba P., Lasota J. 2007. Kierunki doskonalenia metod rozpoznawania siedlisk leśnych [Improvement methods in forest site diagnosis techniques]. *Sylwan*, 151 (2): 26–34.

Czerwiński A. 1999. Rola fitosocjologii w diagnostyce i gospodarce leśnej. *Sylwan*, 143(10): 83–94.

Danielewicz W., Szwed W., Kiciński P. 2013. Znaczenie lasów i ich podział z punktu widzenia leśnictwa, in: Lasy i zarośla (eds. W. Matuszkiewicz, P. Sikorski, W. Szwed, M. Wierzba). Warszawa, Wyd. Naukowe PWN, p. 63–73. ISBN 978-83-01-17064-6.

Dzwonko Z. 2007. Przewodnik do badań fitosocjologicznych. Poznań-Kraków, Wydawnictwo Sorus S.C., 304 p. ISBN 978-83-89949-23-3.

Ellenberg H., Weber H., Düll R., Wirth V., Werner W., Paulißen D. 1992. Zeigerwerte von Pflanzen in Mitteleuropa. *Scripta Geobotanica*, 18: 5–258.

Faliński J. B. 2001. Przewodnik do długoterminowych badań ekologicznych. Warszawa, Wydawnictwo Naukowe PWN, 672 p. ISBN 83-01-13239-6.

Jonczak J. 2012. Wpływ domieszki sosny w drzewostanie bukowym na intensywność wypłukiwania węgla, żelaza i glinu z poziomu organicznego i próchnicznego gleb bielicowo--rdzawych [Effect of pine admixture in a beech stand on the intensity of dissolved organic carbon, iron and aluminium leaching from organic and humic horizons of Dystric Arenosols]. *Leśne Prace Badawcze*, 73 (2): 143–151.

Kasprowicz M. 2010. Acidophilous oak forests of the Wielkopolska region (West Poland) against the background of Central Europe. *Biodiversity Research and Conservation*, 20: 1–138.

Kącki Z., Śliwiński M. 2012. The Polish Vegetation Database: structure, resources and development. *Acta Societatis Botanicorum Poloniae*, 81 (2): 75–79.

Lasota J., Karp M., Biskup S. 2005. Siedliska kwaśnej dąbrowy trzcinnikowej *Calamagrostio arundinaceae-Quercetum petraeae* w środkowej Wielkopolsce [Site conditions of acidophilous sessile oak forest (*Clamagrostio arundinaceae-Quercetum petraeae*) in central part of Wielkopolska]. *Silvarum Colendarum Ratio et Industria Lignari*a, 4 (1): 23–39.

Lepš J., Šmilauer P. 2003. Multivariate analysis of ecological data using CANOCO. Cambridge University Press, Cambridge, 269 p. ISBN 0-521-8910-6.

Łaska G. 2006. Tendencje dynamiczne zbiorowisk zastępczych w Puszczy Knyszyńskiej. Białystok–Poznań, Politechnika Białostocka, Instytut Inżynierii i Ochrony Środowiska, Bogucki Wyd. Naukowe, 503 p. ISBN 83-60247-41-2.

Matuszkiewicz W. 2001. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Wyd. Naukowe PWN, Warszawa, 537 p. ISBN 83-01-13520-4.

Muller-Dombois D., Ellenberg H. 2002. Aims and methods of vegetation ecology. The Blackburn Press, 547 p. ISBN 1-930665-73-3.

Olaczek R. 1974. Etapy pinetyzacji grądu [Phases of oak-linden-hornbeam forest pinetization]. *Phytocoenosis*, 3 (3/4): 201–213.

Operat glebowo-siedliskowy 2007. Nadleśnictwo Turawa. Biuro Urządzania Lasu i Geodezji Leśnej, Brzeg.

Piernik A. 2008. Metody numeryczne w ekologii na przykładzie zastosowań pakietu MVSP do analiz roślinności. Toruń, Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 98 p. ISBN 987-83-231-2279-1.

Plan urządzenia lasu dla Nadleśnictwa Turawa na okres od 1 styczna 2007 r. do 31 grudnia. 2016 r. Biuro Urządzania Lasu i Geodezji Leśnej Oddział w Brzegu, Brzeg 2007.

Rutkowski P. 2009. Natura 2000 w leśnictwie [Nature 2000 and Forestry]. Warszawa, Ministerstwo Środowiska, 69 p. ISBN 978-83-89994-03-5.

Rutkowski P. 2012. Stan i perspektywy rozwoju typologii leśnej w Polsce. Uniwersytet Przyrodniczy w Poznaniu [State and perspectives of forest typology in Poland]. *Rozprawy Naukowe*, 436: 3–248.

Sewerniak P. 2011. Zróżnicowanie wybranych właściwości gleb drzewostanów sosnowych w południowo-zachodniej Polsce. *Roczniki Gleboznawcze*, 62 (1): 142–151.

Sewerniak P. 2013. Bonitacja drzewostanów sosnowych w południowo-zachodniej Polsce w odniesieniu do typów siedliskowych lasu i taksonów gleb [Site index of Scots pine stands in south−western Poland in relation to forest site types and soil units]. *Sylwan*, 157 (7): 516–525.

Siedliskowe podstawy hodowli lasu. Załącznik do Zasad Hodowli Lasu. 2004. Bedoń, Ośrodek Rozwojowo-Wdrożeniowy Lasów Państwowych, 264 p. ISBN 83-913320-6-3.

Sikorska E., Lasota J. 2007. Typologiczny system klasyfikacji siedlisk a fitosocjologiczna ocena siedlisk [Comparisson between typologique and phytosociological forest site classification], in: Siedliska i gatunki wskaźnikowe w lasach (ed. D. Anderwald) [Habitats and indicative species in the forests]. *Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej w Rogowie*, 2/3 (16): 44–51.

StatSoft Inc. 2013. Electronic Statistics Textbook. Tulsa, OK: StatSoft. http://www.statsoft.com/textbook/ [14.10.2013].

Stefańska E. 2007. Wskaźniki siedlisk boru świeżego i mieszanego świeżego w borach sosnowych Polski południowo-zachodniej [Indicators of fresh coniferous and fresh mixed coniferous forest sites in south-western Poland], in: Siedliska i gatunki wskaźnikowe w lasach [Habitats and indicative species in the forests] (ed. D. Anderwald). *Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej w Rogowie*, 2/3 (16): 141–152.

Stefańska-Krzaczek E. 2011. Plant communities of Scots pine stands in the south-eastern part of the Bory Dolnośląskie forest (SW Poland). *Acta Botanica Silesiaca, Monographiae*, 6: 1–98.

Tichý L. 2002. JUICE, software for vegetation classification. *Journal of Vegetation Science*, 13: 451–453.

Tichý L., Holt J., Nejezchlebová M. 2010. JUICE program for management, analysis and classification of ecological data. 2nd Edition of the Program Manual. 2nd part. Vegetation Science Group, Masaryk University Brno, Czech Republic. http://www.sci.muni.cz/botany/juice/ [14.10.2013].

Zielony R., Kliczkowska A. 2012. Regionalizacja przyrodniczo-leśna Polski 2010. Warszawa, Centrum Informacyjne Lasów Państwowych, 356 p. ISBN 978-83-61633-62-4.

Contributions

E.S-K. – an author of the article conception, designed the study, performed numerical analysis, wrote the article, prepared figures and tables. P.P. acquired materials to perform the study, performed field work, prepared data for analysis and editorial revision of the article content.

Translated by: Katarzyna Kreft