POLSKA AKADEMIA NAUK
MUZEUM I INSTYTUT ZOOLOGII

FRAGMENTA FAUNISTICA

Tom 36 Warszawa, 30 X 1993 Nr 2

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Description of the plant association structure and soils of pine forest stands situated in five regions of Poland

[With 7 tables and 9 figures in the text]

Abstract. Paper presents some geobotanical and soil research, which are carried out in pine forest, situated in the five geographical regions of Poland (Wielkopolska, Bory Tucholskie, Puszcza Biała, Puszcza Białowieska and Roztocze). The aim of the study was to make a phytosociological diagnosis, estimation of soil condition and analysis of phytocenoses for zoocenological purposes. Studied plant communities are represented by two regional association: *Leucobryo-Pinetum* and *Peucedano-Pinetum* and two types of soil: podzolic and rusty soil belonging to the podzolic earthe. Physical and chemical soil properties, phytosociological data, as well as results of floristic composition of different regeneration stage of pine forest are presented.

AN INTRODUCTION

The study areas chosen have been described in geobotanical and pedologic terms to the extent that was required by zoocenological studies. The areas are situated in five regions of Poland, three areas in each: Babimost forest district in the region of Wielkopolska (stand 1 is located in forest section 105, stand 2 – in forest section 105a, stand 3 – in section 103); Roztocze National Park in the region of Roztocze (stand 1 in section 287, stand 2 in section 278, stand 3 in division 155); Osie forest district in Bory Tucholskie (stand 1 in section 340, stand 2 in section 306, stand 3 in section 346); Ostrów Mazowiecka forest district in Puszcza Biała (stand 1 in section 62, stand 2 in section 38, stand 3 in section 34); Hajnówka forest district (Starzyna subdistrict) in Puszcza Białowieska (stand 1 in section 668, stand 2 in section 667, stand 3 in section 538).

The study consisted of:

– a phytosociological analysis – based on phytosociological releve protocols obtained according to Braun-Blanquet's technique. This study provided data for a general description of the phytocenoses, syntaxonomic evaluation, comparisons between phytocenoses of different regions as well as between phytocenoses exhibiting various degrees of regeneration.

– a pedologic analysis – this provided a description of soil conditions in the stands studied, including some of the chemical characteristics of the soils (to be used in the analysis of the data on soil fauna).

– an analysis of the structure of the phytocenoses – this study used data collected from a network of "checks". The purpose of this analysis was to examine the spatial diversity of the ground layers of the plant associations.

PHYTOSOCIOLOGICAL ANALYSIS OF THE STUDY AREAS.

As far as the habitat type is concerned, all the stands studied are situated in pine forests. For the sake of a phytosociological analysis, releve protocols were taken at each stand (Tab. 1). The plant communities represent more or less transformed disturbed forms of two regional plant associations: the suboceanic type of pine forest (Wielkopolska, Roztocze and Bory Tucholskie) and the subcontinental type of pine forest (Puszcza Biala and Puszcza Białowieska). The subcontinental type of pine forest, seen predominantly in mixed forests of the continental climate zone, is characterized by a much greater number of plant species growing in various microhabitats and by a greater proportion of the so-called "Sarmatian" plant species than that found in suboceanic pine forests growing mostly in Central Europe.

Apart from differences between the varieties of pine forests in Europe, there also are differences between plant communities of the same type growing in different regions as well as between phytocenoses situated within one region. The latter are due to biogeographical factors (species occupying areas of unequal sizes), habitat conditions (certain differences in soil fertility and humidity) and anthropogenic impact.

The pine forest communities in Babimost forest district, Wielkopolska, are situated in the mezoregion of Bruzda Zbąszyńska on the border of the Kotlina Kargowska mezoregion. These communities exhibit a considerable degree of anthropopression. The pine forests of the three communities are of approximately the same age (100 years old) and grow on formerly arable soils, consequences of which can be seen both in the floristic composition, the structure and the soil profiles. The communities can be classified as regenerating pine forests of the suboceanic type with various degrees of transformation.

Stand 1 (forest section 105) comprises a pine forest in the stage of advanced regeneration. The forest does not differ considerably from a typical pine forest of the suboceanic type (*Leucobryo-Pinetum*). The floristic composition of this stand is slightly poorer than could be expected in this region, with a moderate transformation of its structure (too high a proportion of *Deschampsia flexuosa*, lack of spatial homogeneity of the ground cover and signs of a recent mechanical damage to the bryophyte layer). The underground water level in this forest is rather high for a pine forest, owing to which *Molinia coerulea* can grow here.

Table I. The floristic composition of the plant associations studied

		Leucobryo-Pinetum									*Peucedano-Pinetum*					
Number of stand		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Region	0	W	W	W	R	R	R	T	T	T	K	K	K	B	B	B
Nr of stand in the region	0	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Cover of tree layer	0	60	60	60	60	70	70	80	85	70	60	70	60	50	50	60
Cover of shrub layer	0	30	25*	–	5	10	30	+	10	+	20	20	40	20	25	30
Cover of herb layer	0	80	70	5	80	80	90	70	30	70	70	80	70	60	70	70
Cover of bryophyt. layer	0	90	40	80	99	95	95	90	99	99	90	90	99	90	90	80
The number of species	0	18	17	8	36	29	36	30	18	21	41	39	49	57	46	40
Trees																
Pinus silvestris	a	4	4	4	4	4	4	5	5	4	4	4	4	3	3	3
Pinus silvestris	b	3	4/+	–	1	+	1	–	1	–	1	2	+	–	–	3
Pinus silvestris	c	2	+	+	1	+	–	+	1	+	–	+	–	–	+	–
Betula verrucosa	a	–	–	–	–	–	–	–	–	–	2	–	–	1	1	3
Betula verrucosa	b	–	–	–	–	–	+	–	–	–	+	–	–	–	+	–
Betula verrucosa	c	+	+	–	+	–	+	+	–	+	–	+	+	–	+	–
Quercus robur	a	–	–	–	–	–	–	–	–	–	–	–	–	+	+	1
Quercus robur	b	–	–	–	–	–	+	–	–	–	–	–	–	+	–	1
Quercus robur	c	–	+	–	+	+	+	–	–	–	+	+	+	+	+	+
Sorbus aucuparia	b	–	–	–	–	+	+	–	–	–	–	–	–	+	+	–
Sorbus aucuparia	c	–	–	+	+	+	r	–	–	–	+	+	+	–	+	+
Picea excelsa	a	–	–	–	1	1	3	–	–	–	–	–	–	+	2	2
Picea excelsa	b	–	–	–	–	2	2	–	–	–	–	–	–	2	2	3
Picea excelsa	c	–	–	–	–	–	–	–	–	–	–	–	–	+	+	+
Abies alba	b	–	–	–	+	+	+	–	–	–	–	–	–	–	–	–
Abies alba	c	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
Fagus silvatica	a	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Fagus silvatica	b	–	–	–	+	+	1	–	–	–	–	–	–	–	–	–
Fagus silvatica	c	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
Populus tremula	a	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
Populus tremula	c	–	–	–	–	–	r	–	–	–	–	–	+	+	–	–
Differential species of the regional associations																
Leucobryum glaucum	d	+	+	2	3	2	2	–	–	–	–	–	–	–	–	–
Solidago virga-aurea	c	–	–	–	–	–	–	+	–	–	+	+	+	+	+	–
Anthericum ramosum	c	–	–	–	–	–	–	r	–	–	–	+	+	+	+	–
Peucedanum oreoselinum	c	–	–	–	–	–	–	–	–	r	–	–	+	+	+	–
Convallaria maialis	c	–	–	–	–	–	–	–	–	–	+	–	+	+	1	–
Polygonatum odoratum	c	–	–	–	–	–	–	–	–	–	–	+	+	+	+	–
Rubus saxatilis	c	–	–	–	–	–	–	–	–	–	+	–	–	+	+	+
Scorzonera humilis	c	–	–	–	–	–	–	–	–	–	–	–	+	+	+	–
Other species																
Dicranum undulatum	d	3	3	3	2	3	3	3	4	3	3	4	3	2	3	1
Entodon schreberi	d	3	4	2	5	4	3	3	2	3	4	3	4	3	3	4
Calluna vulgaris	c	1	2	–	+	+	+	+	1	2	1	2	+	+	1	r
Vaccinium myrtillus	c	2	3	–	4	4	3	3	+	3	2	3	3	2	3	3
Vaccinium vitis-idaea	c	2	3	–	2	2	2	1	2	2	1	2	+	1	1	+
Festuca ovina	c	r	–	–	+	+	+	1	+	+	3	2	1	+	1	1
Melampyrum pratense	c	+	–	–	2	3	3	2	+	1	2	2	+	1	1	+
Frangula alnus	b	–	–	–	+	+	–	–	–	–	+	+	+	–	–	–
Frangula alnus	c	+	+	–	1	+	+	+	–	–	+	–	+	–	+	+

Juniperus communis	b	–	–	–	1	r	–	1	+	+	2	2	3	–	–	–
Juniperus communis	c	–	–	–	+	–	–	–	–	+	+	+	–	+	+	+
Hylocomium splendens	d	–	–	–	–	+	+	+	+	+	1	+	+	3	3	2
Deschampsia flexuosa	c	5	3	1	–	–	2	2	1	2	+	–	2	–	+	–
Carex ericetorum	c	r	+	–	r	–	–	+	+	+	+	+	–	r	–	+
Rumex acetosella	c	–	+	–	r	–	r	+	–	–	+	+	+	+	+	+
Luzula pilosa	c	–	–	–	+	+	1	1	–	–	+	+	1	+	+	1
Dryopteris spinulosa	c	–	–	–	+	r	+	+	–	–	+	+	+	r	+	–
Agrostis vulgaris	c	–	–	–	r	–	+	+	–	–+	+	+	+	+	+	+
Polytrichum juniperinum	d	–	–	–	+	–	+	–	–	1	+	+	+	+	+	+
Dicranum scoparium	d	+	–	–	+	+	+	+	1	+	+	–	–	–	–	–
Polytrichum commune	d	–	–	–	+	+	+	–	–	+	–	1	+	–	+	+
Luzula multiflora	c	–	–	–	+	+	–	+	–	+	+	+	+	–	+	–
Calamagrostis arundinacea	c	–	–	–	+	–	–	+	–	–	+	+	+	2	2	+
Carex pilulifera	c	–	–	–	–	+	+	+	–	–	+	+	+	+	–	+
Trientalis europaea	c	–	–	–	–	–	+	–	–	–	2	+	2	1	1	+
Pohlia nutans	d	+	+	3	–	–	–	1	+	1	–	–	–	–	–	–
Anthoxanthum odoratum	c	–	–	–	–	–	–	r	–	–	+	1	+	+	–	+
Corylus avellana	c	–	–	–	r	r	–	–	–	–	–	–	–	+	r	r
Polytrichum attenuatum	d	–	–	–	–	–	+	–	+	–	+	+	+	–	–	–
Sieglinglia decumbens	c	–	–	–	r	–	–	–	–	–	+	+	+	+	–	–
Hieracium pilosella	c	–	–	–	–	–	–	–	–	–	+	+	+	+	+	–
Cytisus ruthenicus	c	–	–	–	–	–	–	–	–	–	+	+	+	+	+	–
Veronica officinalis	c	–	–	–	–	–	–	–	–	–	+	+	–	+	+	+
Pteridium aquilinum	c	1	+	–	1	1	–	–	–	–	–	–	–	–	–	–
Cytisus ratisbonensis	c	–	–	–	+	–	–	–	–	–	+	+	+	–	–	–
Cladonia sp.	d	–	+	+	–	–	–	–	+	–	–	–	–	–	–	–
Chamaenerion angustifolium	c	–	–	–	r	–	r	–	–	–	–	–	+	–	–	–
Calamagrostis epigeios	c	–	–	–	–	+	–	–	–	–	–	+	–	+	–	–
Cladonia rangiferina	d	–	–	–	–	–	–	+	2	+	–	–	–	–	–	+
Maianthemum bifolium	c	–	–	–	–	–	+	–	–	–	–	–	–	+	1	–
Carex fusca	c	–	–	–	–	–	–	–	–	+	+	–	+	–	–	–
Lycopodium clavatum	c	–	–	–	–	–	–	–	–	–	+	1	–	–	–	+
Hieracium umbellatum	c	–	–	–	–	–	–	–	–	–	r	–	r	–	r	–
Ptilium crista-castrensis	d	–	–	–	–	–	–	–	–	–	–	–	+	+	+	–
Mnium sp.	d	–	–	–	–	–	–	–	–	–	–	–	–	+	+	+

Moreover in one or two releves: *Alnus glutinosa* b w 4 (r), *Campanula rotundifolia* w 2 (r), *Carex digitata* w 13 (+), *C. leporina* w 10 i 12 (+), *Carpinus betulus* w 13 i 15 (r), *Chimaphila umbellata* w 11 i 12 (+), *Cladonia silvatica* w 7 (+) i w 8 (1), *Dactylis glomerata* w 1 (r), *Dianthus arenarius* w 13 (+), *Festuca rubra* w 10 i 12 (+), *Fragaria vesca* w 13 i 14, (+), *Galeopsis tetrahit* w 5 (r), *Galium mollugo* w 13 (+), *Genista tinctoria*, w 14 i 15 (+), *Geranium sanguineum* w 13 (+), *Goodyera repens* w 14 (+), *Hieracium murorum* w 13 (r), *Holcus mollis* w 12 (+), *Hypericum perforatum* w, 15 (+), *Lycopodium annotinum* w 6 (+), *L. complanatum* w 12 (+), *Malus silvestris* c w 6 (r), *Melica nutans* w 13 (+), *Milium effusum* w 13 (+), *Moehringia trinervia* w 14 (+), *Molinia coerulea* w 1 i 15 (+), *Nardus stricta* w 4 i 5 (+), *Oxalis acetosella* w 5 (+), *Pirola secunda* w 15 (+), *Pinus communis* w 11 i 12 (+), *Poa pratensis v. angustifolia* w 13 i 15 (+), *P. trivialis* w 15 (+), *Potentilla erecta* w 12 i 14 (+), *Prunus serotina* w 4, i 6 (+), *Pulsatilla pratensis* w 7 (+), *P. teklae* w 13 (+), *Rubus plicatus* w, 6 (r), *Senecio silvaticus* w 15 (+), *Silene nutans* w 13 (r), *Stellaria graminea* w 15 (+), *Trifolium alpestre* w 7 (+), *Urtica dioica* w 13 i 14 (r), *Vaccinium uliginosum* w 4 (+), *Veronica chamaedrys* w 13 i 14 (+), *Viola* sp., w 12 i 13 (+), *Vincetoxicum officinale* w 13 (+).

Stand 2 (section 105a) exhibits a much greater degree of transformation mostly in spatial structure. It seems that in addition to the "primary" process of forest regeneration following afforestation of an arable land, two other kinds of regeneration can be seen at this stand: regeneration following a small forest fire and regeneration after a mechanical damage the plant cover caused by silvicultural practices.

The plant community of stand 3 (section 103) represents the stage of greater degeneration so that it is impossible to classify this association as a *Leucobryo-Pinetum* pine forest, even though it definitely remains in a dynamic relationship with this association type. The major signs of transformation at this stand are: lack of shrub layer in large areas, an almost complete absence of ground cover (a few aggregations of *Deschampsia flexuosa*) and the resultant poor floristic composition of this stands as well as atypical proportions of species in the bryophyte layer.

The pine forest sites studied in Roztocze (the mezoregion of Middle Roztocze), located in Roztocze National Park, are prime representatives of the suboceanic type of pine forest in its region-specific variety. Characteristic of this variety is the occurrence of fir, spruce and beech, mostly in the layer of shrubs. Stands 1 and 2 have floristic composition and structure typical of the pine forest of this region, while stand 3 represents a dynamic phase of this community type where a high proportion of the shrub layer slightly changes quantitative relations in the ground cover.

The pine forest communities studied in Bory Tucholskie (Osie forest district) represent the Pomeranian variety of the suboceanic pine forest type. Since the study area is situated near the eastern border of this association, plant species distinctive of the suboceanic type of pine forest are not abundant. The majority of the forests have been markedly distorted from their natural state by intensive silvicultural practices. From among the three stands selected in this region, two (stands 1 and 3) are typical pine forests, while stand 2 can be classified as a *Cladonio-Pinetum* forest with its small proportion of *Vaccinium myrtillus* and a high proportion of lichens of the genus *Cladonia*.

The pine forest studied in Puszcza Biała (the mezoregion of Międzyrzecze Łomżyńskie) are situated in Ostrów Mazowiecka forest district, the subdistrict of Dybki. They represent the "Sarmatian" variety of the subcontinental type of pine forest (*Peucedano-Pinetum*). A characteristic feature of these communities is a high proportion of grass species (*Agrostis vulgaris*, *Sieglingia decumbens* and *Anthoxanthum odoratum*) and of juniper. This may be due to the fact that until quite recently cattle was put out to pasture in those forests.

The associations of pine forests studied in Puszcza Białowieska are located in the mezoregion of Wysoczyzna Bielska (the district of Hajnówka, the subdistrict of Starzyna). They represent the subboreal variety of the subcontinental type of pine forest (*Peucedano-Pinetum*) with spruce in forest stands and in the shrub layer. A peculiarity of the pine forests of Puszcza Białowieska is the occurrence of hazel and hornbeam trees since these species are mostly found in deciduous forests. However, the specimens of these tree species are not abundant and very small. The structure and floristic composition of stands 1 and 2 are typical of the association type mentioned above, while stand 3 is in the phase of regeneration following clear-cutting of the adjacent forest division, which has resulted in the thinning out of the bryophyte layer and poorer floristic composition of the stand studied.

SOIL CONDITIONS IN THE PINE FORESTS STUDIED

All the soils studied have developed from the same type of lithologic material, i.e. sands, which, however, differ in their morphogenesis. The sands in Puszcza Biała are connected with glacial accumulation, the sands in Roztocze with fluvial accumulation, while the sands in the remaining three regions (Puszcza Białowieska, Bory Tucholskie and Babimost in Wielkopolska) are connected with glaciofluvial sedimentation.

Compared with the soils derived from glaciofluvial sands, the soils which have developed from glacial sands contain slightly larger proportions of the skeletal fractions (i.e. particles larger than 1 mm) and of the fine sand fraction (i.e. particles between 0.5 mm and 1 mm in diameter). A higher proportion of fine sand in these soils is indicative of a richer mineral composition, which, in turn, is connected with the occurrence of greater food reserves for plants. As to mechanical composition, the upper horizons of the soils formed from glacial sands as well as of some of the soils derived from fluvial sands contain coarse sand, while the lower horizons of these soils can be classified as loose sands. The soils formed from glaciofluvial sands have the loose sand texture throughout their soil profiles.

Irrespective of the litho-petrographic characteristics of the geological material, in which the soils studied have originated, all of them are acid with low base saturation. The upper horizons are more acid than the lower ones.

The fact that the soils studied do not differ much in their physicochemical characteristics can be ascribed to similar conditions of soil formation: similar lithologic and higro-thermal conditions as well as similarities between plant associations growing on these soils.

In terms of soil typology, all the soils studied belong to the class of Spodosols and fall into two soil types: podzolic soils (4 stands) and rusty soils (11 stands). All of them are acid soils of low base saturation. The upper soil horizons are more acid than the lower soil horizons (Tab. II). The ectohumus that develops in the soils studied belongs either to the mor type (with the litter, fermentation and epihumus horizons) or to the moder type (with the litter and detritus horizons). Intermediate forms of ectohumus can develop as well. The soils of Babimost forest district, Wielkopolska, are clearly distinct from the soils of the other regions because they were used for farming purposes up to the end of the 19th century, and now contain a plow horizon.

Table II. Soil properties in the stands studied.

Region	Stand (nr for. sec.)	Soil type (humus type)	Soil horizon	Depth (cm)	Sand type	Chemical characteristics			
						pH in KCl	NO_3 (mg/l)	NH_4 (mg/l)	C org. (%)
Babimost	1(105)	rusty	Ah	0–3	l.s.	3,0	5.0	48	2,25
		proper	Ahp	3–30	l.s	4.1	4.4	31	0,31
		[moder-	Br	30–70	l.s	4.2	3.2	30	0,13
		mor]	C	>70	l.s	4.3	3.2	20	0,11
Babimost	2(105a)	rusty	Ah	0–3	l.s.	3,3	3,3	166	4,27
		proper	Ahp	3–20	l.s.	3,2	4,4	120	4,65
		[mor]	Br	20–60	l.s.	4,3	3,2	24	0,52
			C	>60	l.s.	4.7	3.2	20	0.11
Babimost	3 (103)	rusty	A1	0–5	l.s.	3,3	3.3	66	2,27
		proper	Br	5–25	l.s.	3,9	1,9	10	0,31
		[mor]	BrC	25–60	l.s.	4,5	1,9	14	0,31
			C	>60	l.s.	4.7	3.2	12	0.05
Roztocze	1 (287)	spodosol	A1A2	0–11	l.s.	3,2	3,4	23	1,21
		ron	A2	11–23	l.s.	3,8	2,6	18	0,38
		humic	BH	23–31	l.s.	4,0	2,3	29	0,63
		[mor]	BHS	31–40	l.s.	4,5	2,3	17	0,20
			BS	40–80	l.s.	4,6	2,3	17	0,08
			C	>80	l.s.	4.6	1.6	17	0.01
Roztocze	2 (278)	rusty	A1	0–23	c.s.	3,1	4,8	19	0,93
		proper	Br	23–54	c.s.	4,2	3,5	20	0,43
		[moder]	BrC	54–104	c.s.	4,4	2,8	18	0,08
			C	>104	l.s.	4.6	3.1	18	0.02
Roztocze	3 (155)	podzolic	A1A2	0–11	c.s.	3,8	2,5	26	1,34
		proper	A2	11–20	l.s.	3,8	2,7	19	0,97
		[mor]	B	20–27	l.s.	4,2	2,2	23	0,30
			BC	27–72	l.s.	4,4	2,4	15	0,24
			C	>72	l.s.	4.6	1.5	24	0.04
Bory	1 (340)	rusty	A1	0–12	l.s.	3,3	3,6	19	1,33
Tucholskie		proper	Br	12–64	l.s.	4,2	2,8	16	0,79
		[moder]	C	>64	l.s.	4.4	3.2	17	0.35
Bory	2 (306)	rusty	A1	0–11	l.s.	3,3	3,5	20	1,39
Tucholskie		proper	Br	11–53	l.s.	4,1	2,6	16	0,55
		[moder]	C	>53	l.s.	4.5	2.7	16	0.20
Bory	3 (346)	rusty	A1	0–9	l.s.	3,4	4,8	18	2,20
Tucholskie		proper	Br	9–54	l.s.	4,3	3,6	17	0,67
		[moder]	C	>54	l.s.	4.5	2.3	18	0.31
Puszcza	1 (62)	rusty	A1	0–12	c.s.	3,1	2,9	30	2,53
Biała		proper	Br	12–72	c.s.	4,3	2,4	33	0,58
		[mor-	BrC	72–90	l.s.	4,6	1,8	24	0,02
		moder]	C	>90	l.s.	4.5	3.0	18	0.05
Puszcza	2 (38)	rusty	A1	0–14	c.s.	2,7	6,8	23	3,91
Biała		proper	Br	14–54	c.s.	3,4	3,2	17	0,97
		[moder]	BrC	54–90	l.s.	4,5	2,5	15	0,07
			C	>90	l.s.	4.6	1.5	24	0.05
Puszcza	3 (34)	rusty	A1	0–9	c.s.	3,5	3,5	22	2,70
Biała		proper	Br	9–64	c.s.	4,2	3,0	19	0,79
		[moder]	BrC	64–88	l.s.	4,2	2,2	13	0,13
			C	>88	l.s.	4.3	2.3	18	0.09
Puszcza	1 (668)	rusty	A1	0–9	l.s.	3,1	3,4	46	1,33
Białowieska		proper	Br	9–30	l.s.	4,2	2,8	16	0,48
		[moder]	BrC	30–80	l.s.	4,4	2,4	12	0,13
			C	>80	l.s.	4.6	2.6	28	0.06
Puszcza	2 (667)	podzolic	A1A2	0–16	l.s.	3,2	3,1	20	1,32
Białowieska		proper	B	16–28	l.s.	3,8	2,3	46	0,73
		[mor-	BC	28–75	l.s.	4,3	2,3	36	0,31
		-moder]	C	>75	l.s.	4.5	3.7	46	0.03
Puszcza	3 (538)	podzolic	A1A2	0–11	l.s.	2,8	5,6	32	2,70
Białowieska		proper	A2	11–17	l.s.	3,9	2,9	40	1,13
		[mor]	B	17–29	l.s.	3,4	2,3	25	0,55
			BC	29–64	l.s.	4,5	2,8	30	0,28
			C	64	l.s.	5.0	2.3	23	0.03

Type of sand: l.s.– loose sand, c.s.– coarse sand.

SPATIAL DIVERSITY OF THE GROUND LAYERS OF THE FOREST PHYTOCENOSES STUDIED

An investigation of the spatial diversity of the ground layers of plant associations growing in the study areas was carried out in four regions: Roztocze, Bory Tucholskie, Puszcza Biała and Puszcza Białowieska. At each stand, a plot representative of the whole association was selected and in this plot a "grid" (25× 25m) was chosen. The "grid" was then divided into 25 basic research fields (5× 5 m) squares). A releve protocol was taken at each of the basic fields (25 protocols at a stand). The protocols comprised the layers of shrubs, herbs and bryophytes.

The investigation consisted of:

– an analysis of coefficiency of releve protocols taken at each "grid" (the data from all the stands in one region were analysed collectively). The analysis was based on Czekanowski's coefficient (Fig. 1–4) and served to draw the borders of spatial groups of basic research fields (Fig. 5).

– an analysis of average coefficiency index values obtained for the 25 basic research fields at each of the stands (Tab. III).

– an analysis of frequency of species within each stand – frequency index was calculated for each "grid" (Tab. IV).

– an analysis of abundance and spatial distribution of selected plant species (*Vaccinium myrtillus*, *Calluna vulgaris* and *Melampyrum pratense*) and groups of species (ferns and grasses), as well as of certain characteristics of the phytocenosis structure (Fig. 6–8, Tab. V).

– an analysis of coefficiency of stands, based on the data concerning the frequency of various species in the "grids" (Fig. 9, Tab. VI).

Table III. Average values of coefficiency indices

Region	Number	P average coefficiency index	S
Roztocze	1	77.1	6.8
Roztocze	2	78.9	6.5
Roztocze	3	67.3	8.0
Bory Tucholskie	1	70.3	9.1
Bory Tucholskie	2	75.5	7.2
Bory Tucholskie	3	77.7	6.2
Puszcza Biała	1	73.2	7.8
Puszcza Biała	2	69.7	7.8
Puszcza Biała	3	69.1	8.5
Puszcza Białowieska	1	69.8	8.1
Puszcza Białowieska	2	69.1	7.9
Puszcza Białowieska	3	70.0	8.3

Table IV. The frequency of species within the "grids"

Frequency	Roztocze			BoryTucholskie			P.Biała			P.Białowieska			Average values classes		
	1	2	3	1	2	1	1	2	3	1	2	3	L-P	P-P	both
1-2	9	9	17	12	7	4	16	14	11	21	13	13	9.7	14.7	12.2
3-5	3	2	3	1	1	7	5	7	5	5	12	5	2.8	6.5	4.7
6-8	1	1	1	4	2	0	4	5	8	6	4	0	1.5	4.5	3.0
9-11	1	1	4	0	1	2	4	2	2	3	4	3	1.5	3.0	2.2
12-14	1	0	1	1	1	0	0	0	2	1	1	0	0.7	0.7	0.7
15-17	0	2	2	1	1	2	1	4	3	2	5	2	1.3	2.8	2.1
18-20	1	3	2	1	1	3	0	2	0	1	0	3	1.8	1.0	1.4
21-23	1	1	1	2	0	3	1	1	0	7	5	2	1.3	2.7	2.0
24-25	5	5	7	6	6	6	9	8	9	7	8	4	5.8	7.5	6.7
Nr sp.	22	24	38	28	20	27	40	43	40	53	52	32	26.5	43.3	34.9

L-P – *Leucobryo-Pinetum*, P-P – *Peucedano-Pinetum*

Table V. Some characteristics of the ground layer structure of the phytocenoses studied. Average data from 25 basic research fields situated in a stand

Stands		a	b	c	d	e	f
Roztocze	1	50.7	–	16.9	+	18	10
Roztocze	2	31.5	2.6	24.7	+	28	16
Roztocze	3	18.4	+	16.0	25.5	24	29
Bory Tucholskie	1	27.8	13.3	0.1	9.9	41	10
Bory Tucholskie	2	0.4	16.8	+	2.2	71	8
Bory Tucholskie	3	38.6	6.1	4.7	0.1	45	9
Puszcza Biała	1	17.1	18.4	27.1	16.9	38	2
Puszcza Biała	2	13.9	20.0	12.7	6.2	55	4
Puszcza Biała	3	36.7	3.1	2.4	5.5	44	4
Puszcza Białowieska	1	12.3	14.8	0.3	31.1	33	16
Puszcza Białowieska	2	37.4	3.4	3.3	33.9	38	10
Puszcza Białowieska	3	44.5	+	1.9	2.1	9	38

a – percentage of *Vaccinium myrtillus*, b – percentage of *Calluna vulgaris*, c – percentage of *Melampyrum pratense*, d – total area occupied by grasses, e – percentage of bryophytes minus percentage of herbs, f – area not occupied by bryophytes.

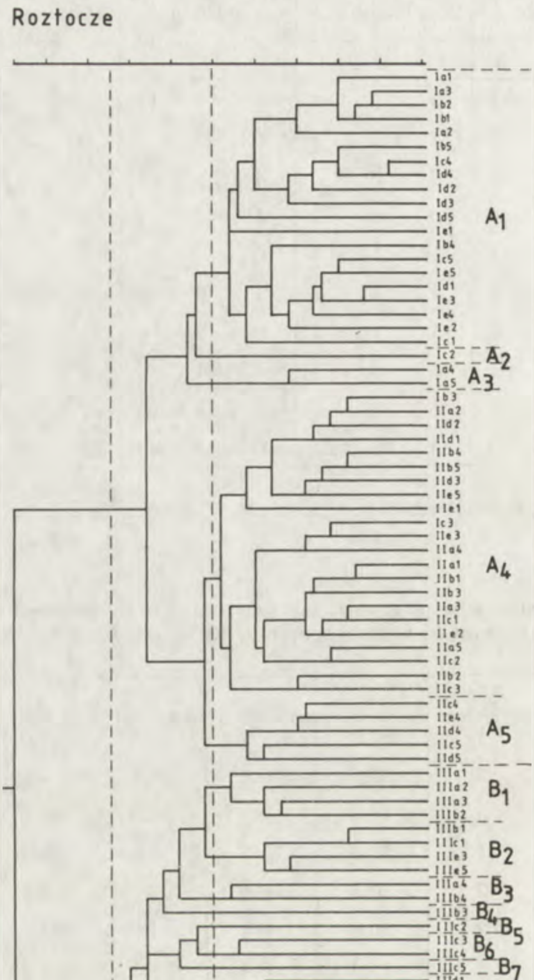

Fig. 1. Roztocze – a dendrogram grouping 75 basic research fields (5 × 5m) estimated after Czekanowski's coefficient and the farthest neighbour clustering method. Spatial groups of basic research fields are separated. Stands are marked with Roman numerals, and the basic research fields, with a combination of a lower-case letter and a numeral. The division of the fields into groups was done on two distinct bases.

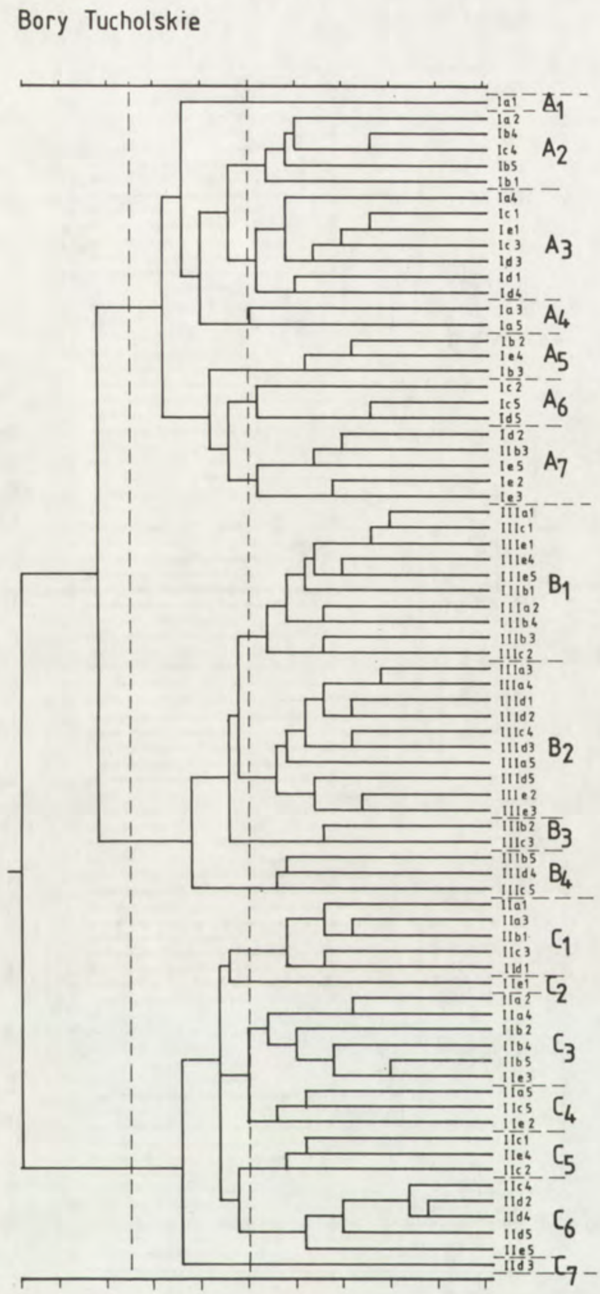

Fig. 2. Bory Tucholskie – a dendrogram of 75 basic research fields. For details see Figure 1.

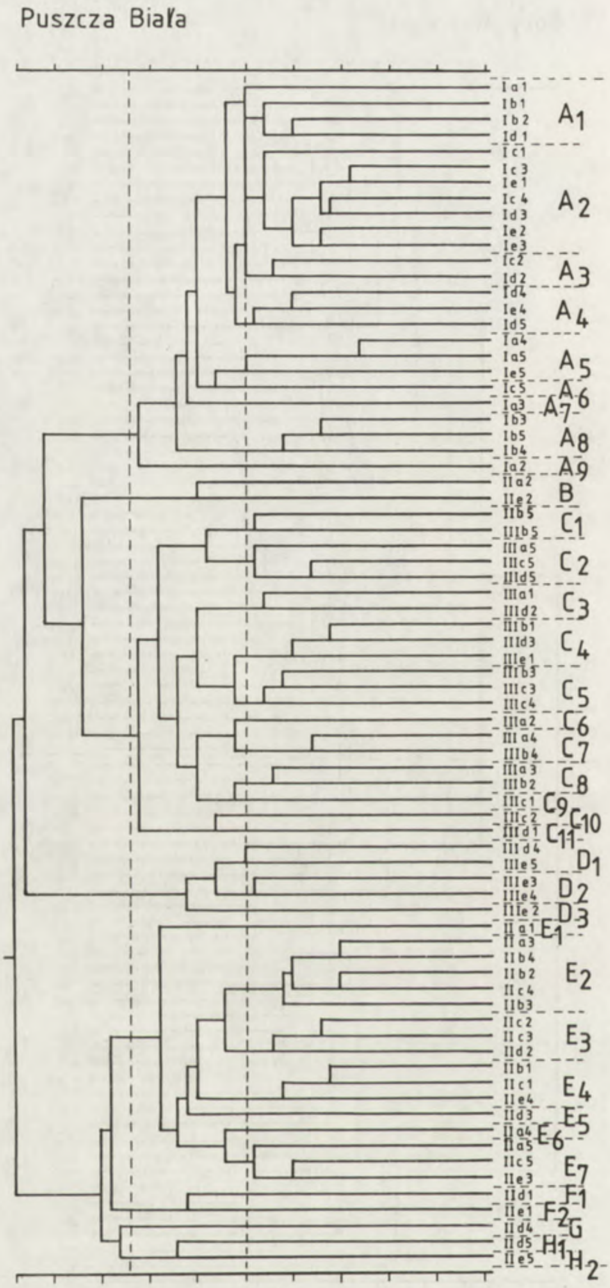

Fig. 3. Puszcza Biała – a dendrogram of 75 basic research fields. For details see Figure 1.

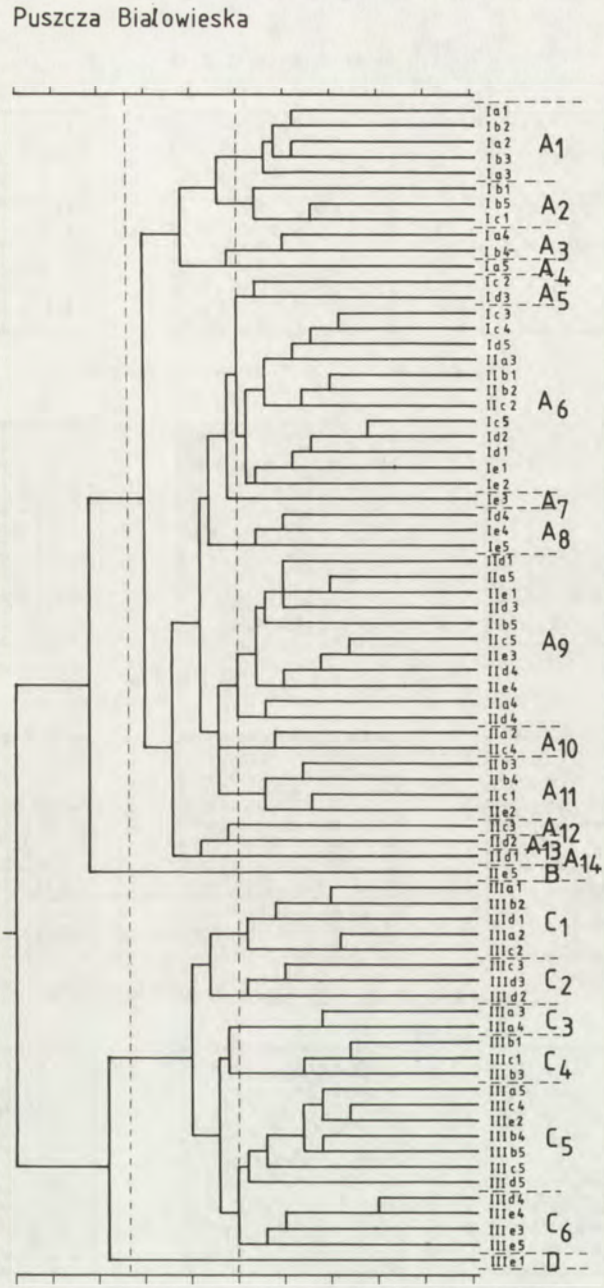

Fig. 4. Puszcza Białowieska – a dendrogram of 75 basic research fields. For details see Figure 1.

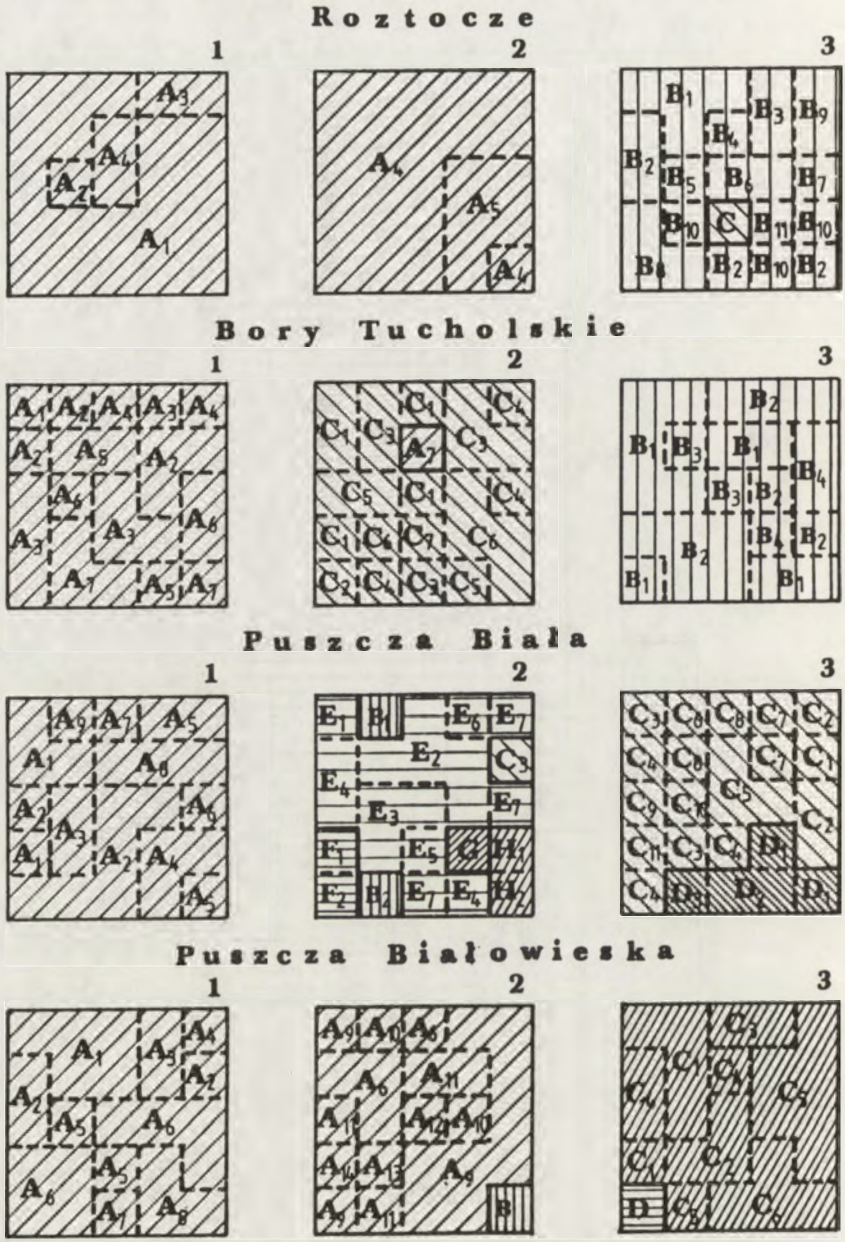

Fig. 5. Division of the basic research fields into spatial groups, based on Figures 1–4

Table VI. A matrix of coefficiency indices of the stands. Czekanowski's coefficient values obtained from the data on frequency of species in the "grids"

	R1	R2	R3	T1	T2	T3	BK1	BK2	BK3	B1	B2	B3
R1	100	77	60	60	51	57	56	40	48	37	39	48
R2	77	100	69	62	56	60	56	44	49	47	47	49
R3	60	69	100	57	45	61	52	48	53	49	53	57
T1	60	62	57	100	72	69	73	59	63	52	51	56
T2	51	56	45	72	100	62	53	39	46	36	34	34
T3	57	60	61	69	62	100	56	52	50	47	49	52
BK1	56	56	52	73	53	56	100	68	76	61	61	57
BK2	40	44	48	59	39	52	68	100	76	56	56	49
BK3	48	49	53	63	46	50	76	76	100	60	59	53
B1	37	47	49	52	36	47	61	56	60	100	84	55
B2	39	47	53	51	34	49	61	56	59	84	100	61
B3	48	49	57	56	34	52	57	49	53	55	61	100

R – Roztocze, T – Bory Tucholskie, BK – Puszcza Biała (Kurpiowska), B – Puszcza Białowieska.

Analysis of homogeneity of the plant associations studied.

Two conclusions can be drawn from the analysis that hold true for each region:

– although the basic research field of 25 sq.m. is a relatively small part of a phytocenosis, such areas are usually representative of the "grids" they are situated in and, in most cases, show a greater similiarity to other basic research fields located in the same "grid" than to fields situated in other stands of the same region (Fig. 1–4). Only in 4 cases out of 300 were the basic research fields more similar to areas located in some other "grid" rather than to any area situated in "their grid". This means that information about certain specific structural features of a given phytocenosis can be elicited from an area as small as 25 sq.m.

– it was observed that the basic research fields which exhibit a high degree of similarity form a whole composed of a dozen or so fields (Fig. 5). Thus, the inner structure of a phytocenosis shows, within which plots as large as several hundreds of square meters can be seen. Apart from large structures, smaller ones can also be observed, with an area of several dozens of square meters. The smaller structures often arise in connection with irregular distribution of the cover of shrubs. One should also expect even smaller structures to exist in a phytocenosis. These structures, however, cannot be observed with the basic research field as large as 25 sq.m.

A comparison of the degree of complexity of the plant communities studied shows that stands 1 and 2 in Roztocze have much more homogenous structures than any of the remaining stands. On the other hand, stands 2 and 3 in Puszcza Biała as well as stands 1 and 2 in Bory Tucholskie and stand 3 in Roztocze exhibit a high degree of heterogeneity. The diversity of the spatial structure, as observed within one "grid", may be of a "patchwork" nature – when similar study fields are situated in different parts of a "grid", or of a "cluster" nature – when similar study fields group together to divide a "grid" into distinct parts. The former type of spatial diversity is observed in the majority of the stands, while the latter is found at stand 1 in Puszcza Białowieska where the "upper" study fields are located at the top of a local elevation with a higher proportion of xerothermal species, while the "lower" fields with poorer floristic composition are situated literally lower. Stand 3 in Puszcza Biała and stand 2 in Puszcza Białowieska are less characteristic examples of the aggregation type of spatial diversity.

The data on average coefficiency of the study fields in one "grid" (Tab. III) provide a basis for classification of the stands studied into groups of increasing degree of stand heterogeneity:

– the most homogenous: stands 1 and 2 in Roztocze,

– less homogenous: all the stands in Bory Tucholskie and stand 1 in Puszcza Biała,

– the least homogenous: all the stands in Puszcza Białowieska, stands 2 and 3 in Puszcza Biała and stand 3 in Roztocze.

Differences in the frequency of plant species registered in the areas studied.

Two groups of plant species can be easily distinguished in the species composition structure of pine forest phytocenoses. The first group comprises species that are found almost in every basic research field (the 5 × 5 square), while the other group consists of rare species i.e. those which are found in 1 or 2 basic research fields only (Tab. IV). The number of species in the second group is twice bigger than in the first group. Taken together, both groups account for more than fifty per cent of the plant species found in pine forests. A more detailed analysis will reveal that from among herbaceous plant species, 2 to 6 are found in every basic study field, more species being registered in the subcontinental (*Peucedano-Pinetum*) than in the suboceanic (*Leucobryo-Pinetum*) type of pine forest. As far as bryophyte species are concerned, two species occur almost in every basic research field in a "grid".

The number of species which are regularly found in a phytocenosis may vary. The species registered in all the four regions are: two moss species (*Dicranum undulatum* and *Entodon schreberi*), two species of dwarf shrubs (*Vaccinium myrtillus* and *V. vitis-idaea*) and one annual herbaceous plant (*Melampyrum pratense*).

The *Peucedano-Pinetum* type of pine forest was shown to have much richer floristic composition than the *Leucobryo-Pinetum* forest type (Tab. IV). The pine forest in Puszcza Białowieska have particularly rich floristic composition except stand 3, which is indicative of a disturbance of phytocenosis structure at this stand.

Percentages of selected plant species in the study areas

A detailed analysis was carried out of the occurrence of the following plant species and groups of species: whortleberry (*Vaccinium myrtillus*), heather (*Calluna vulgaris, Melampyrum pratense*), fern species (in fact, one fern species was found, namely, *Dryopteris spinulosa*) and various grass species (Fig. 6–8 and Tab. V).

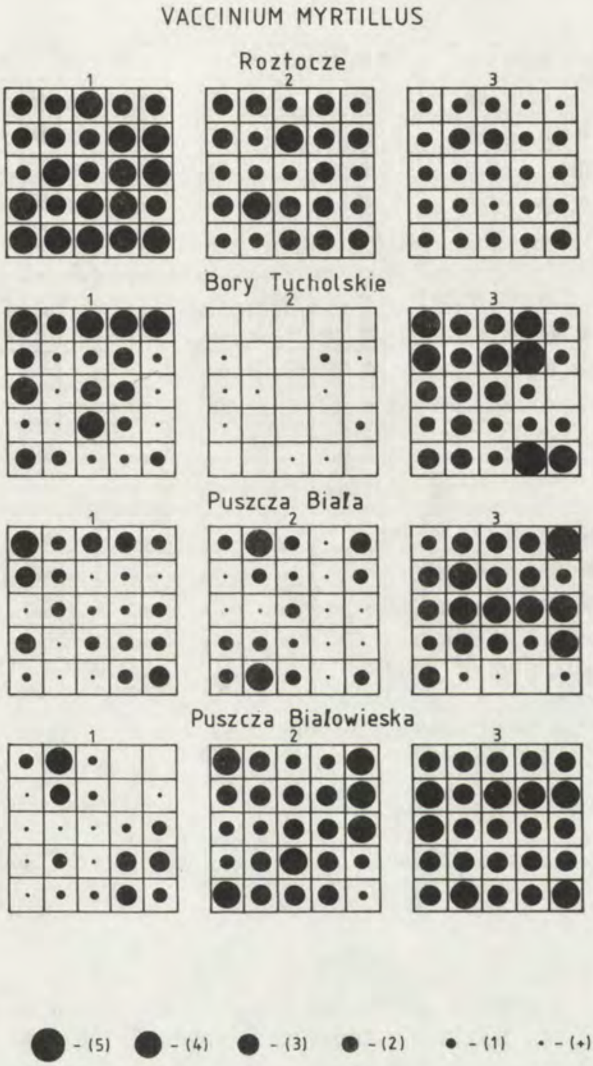

Fig. 6. Distribution of *Vaccinium myrtillus* in the research fields (6-grade quantitative scale by Braun-Blanquet)

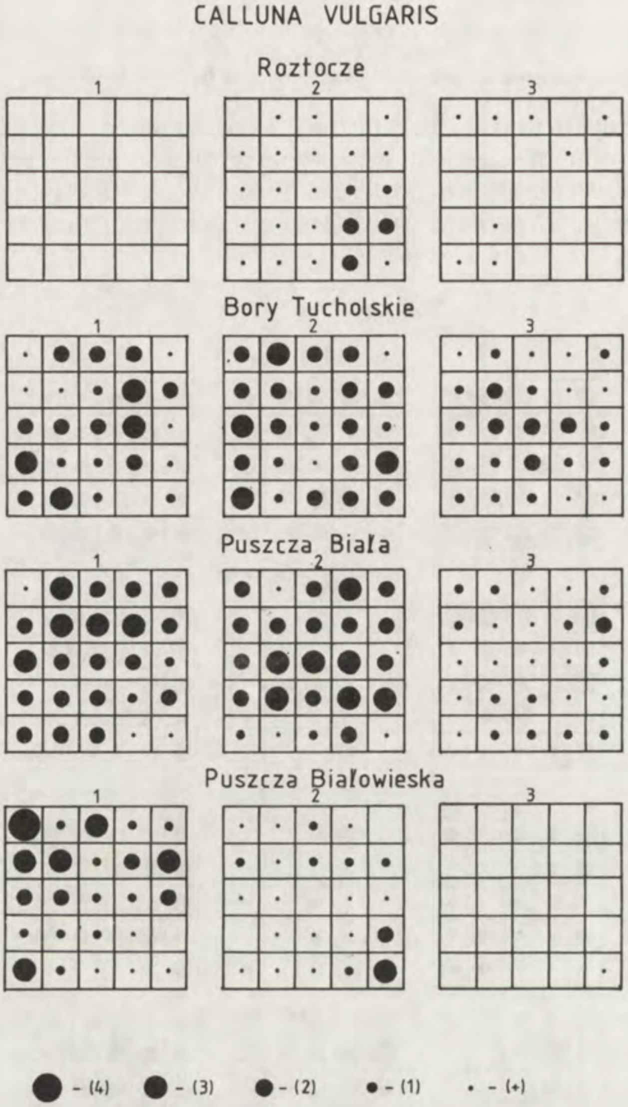

Fig. 7. Distribution of *Vaccinium myrtillus* in the research fields (6-grade quantitative scale by Braun-Blanquet)

Whortleberry (*Vaccinium myrtillus*) is a very important species found in the ground cover of the forest phytocenoses studied. Only at stand 2 in Bory Tucholskie does this species play a minor role, which is a consequence of specific conditions of that stand, and may serve as a basis for classifying it as a variety of the *Cladonio-Pinetum* pine forest type. At any of the other stands, whortleberry specimens occupied from some 15 per cent to more than 50 per cent of the whole area. Whortleberry was either quite uniformly distributed within the area (as was revealed by the releve protocols), especially at stand 1 in Roztocze and stand 3 in Puszcza Białowieska, or it tended to form aggregation (stand 1 in Bory Tucholskie, stand 1 and 2 in Puszcza Biała and stand 1 in Puszcza Białowieska).

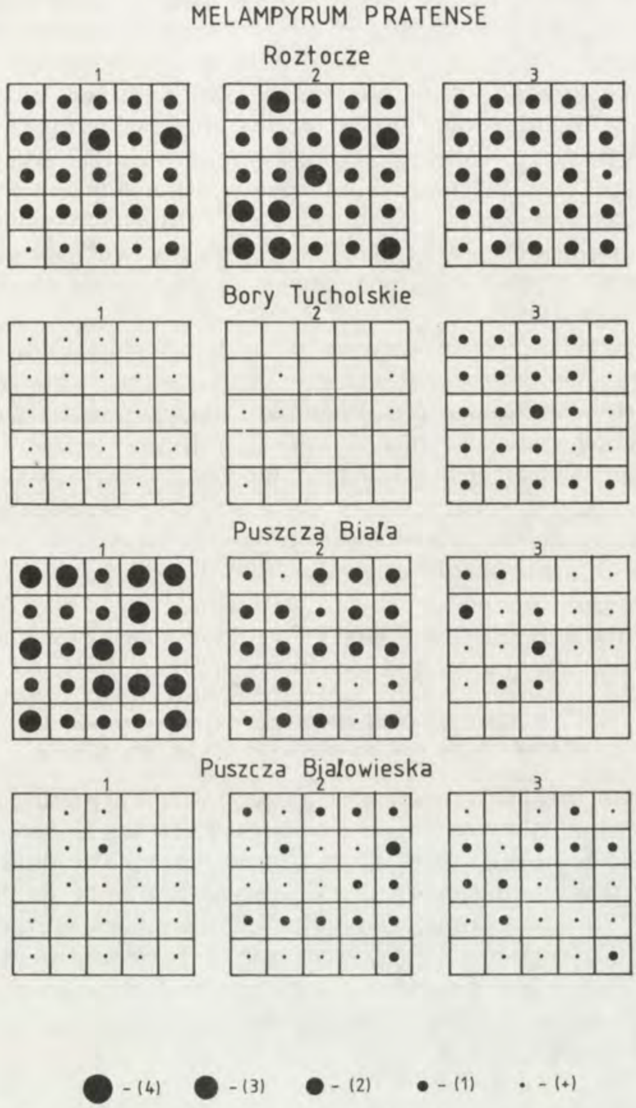

Fig. 8. Distribution of *Vaccinium myrtillus* in the research fields (6-grade quantitative scale by Braun-Blanquet)

The proportion of heather (*Calluna vulgaris*) varies considerably from stand to stand. At stand 1 in Roztocze, there are no specimens of this species because for some reason it has become extinct. At the other stands, the proportion of heather varies from "sparse" to about 20 per cent of the ground cover. This species has aggregated distribution.

Melampyrum pratense specimens were registered in all the phytocenoses studied, their contribution varying from very small to 27 per cent of the ground cover. With the 5 × 5m basic research fields, the spatial distribution of this species was usually regular. However, data from some stands show that it can form large aggregations occupying an area of several hundred square meters.

The proportion of ferns in the phytocenoses studied was small. *Dryopteris spinulosa* was occasionally registered at a couple of stands. Another fern species that occurred in phytocenoses of the type studied is *Pteridium aquilinum*. This species was registered in some of the phytocenoses studied, but it was not found within any of the "grids". This is due to the fact that this species usually grows in large aggregations and it is either by chance or due to the researcher's decision that a "grid" with an area of 625 sq.m. will or will not cover the whole aggregations. The "grids" should be much larger, if one tried to analyse the occurrence of this species.

The percentages of grass species in the phytocenoses studied also vary considerably. A phytocenosis with a larger or smaller proportion of grass species can be found in any of the regions. In general, the proportion of grasses is larger in Puszcza Białowieska and Puszcza Biała than in the remaining two regions. If the grass species were classified into latifolious (e.g. *Calamagrostis arundinacea*) and narrow-leaved (e.g. *Deschampsia flexuosa* and *Festuca ovina*) and only the first group were analysed, differences between regions would become even more evident. Although the tendency of grasses to form agregations is very noticeable in the phytocenoses, it is not confirmed by the materials collected, because such clusters are usually small, and a smaller basic research field would be required if one decided to carry out an analysis of grass populations.

Similarity of the plant associations studied (based on the frequency of species in the "grids")

A comparison of 12 stands was carried out using methods of numerical taxonomy. The analysis was based on data concerning the frequency of particular plant species in the "grids" (Tab. VI and Fig. 9). The data collected make possible a general evaluation of the degree of similarity in the associations' structure and floristic composition. The phytocenoses studied fall into two groups, which correspond to the suboceanic and subcontinental types of pine forest and into other four groups which correspond to the four regions studied. This fact confirms the previous findings based upon less precise data obtained from releve protocols.

FLORISTIC DIFFERENCES IN REGENERATION PHASES OF THE CONIFEROUS FORESTS STANDS

In order to specify the nature of floristic differences between regeneration phases of those coniferous forest plant communities that are managing by silvicultural practices, comparative analyses of the floristic composition of plant communities in various stages of conifer plantation development were carried out in three regions (Bory Tucholskie, Puszcza Biała, Puszcza Białowieska). Apart from the releve protocols taken in mature pine forest stands, another series of releve protocols was taken in areas representing three phases of forest regeneration: clear cut area seedling pine, young stand of pine in the age of about 10 years and pine pole woods of pine in the age of about 60 years. Three representatives of each regeneration phase were selected. The researchers usually selected stands located near a mature coniferous forest phytocenosis.

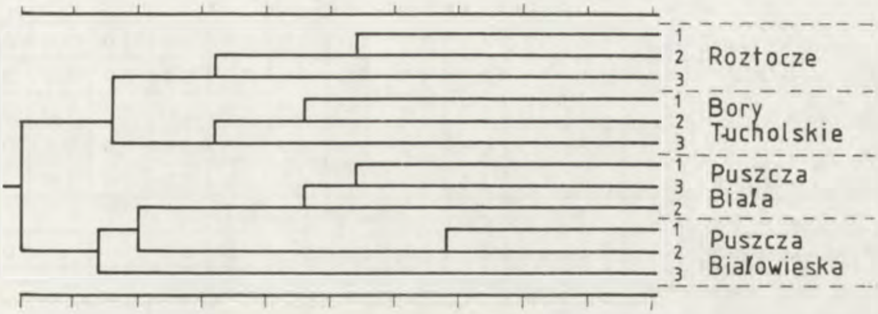

Fig. 9. Basic research fields coefficiency graph based on data concerning the frequency of species in the "grids" – a dendrogram

The analysis of diversity of phytocenoses representing various stages of growing of a managing forest (Tab. VII) shows that the differences are relatively small even if the stands compared are as different in terms of their appearance as a mature forest and a clear-cuting one seedling of pine. The clear-cut area as well as some of the young stands contain a relatively higher proportion of those plant species which grow on newly-planted sandy grounds as *Carex ericetorum*, *C. leporina*, *Calamagrostis epigeios*, sometimes also *Spergula vernalis*, *Corenephorus canescens*, *Senecio silvaticus* or *Arctostaphylos uva-ursi*.

Table VII. Comparation of floristic composition of pine forests in various regeneration phases (Index: total coverage from three releves varies from 0.5 to 15)

Number	1	2	3	4	5	6	7	8	9	10	11	12
Region	Bory Tucholskie				Puszcza Biała				Puszcza Białowieska			
Phase	I	II	III	IV	I	II	II	IV	I	II	III	IV
Species typical for different regeneration phases												
Rumex acetosella	2.5	1.0	0.5	–	4.5	1.0	1.5	1.5	1.5	1.0	1.5	0.5
Carex ericetorum	2.0	–	0.5	0.5	2.0	0.5	0.5	0.5	1.0	1.0	–	–
Carex leporina	1.5	0.5	–	–	1.5	–	0.5	1.0	1.0	–	–	–
Spergula vernalis	1.0	0.5	–	–	2.0	–	–	–	0.5	–	–	–
Senecio silvaticus	0.5	–	–	–	3.5	–	–	–	0.5	–	–	0.5
Calamagrostis epigeios	–	–	–	–	4.0	–	–	0.5	1.5	1.0	–	–

Corynephorus canescens	1,5	–	–	–	–	–	–	–	–	–	–	–
Calluna vulgaris	4,5	5,0	3,5	3,5	2,0	5,0	2,5	3,5	8,0	4,5	3,0	1,5
Dicranum undulatum	–	11,0	9,0	11,0	0,5	8,0	8,0	10,0	3,5	8,0	8,0	6,0
Entodon schreberi	–	2,0	11,0	8,0	–	7,0	9,0	11,0	3,5	6,0	11,0	10,0
Melampyrum pratense	–	–	1,0	3,5	0,5	0,5	2,5	4,0	1,0	0,5	2,0	2,5
Vaccinium myrtillus	–	1,0	4,5	6,5	1,5	2,5	6,0	8,0	3,5	1,5	6,0	8,0
Juniperus communis	0,5	–	2,0	2,0	1,0	1,5	2,0	7,0	–	0,5	1,5	1,0
Hylocomium splendens	–	–	0,5	0,5	–	–	1,0	1,5	1,0	1,0	7,0	8,0
Frequent species in all phases												
Vaccinium vitis idaea	3,0	3,5	4,5	5,0	3,0	2,5	4,5	3,5	3,0	3,0	3,0	2,5
Festuca ovina	1,0	1,0	1,5	1,5	4,5	5,0	6,0	6,0	2,0	3,0	2,0	2,5
Luzula pilosa	–	0,5	0,5	1,0	1,5	1,0	1,0	2,0	1,5	1,0	1,0	2,0
Luzula multiflora	0,5	0,5	0,5	1,0	2,0	1,0	1,5	1,0	1,5	0,5	0,5	0,5
Polytrichum juniperinum	–	–	1,5	1,0	–	4,0	2,0	1,5	3,0	1,5	–	0,5
Differential species of regional pine forest types												
Deschampsia flexuosa	7,0	3,5	4,5	5,0	1,0	–	0,5	2,5	–	–	0,5	0,5
Anthoxanthum odoratum	–	–	0,5	–	2,5	1,5	3,0	2,0	–	–	–	0,5
Cytisus ratisbonensis	–	–	–	–	0,5	1,0	1,5	1,5	–	–	–	–
Agrostis vulgaris	–	–	–	0,5	3,5	1,0	2,5	1,5	2,5	1,5	1,0	1,0
Viola sp.	–	–	–	–	0,5	1,5	1,0	0,5	1,0	1,0	1,5	0,5
Hieracium pilosella	–	–	–	–	2,0	1,0	1,0	1,5	1,5	1,5	–	1,0
Veronica officinalis	–	–	–	–	2,0	1,0	0,5	0,5	1,5	1,0	–	1,0
Calamagrostis arundin.	–	–	1,0	0,5	2,0	7,0	1,5	1,5	5,0	4,5	6,0	4,5
Convallaria maialis	–	–	–	–	1,5	2,5	1,0	0,5	1,5	2,0	2,5	1,5
Peucedanum oreoselinum	–	–	–	–	0,5	0,5	1,5	0,5	1,0	0,5	1,5	1,0
Scorzonera humilis	0,5	0,5	–	–	0,5	0,5	1,5	0,5	0,5	0,5	1,5	1,0
Polygonatum odoratum	–	–	–	–	0,5	1,0	1,5	–	0,5	1,0	1,0	1,0
Solidago virga-aurea	–	–	–	0,5	1,0	1,0	1,5	0,5	1,0	–	1,5	1,0
Cytisus ruthenicus	–	–	–	–	1,0	0,5	0,5	1,5	3,0	2,5	1,5	1,0
Rubus saxatilis	–	–	–	–	–	0,5	-	0,5	1,5	1,0	1,5	1,5
Trientalis europaea	–	–	–	–	0,5	1,5	1,0	4,0	1,5	1,0	2,5	2,5

1 – Bory Tucholskie (for. distr. Osie, for. sect.: 319b, 15c, 3c), phase I;
2 – Bory Tucholskie (for. distr. Osie, for. sect.: 319a, 3b, 4b), phase II;
3 – Bory Tucholskie (for. distr. Osie, for. sect.: 306c, 347c, 347f), phase III;
4 – Bory Tucholskie (for. distr. Osie, for. sect.: 306d, 340, 346), phase IV;
5 – Puszcza Biała (for. distr. Ostrw Maz., for. sect.: 62g, 34f, 32), phase I;
6 – Puszcza Biała: 62d, 49f, 34c), phase II;
7 – Puszcza Biała: 48b, 46a, 63c), phase III;
8 – Puszcza Biała: 34f, 62g, 38b), phase IV;
9 – Puszcza Białowieska (for. distr. Hajnówka, for. sect.: 668Cc, 634Ec, 538Bf), phase I;
10 – Puszcza Białowieska: 668Ad, 538Bc, 538D), phase II;
11 – Puszcza Białowieska: 634Ef, 668A, 538Ba), phase III;
12 – Puszcza Białowieska: 668Af, 667Bf, 538Bf), phase IV.

Characteristic of the clear-cut area associations is the absence of a dense bryophyte layer as well as of the moss species of *Dicranum undulatum* and *Entodon schreberi* so commonly found in coniferous forests. *Melampyrum pratense* follows a similar pattern of being constant and numerous in older pine forest stands, a little less numerous but still constant in younger stands and usually absent from the clearing associations and young growths of pines. Similarly, the fern *Dryopteris spinulosa* grows in medium-age and mature forest stands. Whortleberry *(Vaccinium myrtillus)* is found almost in all the plots, but it can grow luxuriantly only in medium-age and mature forest stands.

Generally, it can be said that unlike deciduous forests, coniferous forest plant communities of clearings and young stands are not distinct in phytosociological terms. Communities growing in such stands are composed of some of typical pine forest species and of a few species specific to sandy grounds. The floristic differences between regional varieties of pine forest are larger than the differences between forests in different regeneration phases situated in one region.

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STRESZCZENIE

Praca przedstawia wyniki badań geobotaniczno-glebowych, jakie zostały wykonane na powierzchniach badawczych Instytutu Zoologii PAN. Zakres ich był określony z uwagi na potrzeby analizy zoocenologicznej. Badania przeprowadzono w pięciu regionach Polski: w Wielkopolsce (nadl. Babimost), na Roztoczu (Roztoczański Park Narodowy, w Borach Tucholskich (nadl. Osie), w Puszczy Białej (nadl. Ostrów Mazowiecka) i w Puszczy Białowieskiej (nadl. Hajnówka). Obejmowały one następujące etapy:

– diagnozę fitosocjologiczną, której celem była ogólna charakterystyka fitocenoz, kwalifikacja syntaksonomiczna i porównanie międzyregionalne pomiędzy dojrzałymi fitocenozami (Tab. I);

– ocenę warunków glebowych, której celem była klasyfikacja badanych gleb, określenie typu próchnicy nadkładowej oraz oznaczenie niezbędnych z punktu widzenia badania fauny glebowej właściwości fizyko-chemicznych (Tab. II);

– analizę fitocenoz, mającą za zadanie scharakteryzowanie zróżnicowania przestrzennego warstw przyziemnych zbiorowiska roślinnego (Tab. III, IV, V i VI);

– analizę zmian składu florystycznego różnych faz regeneracji zbiorowiska boru po dokonanym wyrębie drzewostanu (Tab. VII).

Badane zbiorowiska reprezentowały mniej lub bardziej odkształcone postacie dwu regionalnych zespołów borów sosnowych świeżych: *Leucobryo-Pinetum* (Wielkopolska, Roztocze i Bory Tucholskie) i *Pseucedano-Pinetum* (Puszcza Biała i Puszcza Białowieska). Zespół *Pseucedano-Pinetum*, związany z obszarami o kontynentalnym klimacie w strefie lasów mieszanych, charakteryzował się

wyraźnie większym bogactwem florystycznych płatów, w tym szczególnie udziałem gatunków o tzw. zasięgu sarmackim typie, niż środkowoeuropejski zespół *Leucobryo-Pinetum*.

Wszystkie badane gleby wykształcone zostały w podobnych warunkach litologiczno-petrograficznych. Podłożem dla ich rozwoju były piaski, różniące się jednak pod względem genezy (piaski morenowe i glacjofluwialne – Puszcza Biała, piaski glacjofluwialne – Puszcza Białowieska, Bory Tucholskie, i piaski fluwialne – Roztocze) oraz składu mechanicznego (od piasków luźnych do słabogliniastych).

Niezależnie od właściwości litologiczno-petrograficznych materiału geologicznego, wszystkie gleby charakteryzowały się kwaśnym odczynem (pH < 5,5), małym stopniem nasycenia kompleksu sorpcyjnego kationami o charakterze zasadowym (V < 20) i wysokim stosunkiem C : N. Z punktu widzenia typologii gleboznawczej wszystkie z badanych gleb zaliczyć można do klasy gleb bielicoziemnych, obejmujących dwa typy: gleby bielicowe i gleby rdzawe, z próchnicą nakładową typu mor, w różnych wariantach.

Porównania jednorodności zbiorowisk roślinnych dokonywano w dwunastu dojrzałych fitocenozach (po trzy stanowiska w czterech regionach) poprzez wykonanie spisów florystycznych na powierzchniach w układzie „krata" (25 powierzchni po 25 m^2 na jednym stanowisku) i przeprowadzenie analizy podobieństwa podstawowych kwadratów (Ryc. 1, 2, 3 i 4). Stwierdzono, że powierzchnie podstawowe 25 m^2 wykazują istnienie w obrębie fitocenoz pewnych jednostek strukturalno-przestrzennych (Ryc. 5), a równocześnie umożliwiają rozpoznanie konkretnej fitocenozy. Średnie podobieństwo podstawowych kwadratów potraktowano jako miarę jednorodności fitocenozy (Tab.III) i na tej podstawie dokonano przeglądu poszczególnych zbiorowisk.

Na podstawie spisów florystycznych z „krat" przeprowadzono analizę przestrzennego zróżnicowania udziału poszczególnych gatunków roślin ważnych dla badań zoocenotycznych (Ryc. 6, 7 i 8) i ich roli w fitocenozach (Tab. V).

Analizowano częstość pojawiania się poszczególnych gatunków w fitocenozie (Tab. IV), przy czym stwierdzono dwa główne typy roli poszczególnych populacji roślinnych w zbiorowiskach borowych: gatunki bardzo częste w zbiorowisku i gatunki pojawiające się w niewielkiej liczbie osobników. Stwierdzono także wyraźne różnice między zespołami regionalnymi w strukturze gatunkowej fitocenoz (Tab. VI, ryc. 9).

Z przeprowadzonej analizy fitosocjologicznej zmian zbiorowisk borowych w trakcie regeneracji po wycięciu drzewostanu, przeprowadzonej dla trzech regionów (Tab. VII) wynika, że różnice w składzie florystycznym kolejnych stadiów są stosunkowo niewielkie (stosunkowo największe na świeżych porębach), znacznie wyraźniejsze są natomiast zmiany ilościowe poszczególnych gatunków.

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