Geographical Differentiation of the Floristic Composition and Structure of the Herb Layer of Forest Permanent Plots in East Germany, Poland, and Belarus[1]

Ewa Roo-Zielinska, Jerzy Solon[2]

Abstract

The influences of a geographical location on floristic composition, horizontal structure, and biomass of the herb layer in pine and mixed pine forest communities along climatic and pollution gradients in East Germany, Poland, and Belarus were determined. Phytosociological records were collected in permanent plots in May 1995. Each record covered an area of 400 m². The floristic composition of the study area provided the basis for the determination of the phytosociological differentiation of the plots along the transect. Similarity index between plots was calculated by using the Czekanowski index; a similarity dendrogram was constructed according to Ward's method. Biomass was determined in six 0.1 m² replications sampled in each permanent plot. All of the identified study areas were representative of the Dicrano-Pinion *alliance and included two communities of pine forest (*Peucedano-Pinetum *and* Leucobryo-Pinetum) *as well as the community of mixed pine forest* (Querco roboris-Pinetum). *On the basis of similarity indices, two geographical groups of plots were distinguished: suboceanic and subcontinental. Geographical differentiation of the stands is related to the presence of the groups of species of different geographical distribution type. For the western part of the transect, characteristic species are* Deschampsia flexuosa *and* Leucobryum glaucum. *Central and eastern parts are characterized by the presence of the following species:* Melampyrum pratense, Luzula pilosa, Veronica officinalis, Lycopodium clavatum, Peucedanum oreoselinum *and* Scorzonera humilis. *On the stands located on the easternmost part of the transect (Belarus) frequent species are:* Pirola chlorantha, Chimaphila umbellata, Koeleria pyramidata *and* Hypochoeris maculata. *The ground flora of the identified areas was not uniform; rather it was characterized by a mosaic of sparse populations of plants. In general, three types of these systems can be distinguished: one is dominated by a cover of mosses, the second is dominated by dwarfshrubs, and the third by species of grass. The ground cover biomass on the west-east transect ranged from 49 to 544 g/sq. m, but for pine forests the correlation between geographical longitude of the stand and biomass of mosses (corr. coeff. 0.701) and total biomass of the ground cover (corr. coeff. 0.779) was statistically significant.*

Introduction

This article presents a geobotanical analysis of the floristic composition of the herb layer and its structure and biomass in East Germany, Poland, and Belarus. It constitutes part of long-term, in-depth community research aimed at defining the influence of geographical location on pine forest ecosystems, in particular pine forests and mixed/pine forests (Breymeyer 1996, Degórski 1996, Smialkowski 1996).

The subjects of geobotanical analyses consisted of 17 permanent plots lying along a west-east transect following the gradient of continentality. These are mature or almost mature pine stands, basically single-species and single-aged (60-95 years). All the analyzed forest communities represent (in accordance with phytosociological typology) the *Dicrano-Pinion* alliance, and within it two communities of pine forest, *Peucedano-Pinetum* and *Leucobryo-Pinetum*, as well as the community of mixed pine forest, *Querco roboris-Pinetum*. In accordance with the principles of forest typology these are different forms of pine forest occurring on sandy substrates. Their economic use does not differ significantly.

The level of differentiation of the herb layer is one of the more important structural characteristics of forest phytocoenoses. On the one hand it influences the spatial differentiation for various processes like the production and decomposition of organic matter, and on the other it may be an indicator of habitat microdifferentiation (in particular topography, fertility, and humidity). A way of describing the level of diversity of the herb layer is through the identification,

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[2] Botanists, Institute of Geography and Spatial Organization, Polish Academy of Sciences, 00-927 Warsaw, Krakowskie Przedmiescie 30, Poland.

analysis, and typology of synusiae. Synusia is a grouping, within one layer of a community, of species characterized by similar life forms and similar ecological requirements. The synusia is sometimes used as a basic spatial unit, as well as a functional-temporal unit within a phytocoenosis (Gillet 1986, Julve and Gillet 1994, Mavriscev 1980).

Because the herb layer reacts most actively to all environmental variables, we attempted to define the influence exerted by climatic differentiation and habitat (also microhabitat) conditions on the species composition, structure, and biomass of the herb layer. The floristic composition and structural characteristics of the studied communities depend on many factors, such as:

- Geographical location, which determines both the richness of the local flora (influencing the occurrence of species of a defined type of range), and is an indicator of macroclimatic differentiation. Climatic characteristics (in particular mean annual temperature, the temperature of the warm and cold periods of the year and total precipitation) have a considerable influence on the phenology and competitive abilities of different populations;
- The type and properties of the habitat, mainly its fertility and humidity, which influence the presence or absence of the species building up a given phytocoenosis;
- Anthropogenic influences linked with the pollution of the environment, the history of its use, and the maturity of phytocoenoses.

This paper describes a study to define the mutual similarities and homogeneity of the study sites on the basis of the floristic composition of the herb layer in East Germany, Poland and Belarus; presents the synusial differentiation of the herb layer; draws up a typology of the pre-analyzed synusias, and defines the mean biomass within the different types of synusia and within the study areas.

Methods

Floristic Composition

The basis for the description of the 17 study sites used in this study was a floristic characterization of the patch of vegetation representing a given type of community and described in the form of a phytosociological record. This contained the following basic information on a given patch of vegetation: the species composition; cover (i.e., the proportion of the area occupied by each species); and layer structure (vertical structure of the community), identified most often as A–trees, B–shrubs, C–herbs, D–ground cover of mosses and lichens. The majority of phytosociological records were taken in May 1995. Each record covered about 400 m^2. The quantitative representation (cover) of species was estimated by using a modified 12-point scale on which r, +, and 1, refer to 0.1 percent, 0.5 percent, and as high as 10 percent, respectively, while the remaining values from 2-10 relate to the successive 10 percent divisions. Vascular plant species were defined by using the key of Szafer and others (1969) and the nomenclature of Rothmaler (1976), while nomenclature of mosses followed Szafran (1957, 1961), liverworts followed Rejment-Grochowska (1950) and lichens followed Faltynowicz (1993).

The phytosociological records obtained were presented in an unordered table, which was interpreted and described in accordance with the system of classification and list of diagnostic species of Matuszkiewicz (1981).

By using Czekanowski's measure of distance, we calculated the mutual similarity of the identified forest communities on the basis of the floristic composition of the herb layer. This was presented with the aid of a dendrogram produced by using Ward's method (Solon 1994).

Synusial Structure

The basis for the description of the synusial structure of an area's ground cover was field mapping of the most typical 5 by 20 m rectangular areas in 9 out of 17 study sites (N1, K092, K098, K061, K023, K055, K117, K126 and K011) lying on the west-east transect in Germany and Poland. In addition, floristic inventories were carried out within the different synusiae. These were the bases for the identification of types of synusia. Inclusions in the typological table were confined to those species whose cover was greater than 10 percent. The mapping and inventory of plant species was done in May 1995.

The similarity of the floristic compositions of different synusiae was calculated by using Czekanowski's measure of distance and presented with the aid of a dendrogram produced by using Ward's method (Solon 1994).

Biomass

Biomass was determined once during September and October 1995 at all 17 sites. Six circular biomass samples were taken from a 0.1 m^2 area of each permanent plot. The choice of the area for replicates was not random; rather, we attempted to take replicates of the dominant types of synusiae at a given study site. The entire biomass was collected in the field and then sorted into living moss biomass and higher plants. The dead parts of plants were removed. The samples were dried to constant weight at a temperature of 90 °C and weighed to an accuracy of 0.01g. The results obtained were averaged for the type of synusia and for the study area and recalculated per m^2.

Results

Floristic Composition

Areas K092 and K023 had *Leucobryo-Pinetum* pine forest in the typical form, while area K061 had a more humid variant with *Molinia caerulea*. In contrast, the two areas N1 and K098 were occupied by communities occurring in an acid beech forest habitat (*Luzulo-Fagion* alliance) or by mixed-pine forest, although they are almost identical to the communities representing *Leucobryo-Pinetum*. The *Peucedano-Pinetum* community is represented by areas K011, B2, B3 and B5 (type or sub-boreal forms), as well as by a more humid variant with *Molinia caerulea* on areas S023 and B7. The remaining areas had mixed pine forest (*Querco roboris-Pinetum*), with the typical form on areas K055, K126, B1, B4 and B6, and area K117 consisted of a degraded habitat that was a poor form of oak-linden-hornbeam forest *Tilio-Carpinetum*.

Analysis of the similarity of the species composition of vascular plants between the different sites clearly points to the occurrence of two large groups of communities: the subcontinental and the suboceanic. But the compositions of these groups differ, depending on the manner in which similarity is defined, e.g., on the basis of cover (quantitative representation) of species or on the basis of the presence or absence of species. The core of the suboceanic group is comprised of areas N1, K092, K098, K061 and S023. As cover (quantitative representation) of species, areas K117 and K126 also belong to this group, but if defined as the similarity of the species composition, these are part of the subcontinental group.

The division into groups of lower rank is also first and foremost geographical in nature. Distinguished within the sub-Atlantic group is a western subgroup, although on the basis of cover the habitat division is more important because it clearly separates out the subgroup of sites of greater humidity (K061, S023) characterized by a greater share of purple moor grass (*Molinia caerulea*). Two geographical subgroups may also be clearly distinguished within the subcontinental group. On the basis of the presence or absence of species, all the Belarus sites (B1-B7) create one subgroup, while on the basis of quantitative representation sites B1 and B3 are more similar to the Polish sites.

One of the factors in the spatial variation of the floristic composition of pine forests dependent on geographical location is the differentiation in the ranges of particular species of plant, which, at least theoretically, consist of vegetation conditions that are appropriate for their existence. A clear suboceanic character is, for example, displayed by *Deschampsia flexuos* and *Leucobryum glaucum*, while the areas of a subcontinental character are most strongly associated with such species as *Chimaphila umbellata, Hypochaeris maculata* and *Koeleria pyramidata* (*fig. 1*).

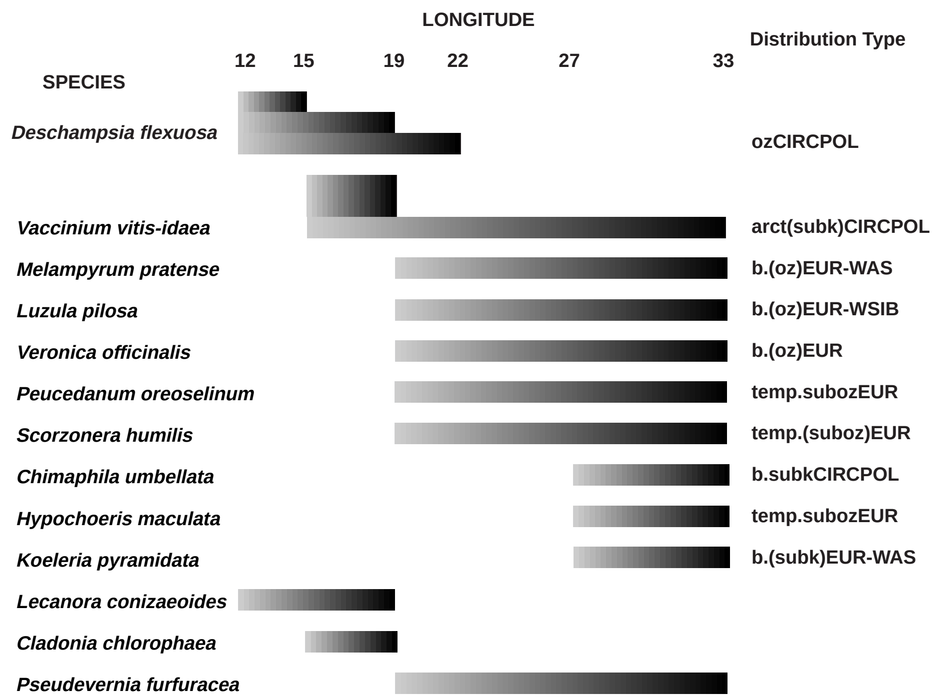


Figure 1 — Presence of chosen species along the the west-east transect (Rothmaler 1976).

Synusial Structure

On the basis of dominant species, life forms, and the degree of cover of the area with vegetation, it is possible to distinguish six main types of synusiae (*table 1*). The first type includes synusiae with an absolute dominance of *Vaccinium myrtillus*, a limited role of mosses, and the sporadic occurrence of various grassy species. The second type is characterized by the dominance of *Vaccinium vitis-idaea* and compared to the first type, it occurs in places that are drier locally. The third type includes mossy synusiae with a predominance of *Pleurozium schreberi*. This is the type occurring most frequently and at the same time most differentiated into subtypes in relation to the presence and character of codominants and subdominants. In particular, it is possible to distinguish pure mossy, mossy-cowberry, mossy-bilberry, mossy-sedge, mossy-fescue, mossy-hairgrass, and mossy-hairgrass-fescue subtypes. The fourth includes synusiae characterized by the codominance of three or four species and the lack of a clear dominant. Within this type, the first subtype includes a mossy-grassy synusia and the second a mossy-heather one. A fifth type includes a synusia with sheep's fescue (*Festuca ovina*) as dominant, while a sixth type is characterized by a very thin vegetation cover not exceeding 20 percent.

Different study areas differ clearly on the basis of the set of synusial types as well as in their spatial distribution (*fig. 2*). Mapped fragments of the areas have 2 to 4 types of synusia creating between 3 and 32 individual patches. However, mixed pine forests have a much more mosaic-like herb layer because these sites are observed to have greater numbers of patches of synusiae of different types (*fig. 2*; for example, compare sites K092 and K126).

The geographical differentiation of synusiae is poorly marked and results from differences in the ranges of the dominant species (Roo-Zielinska and Solon 1996). Western areas are associated with mossy-hairgrass, mossy-hairgrass-fescue, and mixed mossy-grassy synusiae. The majority of types of synusiae occur in both fresh pine forests and mixed/pine forests. The only synusiae to be closely associated with fresh pine forests are mixed mossy-grassy and mossy-heather, as well as mossy-bilberry and pure mossy synusiae. In contrast, mixed/pine forests more often have mossy-fescue, mossy-sedge, or fescue synusiae.

***Table 1** — Floristic composition of synusiae on the west-east transect.*

Type	I.1b	I.1a	II.1	III.2		III.1d			III.1a				III.1c	III.3		III.4
Description number	055 b	N1 a	098 c	061 a	011 d	011 b	023 b	061 d	055 c	023 a	126 a	011 c	126 d	011 a	055 a	055 d
Vaccinium myrtillus	2	5									1	1	1	4	3	3
Vaccinium vistis-idaea			3	4	4	2	3	2		1	1	1	1			
Entodon schreberi	1	2	1	3	4	4	5	5	5	4	5	5	5	5	4	5
Deschampsia flexuosa		1														
Festuca ovina		1								1	1	1	1			
Calluna vulgaris					1							1	2			
Molinia caerulea																
Carex ericetorum																
Calamagrostis arundinacea									1						1	4
Lichenes			1					1								
Bare ground	4	1	3	1	1											

Type	III.5		III.1e	III.6	III.7a	III.7.b	IV.1		V.1b	V.1a		III.1b		IV.2b	IV.2a	VI		
Description number	126 b	117 d	092 b	092 a	098 a	098 b	N1 b	023 c	117 e	117 g	117 c	117 f	117 a	061 c	061 b	126 c	117 c	061 e
Vaccinium myrtillus						2	1											
Vaccinium vistis-idaea					1	1								2				1
Entodon schreberi	5	5	5	5	5	5	3	2	2	1	1	3	3	2	2	1	1	1
Deschampsia flexuosa			1	3	3	3	3	3										
Festuca ovina	3	4	2	1	3	3	3	2	3	4	4	1	1			1	1	
Calluna vulgaris										1		1		2	3			
Molinia caerulea														2	1			
Carex ericetorum									2									
Calamagrostis arundinacea																		
Lichenes																	1	
Bare ground									1		1	2	2	1	1	5	4	4

I. *Vaccinium myrtillus* **type**
I.1. - (a - typical; b - lose)
II. *Vaccinium vitis* **- idaea type**
II.1 *Vaccinium vitis* **- idaea**
III. *Pleurozium schreberi* **type**
III.1. (a - typical; b - lose; c - with *Calluna vulgaris;*
d- with *Vaccinium vitis - idaea;*
e - with *Festuca ovina***)**
III.2. *Pleurozium schreberi - Vaccinium vitis - idaea* **subtype**
III.3. *Pleurozium schreberi - Vaccinium myrtillus* **subtype**
III.4. *Pleurozium schreberi - Calsmagrostis arundinacea* **subtype**
III.5. *Pleurozium schreberi - Festuca ovina* **subtype**
III.6. *Pleurozium schreberi - Deschampsia flexuosa* **subtype**
III.7. *Pleurozium schreberi - Festuca ovina - Deschampais flexuosa* **subtype**
IV. **mixed type**
IV.1. **mixed moss - grass subtype**
IV.2. *Pleurozium schreberi - Celluna vulgaris* **subtype**
(a - typical; b - with *Molinia caerulea*
V. *Festuca ovina* **type**
VI. **degraded**
VI.1. **strongly degraded**

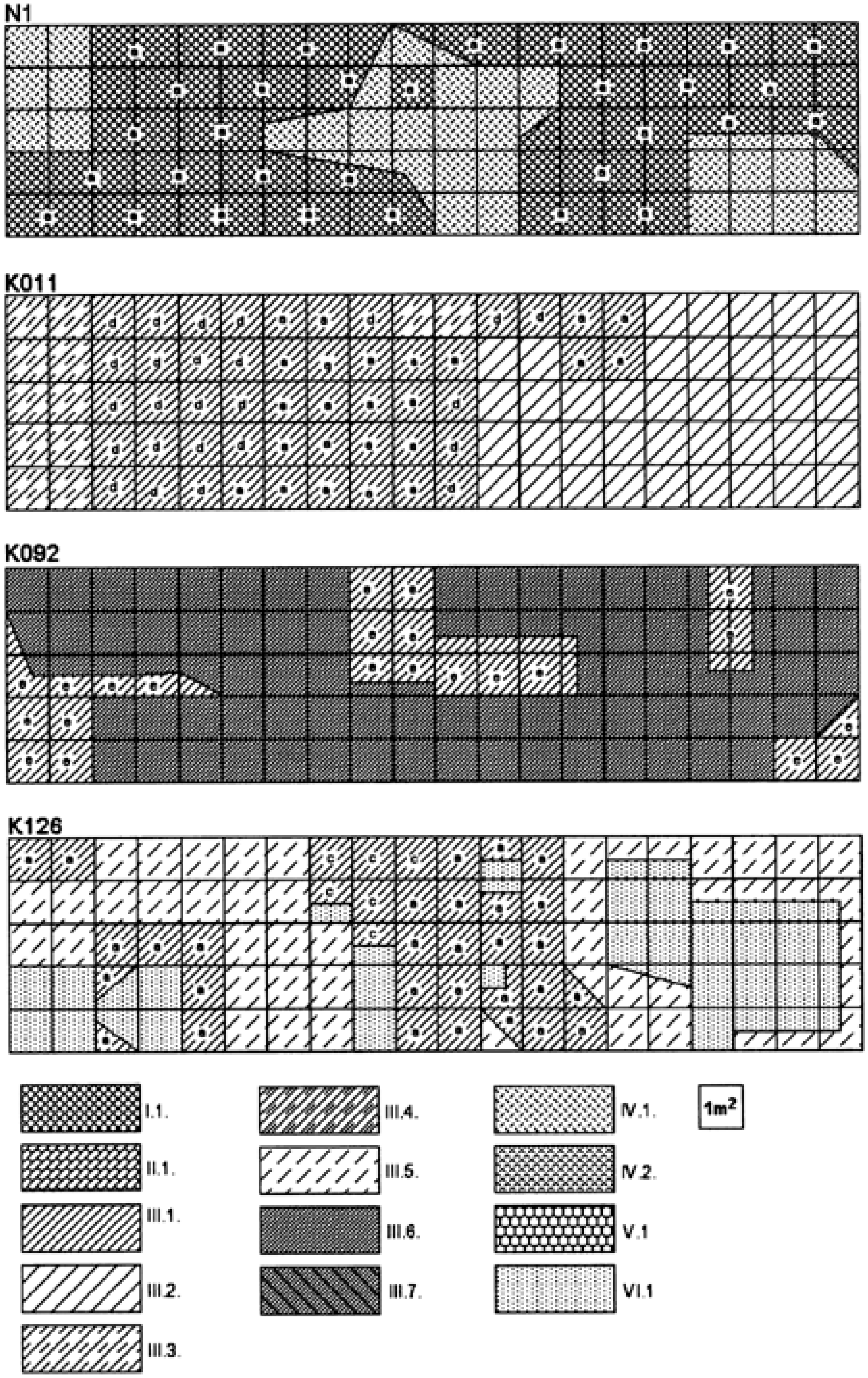
Biomass Differentiation

Biomass in Synusiae

The different synusiae and their types are highly diversified in terms of biomass of mosses and vascular plants. Degraded synusiae (type VI) have total biomass of about 15 g/m^2, while the mossy-cowberry subtype attains more than 600 g/m^2. The variability in the biomass of the different types of synusiae is also relatively great, and the differences between the most luxuriant and the poorest may be as large as 300 percent, as is the case for the mossy-bilberry subtype. This variability may only be partly explained by reference to geographical variability (*fig. 3*). The only statistically significant ($p < 0.05$) correlation ($r=0.67$) with longitude is noted for the biomass of mosses within the mossy-bilberry subtype of synusia. In the case of this subtype the correlations between longitude on the one hand, and the biomass of vascular plants and total biomass on the other are relatively great (about 0.5) but of very low significance. A similar situation is also noted in the case of pure mossy synusiae. The low level of significance of the correlation is linked with the limited abundance of the analyzed sample, and the results may attest to the limited variability of biomass in the different types of synusiae in the west-east direction.

Several types of synusia have ratios of vascular plant to moss biomass that are relatively constant and clearly different from those of other types. However, this is not a consistent ratio. In the case of the bilberry and cowberry synusiae (I and II), the ratio attains values between 4 and 5. For the mossy type (III), it is almost always below 1 (only in a few cases is it greater than 1, reaching about 3). For the mixed type (IV) it varies from about 1 to 3 and in the case of the fescue type (V) from about 3.5 to 5.5. The degraded type has values oscillating around 1, while the purple moor grass type (VII) always has a value more than 2 and sometimes much more than 10 (*table 2*).

Figure 2 — Synusial differentiation of study plots (see *table 2* for legend).



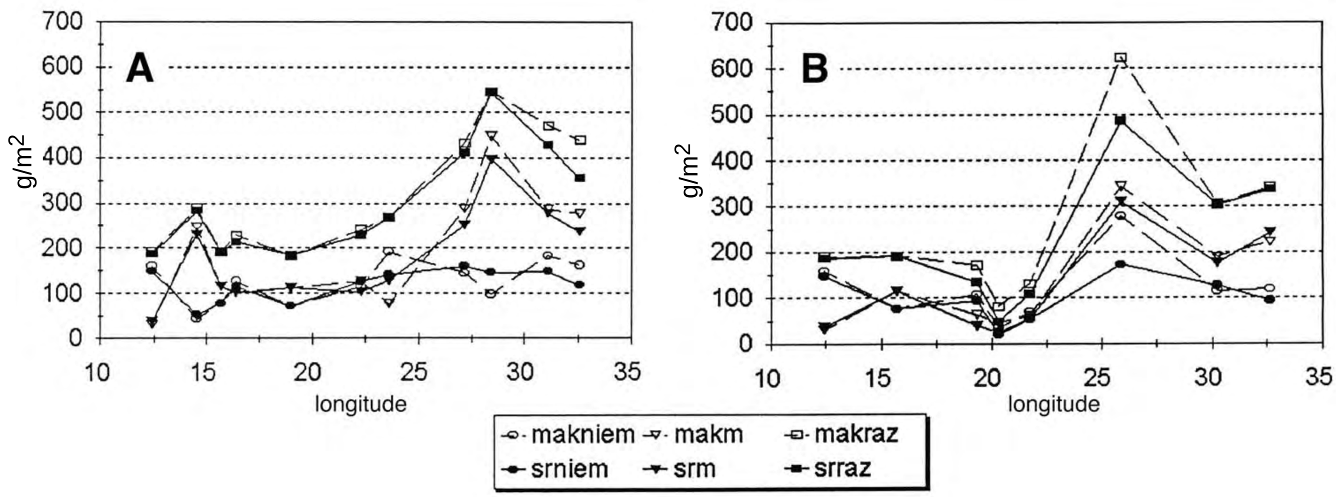


Figure 3 — Changes in biomass of study plots along the west-east transect: pine forests (A); mixed forests (B). Variables: makniem = mean biomass of vascular plants in the richest synusium of the plot; makm = mean biomass of mosses in the richest synusium of the plot; makraz = mean biomass of vascular plants and mosses in the richest synusium of the plot; srniem = mean biomass of vascular plants on the plot; srm = mean biomass of mosses on the plot; srraz = mean biomass of vascular plants and mosses on the plot.

Mean Biomass in the Community

The mean biomass of the herb layers and mossy layers at the study sites vary with geographical location (*fig. 3*). The correlation coefficient for moss biomass against longitude for all 17 sites on the west-east transect amounted to 0.701***, while the values for fresh pine and mixed/pine forests were 0.701* and 0.712*, respectively (in which ***, **, and * respectively indicate significance at the $p < 0.001$, 0.01, and 0.05 levels). Longitude is also correlated with the combined biomass of the herb layer, mosses in pine forests (0.779**), and in all sites (0.779***). If the mean biomass of the richest type of synusia is considered a site characteristic, then correlations have similar values: the correlation coefficient for moss biomass and longitude for all 17 sites on the west-east transect is 0.687***, while that for fresh pine forests is also 0.687*. Moreover, the coefficient defining the relationship between longitude and total biomass of mosses and vascular plants attains respective values of 0.847*** and 0.848***. Both mean biomass of the community and mean biomass of the richest synusia showed no statistically significant correlation between the biomass of vascular plants and longitude.

Discussion and Conclusions

Changes in floristic composition were detected along the west-east transect both within pine forests and mixed-pine forests. Differences in floristic composition correspond to differences in the habitat (connected with the division into pine forests and mixed-pine forests, and the occurrence of typical forms and wetter forms with *Molinia caerulea*) and also to the division into geographically varying communities within pine forests (the division into *Peucedano-Pinetum* and *Leucobryo-Pinetum*). The main spatial geographic factor in the variability of the floristic composition of pine forests is differentiation in the ranges of understory plant species, which find appropriate conditions for their existence in this type of vegetation. Sites in central and southern Poland may be intermediates between the well-defined western and eastern pine forests. The geographical and edaphic differentiation of the study areas is reflected most strongly in the herb layer, although it is not very visible among lichens. Differences in this group are influenced to a greater degree by local factors, including the land use history of the area, than by microhabitat factors.

Pine forests and mixed pine forests did not have homogeneous herb layers; they were differentiated into fragments creating a system of separate micro-areas varying in the dominance of particular species and life forms. A detailed analysis of the spatial variability of the biomass of the herb layer and of bryophytes was

Table 2 – Biomass differentiation (g/sq. m) of synusiae and permanent plots.

Site	Date 1995	Type	Number of replications	Herbs Mean	Herbs Standard deviation	Mosses Mean	Mosses Standard deviation	Herbs & Mosses Mean	Herbs & Mosses Standard deviation
N1	14.09.	IV.1	3	137.83	45.69	45.10	14.67	182.93	59.93
		I.1	3	159.77	24.07	31.57	33.20	191.33	40.53
		mean	6	148.80	38.13	38.33	26.54	187.13	51.33
K092	15.09.	III.1	3	42.70	5.42	247.17	19.19	289.87	13.85
		III.6	3	62.00	8.86	214.33	55.52	276.33	51.73
		mean	6	52.35	12.13	230.75	44.66	283.10	38.47
K098	13.09.	III.7	6	77.30	25.52	114.87	45.99	192.17	69.35
		mean	6	77.30	25.52	114.87	45.99	192.17	69.35
K061	13.09.	III.2	3	101.80	31.25	99.03	24.24	200.83	29.07
		IV.2	3	126.73	52.14	102.53	62.24	229.27	88.69
		mean	6	114.27	44.76	100.78	47.26	215.05	67.51
K023	12.09.	III.1	6	72.00	31.22	112.08	66.32	184.08	59.78
		mean	6	72.00	31.22	112.08	66.32	184.08	59.78
K055	12.09.	III.3	3	107.87	33.10	64.10	17.56	171.97	39.39
		I.1	3	79.97	19.38	16.33	11.80	96.30	26.10
		mean	6	93.92	30.50	40.22	28.18	134.13	50.48
K117	12.09.	III.5	3	34.93	18.66	46.63	3.23	81.57	18.51
		VI.1	3	8.60	4.52	7.03	4.45	15.63	8.20
		mean	6	21.77	18.91	26.83	20.18	48.60	35.94
K126	11.09.	III.3	3	69.13	26.76	61.93	11.77	131.07	17.68
		III.5	3	38.97	9.19	48.10	10.30	87.07	8.56
		mean	6	54.05	25.05	55.02	13.04	109.07	26.02
K011	11.09.	III.3	3	192.57	28.66	76.60	13.49	269.17	16.36
		III.2	3	90.13	5.44	178.73	36.85	268.87	31.47
		mean	6	141.35	55.22	127.67	58.12	269.02	25.08
S023	11.09.	VII.1	3	138.90	7.07	78.77	52.91	217.67	49.15
		III.3	3	114.77	34.71	127.20	38.66	241.97	71.85
		mean	6	126.83	27.80	102.98	52.28	229.82	62.75
B1	24.09.	III.3	3	278.83	39.85	344.33	86.88	623.17	49.99
		III.2	3	68.00	10.37	279.00	68.86	347.60	68.15
		mean	6	173.72	109.07	311.67	84.92	485.38	150.19
B2	23.09.	III.3	3	175.90	38.77	215.00	11.22	390.90	45.67
		IV.2	3	144.67	71.34	288.00	17.47	432.67	54.17
		mean	6	160.28	59.50	251.50	39.34	411.78	54.28
B3	22.09.	III.1	3	97.83	23.39	448.17	58.25	546.00	35.31
		III.3	3	184.33	70.21	347.00	58.8	541.33	126.63
		mean	6	146.08	71.18	397.58	77.38	543.67	92.99
B4	22.09.	III.3	3	115.67	45.84	190.33	21.45	306.00	62.12
		IV.1	3	139.83	27.48	163.67	50.33	303.50	76.46
		mean	6	127.75	39.68	177.00	40.92	304.75	69.67
B5	21.09.	III.3	3	113.00	12.68	270.10	18.61	283.10	28.39
		IV.1	3	183.83	62.28	287.33	16.01	471.17	68.33
		mean	6	148.42	57.22	278.72	19.38	427.13	68.38
B6	20.09.	III.3	3	119.00	57.71	223.00	19.80	342.00	66.71
		III.1	3	69.33	29.10	264.33	41.07	333.67	52.45
		mean	6	94.17	52.01	243.67	38.30	337.83	60.15
B7	20.09.	III.1	3	72.17	20.68	198.33	36.28	270.50	31.31
		III.5	3	162.17	31.56	277.67	50.31	439.83	51.79
		mean	6	117.17	52.32	238.00	59.14	355.17	94.87

done for various forest habitats in Puszcza Kampinoska, Poland (Kwiatkowska and Dudziec 1974). This showed unambiguously that significant differences existed both within and between phytocoenoses. This variability suggests that biomass should be measured in smaller, more uniform structural units of the herb layer. However, the synusial method is suitable for the description and characterization of such spatial systems. Because of the high patchiness of the herb layer the synusial approach to the typology of forest communities is inapplicable in the manner once used in Scandinavia (Du Rietz 1930, Lippmaa 1935) and also still used occasionally in forest communities of other regions (Gillet 1986).

The majority of the types of synusiae described in this work occur in both pine forests and mixed/pine forests. Among the 14 subtypes distinguished only 4 are clearly associated with pine forests and three with mixed/pine forests.

Variability in biomass from east to west occurred in both the different types of herb layer synusiae and in entire study areas. This variability is strongly expressed in the case of the biomass of mosses, and much more weakly in the case of vascular plants. Similarly, stronger and more significant correlations were found for pine forests than mixed/pine forests.

The data presented here on differences in biomass within the synusiae and different study areas along the west-east transect are a supplement to data from the literature. The values obtained are lower than those given for biomass in areas further to the east. Gabeev (1990) showed that pine forests in Western Siberia had mossy-cowberry herb layers with biomass ranging from 110 to 200 g/m^2 (of this the biomass of mosses was between 50 and 140 g/m^2). The pine forests with bilberry had herb layer biomass in the range of 90 to 130 g/m^2, while the biomass of mosses was lower – in the range of 15-20 g/m^2. In contrast, pine forests had grassy herb layers of highly variable biomass, with values as high as 304 g/m^2 but with minimal representation of mosses (about 1 g/m^2). It should be emphasized that mean biomass of the herb layer is influenced not only by geographical location, but by the edaphic conditions of the particular sites. For example, site S023 is characterized by a relatively high mean biomass (230 g/m^2) and at the same time by a higher (46.3 percent) proportion of species requiring moderately moist soils. These sites are also characterized by a higher percentage (17.8 percent) of nitrophilous species.

On the basis of vegetation features analyzed in these studies, we did not detect any changes at any site that can be explained by air pollution. Future studies of vegetation should concentrate on population level and such features of plant species as life form, phenology, and type of hemeroby.

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References

Breymeyer, A. 1998. **Transect studies on pine forest along parallel 52 degrees N, 12-32 degrees West and along a pollution gradient: general assumptions, geographical and ecological conditions.** In: Bytnerowicz, Andrzej; Arbaugh, Michael I.; Schilling, Susan, technical coordinators. Proceedings of the international symposium on air pollution and climate change effects on forest ecosystems; 1996 February 5-9; Riverside, CA. Gen. Tech. Rep. PSW-GTR-166. Albany, CA: Pacific Southwest Research Station, USDA Forest Service [this volume].

Degórski, M. 1998. **Spatial and vertical distribution of soil physico-chemical properties and the content of heavy metals in the pedosphere.** In: Bytnerowicz, Andrzej; Arbaugh, Michael.; Schilling, Susan, technical coordinators. Proceedings of the international symposium on air pollution and climate change effects on forest ecosystems; 1996 February 5-9; Riverside, CA. Gen. Tech. Rep. PSW-GTR-166. Albany, CA: Pacific Southwest Research Station, USDA Forest Service [this volume].

Du Rietz, E. 1930. **Vegetationsforschung auf soziationsanalytischer Grundlage**. Handbuch der biologischen Arbeitsmethoden, Abderhalden 11.5.

Faltynowicz, W. 1990. **A checklist of Polish lichen forming and lichenicolous fungi including parasitis and saprophytic fungi occuring on lichens**. Polish Botanical Studies 5: 1-65.

Gabeev, V.N. 1990. **Ekologia i produktivnost sosnovych lesov (Ecology and productivity of pine forest)**. Novosibirsk, Ed. "Nauka"; 226 p.

Gillet, F. 1980. **Les phytocoenoses forestieres du Jura nord-occidental**. Essai de phytosociologie integree. These, Besancon; 604 p.

Julve, P.; Gillet, F. 1994. **III. Experiences of French authors (Map 3)**. In: Falinski, J.B., ed. Vegetation under the diverse anthropogenic impact as object of basic phytosociological map. Results of the international cartographical experiment organized in the Bialowieza Forest, Phytocoenosis 6 (N.S.), Supplementum Cartographiae Geobotanicae 4: 45-66.

Lippmaa, T. 1935. **Le methode des associations unistrates et le systeme ecologique des associacions**. Acta Instituti Horti Botanici Universitatis Tartuensis, IV.

Matuszkiewicz, J.M. 1993. **Krajobrazy roslinne i regiony geobotaniczne Polski (Vegetation landscapes and geobotanical regions of Poland)**. Prace Geograficzne IGiPZ PAN; 158 p.

Matuszkiewicz, W. 1981. **Przewodnik do oznaczania zbiorowisk roslinnych Polski (Guide to determine plant communities of Poland)**. PWN, Warszawa; 298 p.

Mavriscev, V.V. 1980. **Sinuzialnaja struktura fitocenozov kislicnoj seri tipov lesa, avtoreferat (Synusial structure of Oxalis series of forests)**. Instytut Eksperimentalnoj Botaniki AN BSSR, Minsk; 36 p.

Rejment-Grochowska, J. 1950. **Watrobowce (Liverworts)**. PZWS; 68 p.

Roo-Zielinska, E. [in press]. **Fitoindykacyjna ocena warunków siedliskowych stanowisk badawczych wzdluz gradientu kontynentalizmu (12 - 32 degrees dl. geogr. wsch.) i zanieczyszczenia powietrza, (Phytoindicational evaluation of habitat conditions of permanent plots along continental gradient 12-32 degrees East and air pollutant gradient)**. Dokumentacja Geograficzna.

Roo-Zielinska, E.; Solon J. [in press] **Charakterystyka geobotaniczna zbiorowisk lesnych na stanowiskach badawczych wzdluz gradientu kontynentalizmu (12 - 32 degrees dl. geogr. wsch.) i zanieczyszczenia powietrza (Geobotanical characterization of plant communities on permanent plots along continental gradient 12-32 degrees East and air pollutant gradient)**. Dokumentacja Geograficzna.

Rothmaler, W. 1976. **Exkursionsflora. Kritischer Band.** Verlag, Berlin: Volk und Wissen Volkseigener; 812 p.

Smialkowski, J. 1998. **Transect studies along 52 parallel, 12-32 degrees E: PAR measurements in pure-pine and mixed-pine forests in Poland.** In: Bytnerowicz, Andrzej; Arbaugh, Michael J.; Schilling, Susan, technical coordinators. Proceedings of the international symposium on air pollution and climate change effects on forest ecosystems; 1996 February 5-9; Riverside, CA. Gen. Tech. Rep. PSW-GTR-166. Albany, CA: Pacific Southwest Research Station, USDA Forest Service [this volume].

Solon, J. 1994. **Krajobrazowe zroznicowanie roslinnosci rzeczywistej (Landscape differentiation of real vegetation).** In: Kostrowicki A.S., Solon J., eds. Studium geobotaniczno-krajobrazowe okolic Pinczowa. In: Geobotanical-landscape studium of Pinczow surroundings). Dokumentacja Geograficzna 1-2: 83-94.

Szafer, W.; Kulczynski S.; Pawlowski B. 1969. **Rosliny Polskie (Polish plant species).** PWN, Warszawa; 1020 p.

Szafran, B. 1957. **Flora Polska, Mchy (Polish Flora, mosses).** Part I., PWN Warszawa; 440 p.

Szafran, B. 1961. **Flora Polska, Mchy (Polish Flora, mosses)**. Part II., PWN Warszawa; 407 p.