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Influence of Habitats of Two Forest Ecosystems on Productivity of Pine Stands in Central Roztocze. Part II

Wpływ siedlisk dwóch ekosystemów leśnych na produkcyjność drzewostanu sosnowego na Roztoczu Środkowym. Część II

Влияние местообитания двух лесных экосистем на продуктивность соснового древостоя Центрального Розточе. Часть II

INTRODUCTION

In this paper the authors have presented the results of the second stage of studies on the influence of grud and pine forest habitat on productivity of about 50—60 years old undergrowing pine stands in Roztocze. This time a younger stand than that in part I (6) was taken into consideration. In order to obtain comparative results the authors used the same investigation methods. Observations were carried out in two forest ecosystems similar to those studied previously, as far as their habitat and phytosociological properties are concerned (6).

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THE STUDY AREA

Similarly as in the previous study (6), two-year investigations were carried out in two 0.5 ha experimental areas set up in the Zwierzyniec forest district (former Kosobudy forest district) in Central Roztocze, in 1973 (Fig. 1). One area (denoted area 3) was set up in a grud community from the *Fagetalia* order and *Querco-Fagetea* class with undergrowing pine, the other, a control area, in the subassociation *Vaccinio myrtilli-Pinetum typicum* of the *Dicrano-Pinion* alliance, *Vaccinio-Piceetalia* order and *Vaccinio-Piceetea* class (area 4). The distance between the areas is about 1.2 km and they have undergowing pine stands of the same age, i.e. 50—60 years, about 10—20 years younger than those in the previous paper (6).

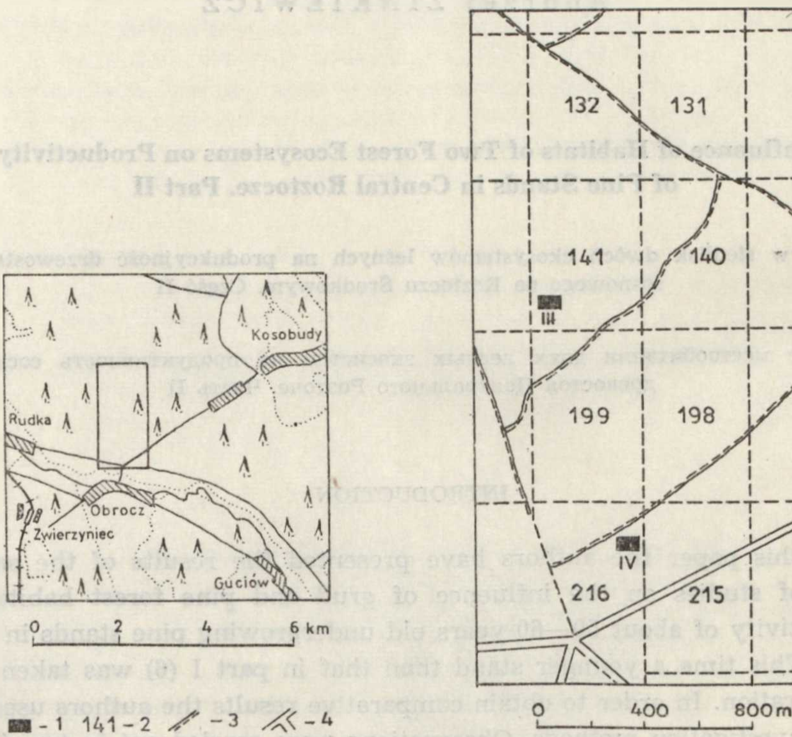


Fig. 1. Map of the studied terrain; III, IV — study areas

Area 3 (Fig. 2) was set up in compartment 141 of the top and upper part of a high elevation (about 60 m of relative height) which is inclined at 4° northwards. The differences in relative height on the surface are 10 m. Brown soil formed from gaizes of cretaceous origin is found in this area covered with mixed forest of a three-stratum structure (Fig. 3).

Its stand is pine-hornbeam with an admixture of aspen, beech, maple and pedunculate oak of 0.8 crown closeness. Distinctly predominating pines do not regenerate here at all. Seven species are found in the weakly developed shrub layer (closeness 0.2), of which maple, aspen and black elder predominate. The herb layer is exuberant and rich in species. Its 48 species reach on the average a closeness of 80%. A distinct predominance is shown by: *Asperula odorata, Oxalis acetosella, Asarum europaeum, Hepatica nobilis* and *Urtica dioica.* Grud species from the order *Fagetalia* and *Querco-Fagetea* class were observed to dominate distinctly. Plants of the *Fagion* and *Carpinion* alliances, however, occur less frequently. Pine forest species do not play here any role.

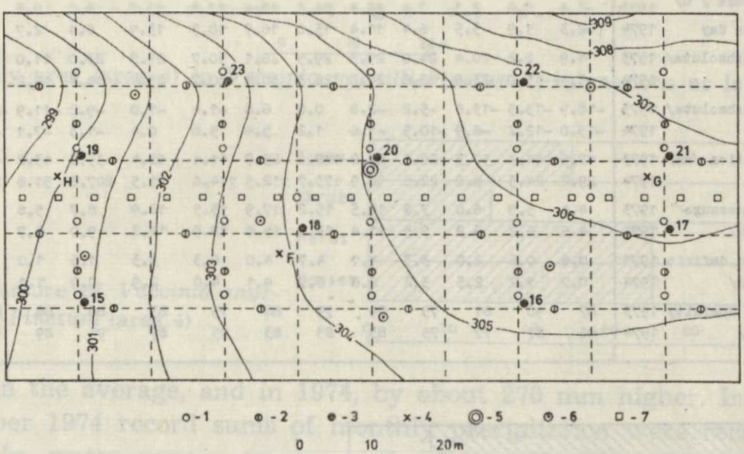


Fig. 2. Study area (area 3) in the grud community of the *Fagetalia* order with pine; 1 — receptacles, 2 — stable 0.5 m² areas for estimation of density of species, 3 — table sites for taking medium soil samples, 4 — soil pits, 5 — basic stands for microclimatic measurements, 6 — subsidiary stands, 7 — stands for measurements of solar radiation and light brightness along the transectional lines

Area 4 (Fig. 4) was set up in compartment 216. The terrain is slightly undulating covered with dunes. The differences in the relative height reach 2 m. The podzolic soil there is formed of loose sand. The forest has a 4-stratum structure (Fig. 5). The stand consists of pines with an admixture of pedunculate oak and mammillary birch of 0.5 crown closeness. Its shrub layer is moderately developed (closeness 0.3). Among its species juniper and alder buckthorn predominate. The herb layer covers the surface in 70%. In this layer 13 species were found to occur with distinct predominance of *Vaccinium myrtillus, Vaccinium vitis-idaea* and *Calluna vulgaris.* In the well-developed moss layer (coverage of 70%) 7 species were recorded. Among them, *Entodon schreberi* and *Dicranum undulatum* show a distinct predominance. Characteristic species of the *Vaccinio-Piceetalia* order and *Vaccinio-Piceetea* class were found to predominate in the community. No species characteristic of this association were found.

The general climatic conditions existing in the study area were discussed in the preceding paper (6); therefore, only a short climatic characteristics of the study period of 1973—74 has been presented in this paper (Table 1).

Table 1. Mean monthly values of the selected meteorological elements at Zwierzyniec in the years 1973—1974

	Years	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Temperature /°C/	1973	-3.4	0.8	2.3	7.4	13.4	16.5	18.4	17.8	13.0	6.0	0.8	-1.4	7.6
a/ middle day	1974	-2.3	1.9	3.5	6.4	11.4	15.0	16.7	18.5	13.9	6.4	2.7	1.5	8.0
b/ max /absolute/	1973	4.9	8.2	20.4	24.0	29.3	29.5	28.1	30.7	29.7	23.0	11.0	10.0	30.7
	1974	5.4	15.0	23.6	20.6	24.0	26.3	30.1	30.7	25.7	14.4	15.2	9.4	30.7
c/ min /absolute/	1973	-18.9	-13.3	-13.6	-5.2	-2.8	0.0	6.6	-1.4	-1.0	-9.2	-11.9	-20.1	-20.1
	1974	-15.0	-12.2	-8.9	-10.5	-1.6	1.2	5.4	5.6	0.4	-1.3	-7.1	-7.5	-15.0
Precipitation /mm/	1973	12.5	64.4	30.3	28.5	86.8	117.0	85.7	11.1	62.4	35.8	43.2	48.1	626.2
	1974	29.2	24.3	6.0	22.6	96.9	173.7	112.5	114.6	71.5	207.6	51.8	78.7	989.4
Vapour pressure	1973	4.4	5.9	6.0	7.8	12.5	15.2	17.9	15.5	12.9	8.7	5.8	5.2	9.8
/mb/	1974	4.6	6.2	6.2	7.3	11.4	14.2	15.8	18.5	14.2	9.0	6.7	6.4	10.0
Saturation deficit	1973	0.6	0.6	2.0	3.3	4.1	4.7	4.0	6.3	3.3	1.6	1.0	0.7	2.7
/mb/	1974	0.7	1.2	2.5	3.2	2.8	3.7	4.1	4.0	2.9	0.9	1.1	0.6	2.3
Relative humidity	1973	87	90	81	73	79	79	84	75	83	86	86	88	83
/%/	1974	86	87	77	75	83	83	83	85	87	91	89	92	85

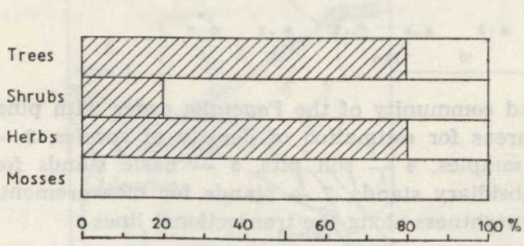


Fig. 3. Structure of the grud community of the *Fagetalia* order with pine (area 3)

Air temperature was slightly above the mean values of many years, particularly those in 1974. The monthly maximum temperature in 1973, as that of many years, was recorded in July and in 1974 — in August, and it was by about 2°C higher than the mean of many years of this month. Temperatures higher than the mean of many years were recorded in the winter period, particularly that of 1974 and in the summer period of 1973. The annual amplitude of air temperature was nearly by 2°C higher in the first than in the second year. Maximum temperature was in both years approximate to the average, whereas minimum temperature was much higher. The total annual precipitation in 1973 was almost by 100 mm

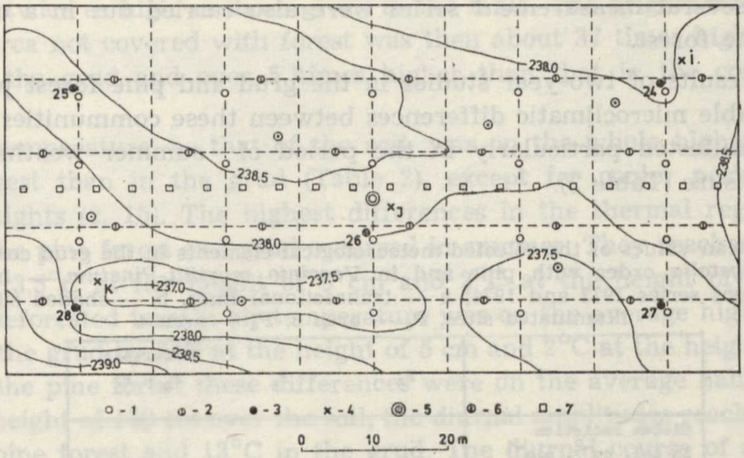


Fig. 4. Study area (area 4) in *Vaccinio myrtilli-Pinetum;* explanations as in Fig. 2

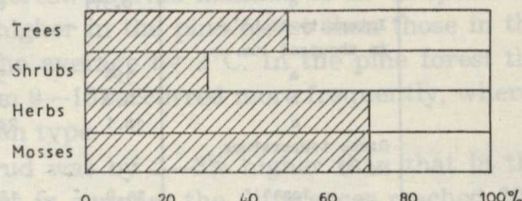


Fig. 5. Structure of *Vaccinio myrtilli-Pinetum* (area 4)

lower than the average, and in 1974, by about 270 mm higher. In June and October 1974 record sums of monthly precipitation were recorded. Accordingly, water vapour tension and relative humidity were higher than the average.

RESULTS

Microclimatic studies

The method of microclimatic studies conducted in two selected forest communities in the years 1973—1974 was similar to that used in the period 1971—1972 (6). The only difference was that measurements of solar radiation and light brightness were performed only at the bottom of the forest (1 m above the ground). The measurements were made along determined transectional lines running through the center of the studied areas, in all, at 20 points plotted at 5 m intervals (Figs. 2, 4). As previously, similar observations were carried out in several shaded and lighted places. In order to compare the microclimatic conditions of the forest and open terrain, several measurement series were also carried out in a clearing beside the forest.

The results of two-year studies in the grud and pine forest point to considerable microclimatic differences between these communities, which were manifested particularly in the period of summer weather with high pressure (Table 2).

Table 2. Mean values of the selected meteorological elements in the grud community of the *Fagetalia* order with pine and in *Vaccinio myrtilli-Pinetum* — from the measurement series 1973 and 1974; a — transectional lines, b — shaded sites, c — illuminated sites, P_3 — area 3, P_4 — area 4

	P_3	P_4	Difference $P_4 - P_3$
Globan radiation in cal. cm^{-2}. min^{-1}			
a	0.031	0.083	0.052
b	0.030	0.045	0.015
c	0.311	0.355	0.044
Intensity light`s in thousand lux			
a	1.4	5.3	3.9
b	0.8	3.1	2.33
c	18.1	23.9	5.8
Glebe temperature in °C			
1cm	11.9	13.4	1.5
10cm	11.1	11.6	0.5
20cm	10.8	11.2	0.4
Air temperature in °C			
5cm	14.3	15.6	1.3
20cm	14.4	15.5	1.1
50cm	14.5	15.5	1.0
150cm	14.8	15.6	0.8

The intensity of total radiation in the pine forest measured along the transectional lines was 2-3 times higher than that in the grud. In the area not covered with forest, the intensity of solar radiation was almost 6 times higher than that in the coniferous forest and about 17 times higher than that in the grud. The highest differences in the daily course occurred during anticyclonic sunny weather (1, 21). In the morning 2—4 times higher radiation was recorded in the pine forest than that in the grud, whereas at noon it was 5—6 times higher. The albedo was higher in the grud than in the pine forest by about 10% according to the data from the transectional lines, 5% in shaded places and 2% in lighted places.

The brightness of daylight was almost 4 times higher in shaded places and on the transectional lines in the pine forest than in the grud. The highest differences occurred in summer and in May and they were on the average twice as high as those given in the table. The brightness of light in the area not covered with forest was then about 37 times higher than that in the grud and over 5 times higher than that in the coniferous forest.

Air temperature, as that of the soil, was on the whole higher in the pine forest than in the grud (Table 2), except for cooler periods and starry nights (2, 15). The highest differences in the thermal regime between the pine forest and grud occurred in summer. They reached on the average 3.5°C at the height of 5 cm and 2°C at the height of 150 cm. In the deforested terrain air temperature was on the average higher than that in the grud by 5°C at the height of 5 cm and 2°C at the height of 150 cm. In the pine forest these differences were on the average half as low. At the height of 150 cm over the soil, the diurnal amplitudes reached 19°C in the pine forest and 13°C in the grud. The diurnal course of air temperature was more equalized in the grud (shallower minima and lower maxima) than that in the pine forest. Diurnal maxima of air temperature were on the average by 1.5°C higher in the pine forest than those in the grud, and diurnal minima on the average by 2°C. In the pine forest the insolation type (particularly from 9—15) occurred more frequently, whereas in the grud — the intervention type.

Relative humidity in the grud was by 2—3% higher than that in the pine forest. In the midday hours in summer the differences reached 20% at the height of 5 cm and about 10% at the height of 150 cm. In spring and autumn, higher humidity was observed in the pine forest, but these differences were half as low as in summer. The diurnal course of relative humidity was more equalized in the grud than in the pine forest. In both ecosystems the wet type dominated in vertical stratification. Vertical differentiation of moisture was higher in the grud. Water vapour pressure showed slightly higher values in the pine forest, on the average by 0.5 mb at the height of 5 cm and 0.1 mb — at the height of 150 cm. Higher differences in the values of this element were recorded in summer — up to 2.5 mb. In the midday hours those differences reached in some cases 9 mb. In deforested terrain (in summer) a higher water vapour pressure was recorded than in the grud and pine forest. These differences generally exceeded 2 mb.

Pedological studies

Comparative analysis of the results of two-year studies indicates that the investigated forest communities grow on different soils with regard to type, physico-chemical properties and fertility (Figs. 6—10, Tables 3—5).

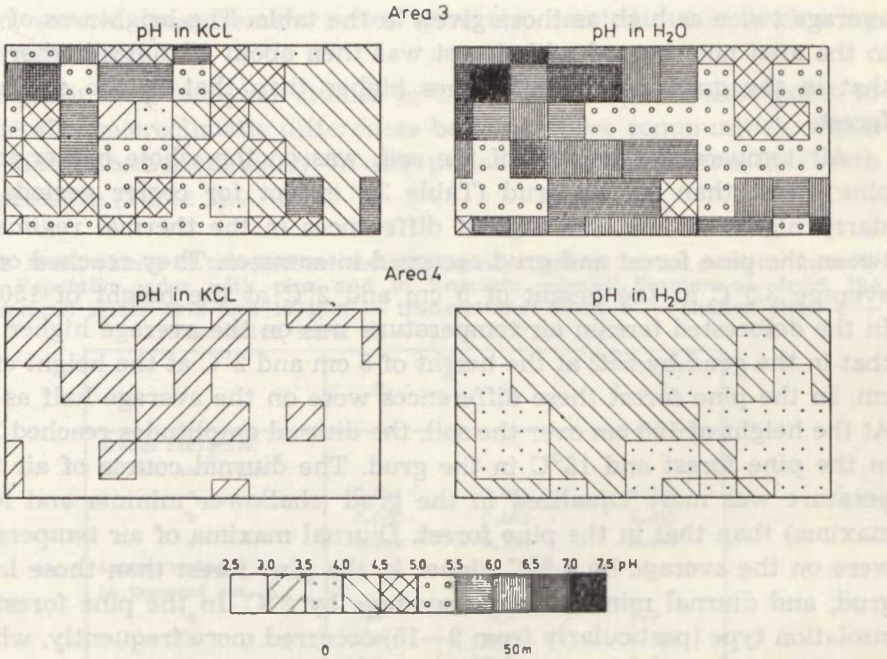


Fig. 6. Reaction of the humus-accumulation horizon of the soil in the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4)

In the grud shallow brown soil was found with mechanical composition of usually light, weakly sandy loam formed from cretaceous gaizes, whereas in the pine forest — podzolic soil formed from loose sand. Its specific gravity, volume weight and permeability turned out to be smaller than those of the soil in the pine forest. Moreover, its permeability in contrast to podzolic soil decreased with the depth of the pit.

In both study years great oscillations in humus content were observed in the humus-accumulation horizon of the soils; e.g., in 1974, it was 2.2 as high in site 16 in the grud as in site 17. Humus content of the mull type, rarer of the moder type, averaged 7.02% per pit in the grud community, whereas in the pine forest one — 4.8% of the moder type.

The acidity rate of the brown soil was lower than that of podzolic soil. In both areas acidity decreased with the depth of the pits. During the vegetative period, soil pH in the pine forest remained almost on the same level, whereas in the grud considerable differences in acidity were found in some places of the area, particularly in the horizon of browning. They were presumably caused by the occurrence of weathered limestone leached in various degree. In this connection changes in the content of

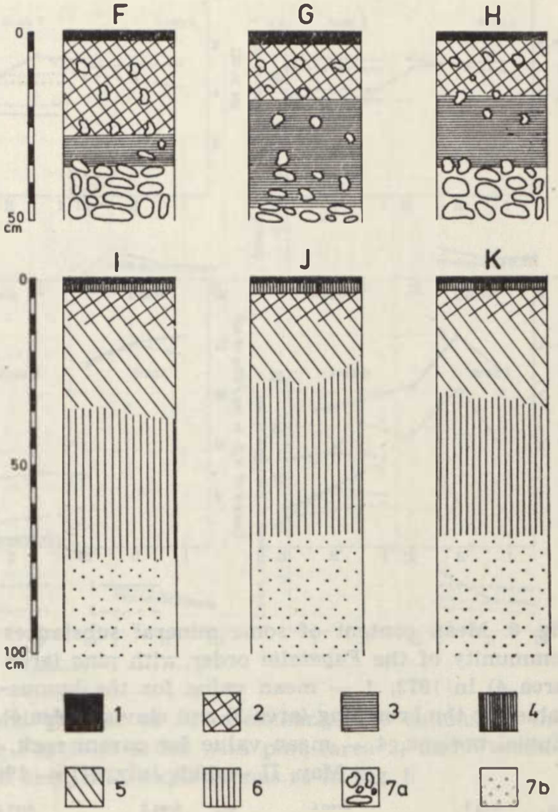


Fig. 7. Soil pits in the grud community of the *Fagetalia* order with pine (area 3, F—H) and in *Vaccinio myrtilli-Pinetum* (area 4 ,I—K); 1—litter A_0, 2 — humus-accumulation horizon A_1, 3 — horizon of browning (*B*), 4 — rotten mosses A_{01}, 5 — eluvial horizon A_2, 6 — illuvial horizon *B*, 7a, b — parent rock C

calcium carbonate of the range 0.42—11.10% were found in the horizon of browning, in study sites 18, 19, 22, 23 in the course of two-year studies.

In both study years the content of available phosphorus and potassium appeared to be much higher in the soil of the grud than that in pine forest. However, it was found to fluctuate considerably in the particular genetic horizons of the soil in different sites of both areas, during the vegetative period as well as in the course of two-year studies. Taking into account the average amounts of these compounds occurring in the particular genetic horizons, it was found that their level in all horizons of podzolic soil was low, that of P_2O_5 in the humus-accumulation horizon of brown soil — medium, and that of K_2O — high, that of P_2O_5 in the horizon of browing — low, and of K_2O — high in 1973 and medium in 1974.

The content of Fe_2O_3 was much higher in brown soil (particularly in the horizon of browning) than that in podzolic soil. Furthermore, unlike in the pine forest, considerable changes in its content were observed in

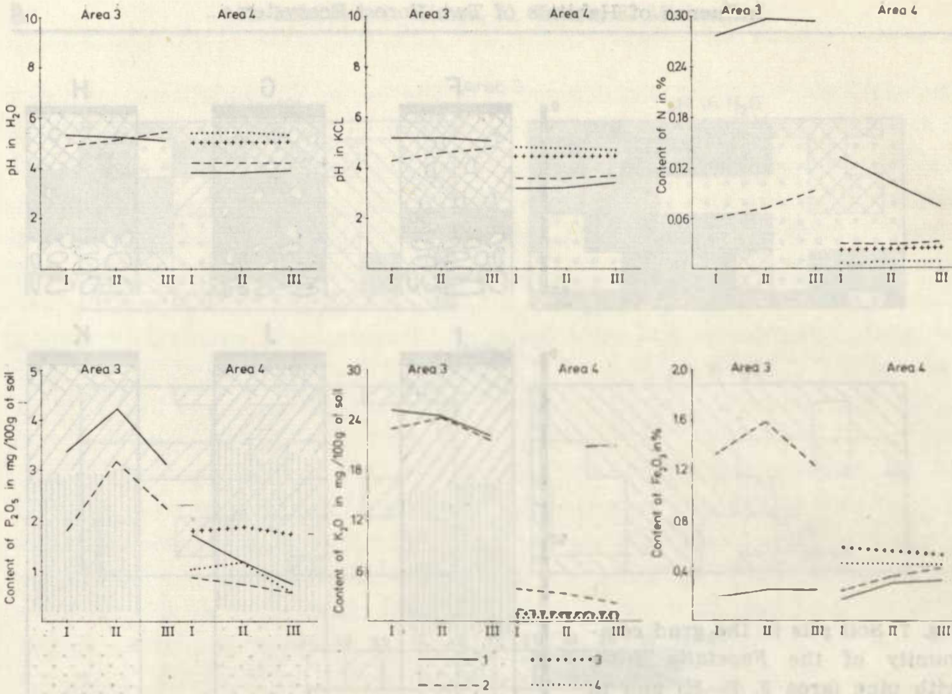
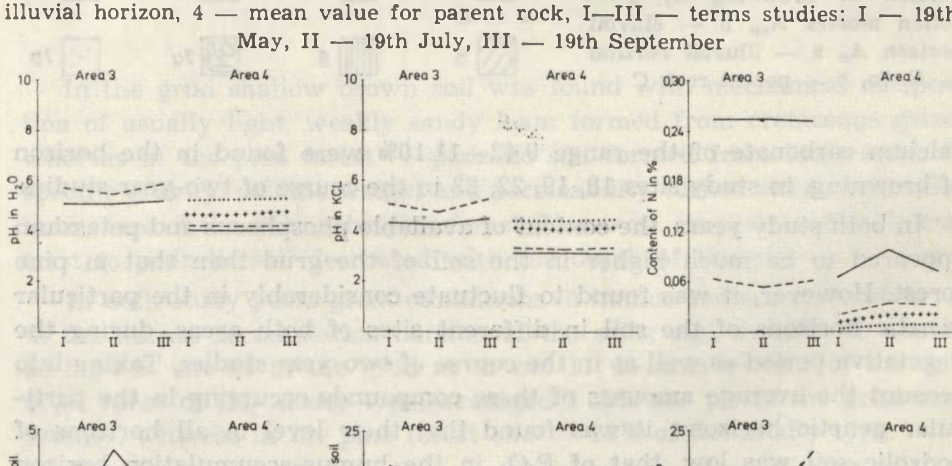


Fig. 8. Mean content of some mineral substances and *pH* in the soil of the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4) in 1973; 1 — mean value for the humus-accumulation horizon, 2 — mean value for the browning (area 3) and eluvial (area 4) horizons, 3 — mean value for the illuvial horizon, 4 — mean value for parent rock, I—III — terms studies: I — 19th May, II — 19th July, III — 19th September



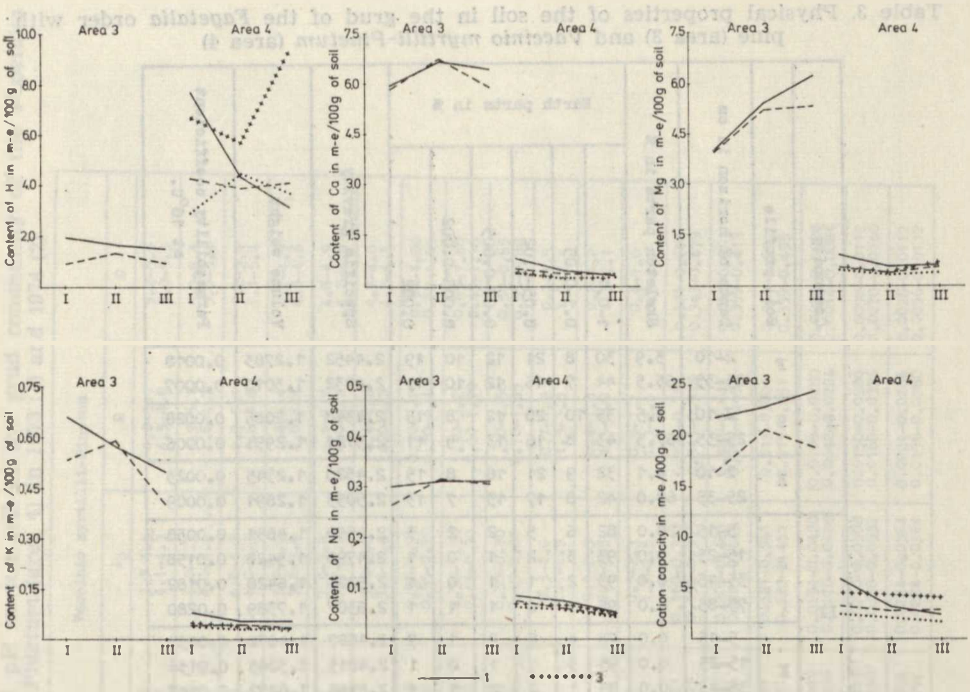


Fig. 10. Mean sorptive capacity and content of some exchangeable cations in the soil of the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4) in 1973; explanations as in Fig. 8

the grud in three study terms. In both soil types the amount of iron was found to increase with the depth of the pits, while in podzolic soil its highest concentration occurred in the illuvial horizon.

The percentage content of nitrogen proved to be highest in the humus--accumulation horizon of both soils. In the course of studies, in the pine forest its considerable changes were observed, and it was at the same time lower than those in the grud.

The soil in the grud, as compared to that in the pine forest, is characterized by higher sorptive capacity and content for exchangeable cations, except H^+. At the same time it is characterized in most cases by different dynamics of these elements during the vegetation period; in the grud (particularly in the horizon of browning) their highest concentration occurred in the second term of studies, though it was found to be the lowest in analogous period in the pine forest.

Fig. 9. Mean content of some mineral substances and *pH* in the soil of the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4) in 1974; explanations as in Fig. 8

Table 3. Physical properties of the soil in the grud of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4)

Community	Soil profile	Depth of horizon in cm	Skeleton parts in %	Earth parts in %						Specific gravity	Volume weight	Permeability coefficient at 10°C.
				1–0.1	0.1–0.05	0.05–0.02	0.02–0.005	0.005–0.002	0.002			
I	F	2–10	3.9	30	8	21	12	10	19	2.4452	1.2783	0.0018
		25–35	65.5	44	7	16	12	10	11	2.4932	1.3010	0.0007
	G	2–10	3.5	35	10	20	12	8	15	2.4348	1.2085	0.0028
		25–35	67.5	43	8	16	13	9	11	2.5121	1.2951	0.0006
	H	2–10	4.1	32	9	21	16	8	15	2.4520	1.2345	0.0023
		25–35	68.0	42	8	17	13	7	13	2.5053	1.2891	0.0009
II	J	5–15	0.0	82	6	5	2	2	3	2.4569	1.4851	0.0038
		15–25	0.0	93	3	2	1	0	1	2.4798	1.5428	0.0158
		35–45	0.0	93	2	1	1	0	1	2.5228	1.6428	0.0182
		75–85	0.0	96	1	0	1	1	1	2.6307	1.7389	0.0280
	K	5–15	0.0	78	4	8	2	1	7	2.4687	1.4678	0.0035
		15–25	0.0	95	3	0	1	0	1	2.4815	1.5265	0.0136
		35–45	0.0	93	1	2	2	1	1	2.5168	1.6272	0.0167
		75–85	0.0	96	1	1	0	1	1	2.6593	1.7520	0.0259

I - Community from order Fagetalia with pine.
II - Vaccinio myrtilli-Pinetum

A higher spatial variation of the soil was observed in the grud. In this connection a higher differentiation of the soil occurred with regard to morphology, physical properties, acidity rate, humus content, moisture and the content of the nutrient components studied.

As regards morphology and physico-chemical properties, the soil of both communities come closer to soils of this type from Roztocze (4, 5, 6).

Microbiological studies

Two-year microbiological studies showed that bacteria were the dominating component of microflora in the litter of the grud (area 3). Their number reached 65 million cells in 1 g of litter in part G_3 (Table 6, Fig. 11). They are high values but not the highest for these communities. Malicki (5, 12) gave much higher numbers, but they were obtained by direct methods of counting. However, he reported that he had obtained much lower values similar to those of the authors and Zimny (26, 27, 28) when using corresponding methods in studies of forest soils of Central Roztocze.

Table 4. Changes of the content of some mineral substances and pH in the soil of the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4) in 1973 (1) and 1974 (2)

Community			Community from order Fagetalia with pine		Vaccinio myrtilli-Pinetum			
Genetic horizon			A_1	/B/	A_1	A_2	B	C
pH in H_2O	I	1	4.3-6.8	4.2-6.0	3.6-4.1	3.8-4.5	4.8-5.1	5.2-5.5
		2	4.6-5.5	4.7-7.4	3.9-4.2	4.1-4.3	4.5-4.8	5.0-5.3
	II	1	4.5-6.0	3.9-7.5	3.7-4.0	4.0-4.3	4.9-5.1	5.3-5.4
		2	4.5-5.4	4.9-6.5	3.9-4.1	4.0-4.4	4.6-4.7	5.0-5.4
	III	1	4.0-5.8	4.5-7.3	3.6-4.0	4.0-4.5	4.9-5.1	5.2-5.4
		2	4.4-6.8	4.7-7.6	3.8-4.1	4.0-4.3	4.6-4.8	5.1-5.4
pH in KCL	I	1	3.9-6.2	3.6-5.2	3.0-3.6	3.2-4.0	4.4-4.6	4.7-4.9
		2	3.9-4.7	4.2-6.8	3.0-3.3	3.2-3.4	4.0-4.4	4.3-4.6
	II	1	3.9-5.5	3.4-7.1	3.1-3.4	3.4-3.8	4.4-4.5	4.8-4.9
		2	3.8-4.7	4.2-5.9	3.0-3.3	3.1-3.5	4.0-4.2	4.2-4.5
	III	1	4.1-5.3	3.7-6.9	3.1-3.6	3.6-4.0	4.4-4.6	4.7-4.8
		2	3.7-6.4	4.0-7.2	2.9-3.3	3.3-3.4	4.0-4.3	4.2-4.7
Content in mg/100 g of soil: P_2O_5	I	1	2.40-5.90	0.70-3.40	0.80-2.75	0.50-1.50	0.30-3.20	0.50-1.80
		2	1.15-4.05	0.45-4.55	0.90-1.80	0.55-0.90	0.90-6.40	0.70-1.05
	II	1	1.80-7.40	0.80-6.40	0.50-2.25	0.50-1.50	1.30-3.20	0.65-1.80
		2	1.60-7.30	0.80-6.40	0.70-1.60	0.45-0.90	0.90-7.90	0.45-1.15
	III	1	0.80-6.70	0.80-9.70	0.65-1.00	0.30-0.80	1.30-2.50	0.50-0.65
		2	1.70-6.40	0.20-8.30	0.65-0.90	0.45-0.80	0.70-1.35	0.55-0.80
K_2O	I	1	17.6-33.8	8.8-50.0	2.0-8.0	0.5-4.0	0.7-1.5	0.2-1.5
		2	10.9-32.4	7.9-28.7	2.5-6.7	2.1-2.9	1.3-3.8	1.3-2.1
	II	1	13.8-43.6	12.0-44.5	2.2-7.0	0.1-2.3	0.4-1.5	0.2-1.2
		2	14.7-27.4	7.9-18.7	2.5-3.8	2.1-2.5	1.3-5.0	1.3-2.1
	III	1	12.3-27.0	10.0-40.0	1.1-3.8	0.5-2.3	0.5-1.2	0.4-1.0
		2	13.0-27.8	9.6-27.0	2.1-2.9	1.7-2.5	1.3-2.1	1.3-1.3
Content in %: Fe_2O_3	I	1	0.040-0.321	0.681-2.244	0.080-0.321	0.160-0.321	0.399-0.761	0.321-0.601
		2	0.156-0.279	1.158-2.515	0.168-0.219	0.192-0.335	0.343-0.515	0.343-0.479
	II	1	0.120-0.441	1.122-2.284	0.160-0.441	0.200-0.481	0.481-0.641	0.401-0.561
		2	0.176-0.335	1.237-2.379	0.136-0.303	0.223-0.445	0.379-0.491	0.399-0.419
	III	1	0.040-0.441	1.002-1.643	0.240-0.401	0.321-0.561	0.519-0.601	0.361-0.601
		2	0.192-0.359	1.365-2.786	0.172-0.231	0.223-0.451	0.419-0.451	0.359-0.455
N	I	1	0.1890-0.4620	0.0028-0.1022	0.0504-0.2240	0.0154-0.0420	0.0168-0.0280	0.0028-0.0098
		2	0.1890-0.3542	0.0028-0.1204	0.0392-0.0896	0.0070-0.0420	0.0042-0.0224	0.0014-0.0084
	II	1	0.2086-0.4312	0.0532-0.0924	0.0672-0.1414	0.0210-0.0308	0.0150-0.0280	0.0098-0.0112
		2	0.1330-0.3206	0.0322-0.0756	0.0602-0.1358	0.0238-0.0532	0.0168-0.0336	0.0070-0.0140
	III	1	0.2100-0.3800	0.0420-0.1690	0.0378-0.1008	0.0224-0.0364	0.0224-0.0266	0.0028-0.0112
		2	0.1736-0.3290	0.0420-0.0756	0.0308-0.1092	0.0224-0.0364	0.0196-0.0280	0.0056-0.0112

I-III - time of research.

Table 5. Changes of the sorptive capacity and the content of some exchangeable cations in the soil of the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4) in 1973

Community			Community from order Fagetalia with pine		Vaccinio myrtilli-Pinetum			
Genetic horizon			A_1	/B/	A_1	A_2	B	C
Content in m-e./100 g of soil	H	I	0.690-3.320	0.360-1.890	4.850-11.800	1.600-6.650	4.450-8.850	1.550-5.750
		II	0.460-2.710	0.940-2.050	2.150-5.800	2.800-5.250	2.450-8.250	2.300-8.250
		III	0.460-2.640	0.400-1.460	1.400-5.750	1.950-7.350	8.200-11.800	1.750-8.250
	Ca	I	4.600-6.600	2.650-10.750	0.600-1.075	0.425-0.625	0.375-0.625	0.350-0.475
		II	4.250-10.650	3.150-12.350	0.325-0.600	0.250-0.450	0.225-0.300	0.175-0.350
		III	2.050-7.300	3.400-9.050	0.250-0.375	0.250-0.450	0.225-0.325	0.275-0.425
	Mg	I	2.400-5.700	1.150-8.160	0.125-1.810	0.335-0.735	0.325-0.775	0.215-0.890
		II	1.750-9.130	2.250-10.450	0.335-0.735	0.225-0.550	0.300-0.910	0.175-0.550
		III	4.400-8.250	2.870-9.190	0.335-0.735	0.285-0.987	0.425-1.220	0.330-0.525
	K	I	0.440-0.850	0.240-1.010	0.025-0.150	0.030-0.070	0.035-0.055	0.025-0.055
		II	0.270-0.920	0.230-1.080	0.030-0.065	0.030-0.050	0.030-0.045	0.025-0.045
		III	0.350-0.610	0.200-0.960	0.025-0.085	0.020-0.080	0.020-0.035	0.025-0.060
	Na	I	0.220-0.470	0.200-0.400	0.095-0.100	0.055-0.095	0.055-0.085	0.060-0.075
		II	0.220-0.460	0.190-0.520	0.060-0.095	0.050-0.072	0.050-0.070	0.045-0.075
		III	0.250-0.380	0.240-0.440	0.040-0.075	0.040-0.055	0.035-0.065	0.030-0.065
	Cation capacity	I	16.250-28.750	13.000-21.250	4.125-7.625	2.250-4.500	3.625-5.250	1.500-3.625
		II	17.250-28.750	15.000-28.500	2.500-4.125	1.750-3.250	3.625-6.250	1.750-2.750
		III	16.250-32.500	11.500-30.250	2.125-2.750	1.750-3.250	2.635-5.750	1.750-2.125

I-III - time of research

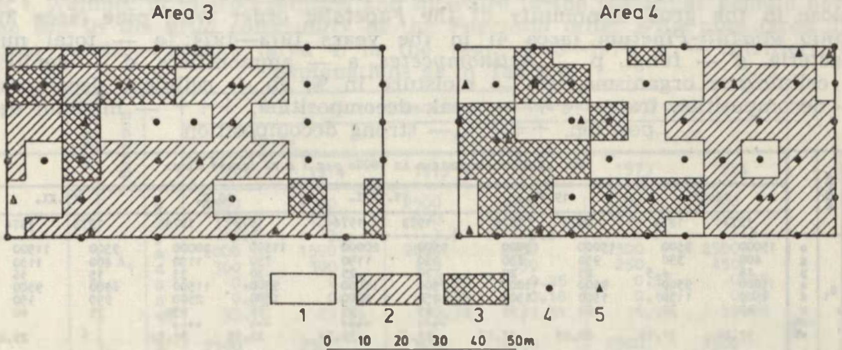


Fig. 11. Areas for microbiological studies of litter in the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4); 1 — part G_1 and B_1, 2 — part G_2 and B_2, 3 — part G_3 and B_3, 4 — sites of sample taking, 5 — study sites of cellulose decomposition

Among the physiological groups, the most numerous were ammonifiers and denitrifiers. The number, particularly that of the former, had a great influence on the total number of bacteria. A high predominance with regard to the number of fungi over *Actinomycetes* results presumably due to their great participation in mineralization of the litter. The grud area proved to be not uniform from the microbiological point of view. The richest microflora was found in sites with higher *pH* (part G_3). As compared with other parts, a great number of cellulolytic organisms was found here. The rate of cellulose decomposition, which was the highest in this place in both study years, confirms the above mentioned observations (Table 6).

The coniferous forest litter is poorer in microflora, particularly in the bacterial component possessing higher requirements as far as the habitat is concerned, which, however, dominated here. Its predominance over fungi was not so great here as it was in area 3. Ammonifiers, being most numerous among the physiological groups, were found even in smaller numbers than fungi in some months. The average number of both groups was only two times smaller than the total number of bacteria. Much fewer denitrifiers and *Actinomycetes* were found, and number of cellulolytic organisms did not exceed dozens or rarely several hundred cells in 1 g of litter. Differences in the numbers of microorganisms of the particular groups were also found within the whole area studied. The richest microflora was recorded in part B_3 and the poorest in part B_2. These numbers correlated with the rate of cellulose decomposition (Table 6). The litter of either area differed in number of microorganisms, mineralization rate and mean annual moisture. In area 3, more bacteria,

Table 6. Number of microorganisms, litter moisture and decomposition rate of cellulose in the grud community of the *Fagetalia order* with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4) in the years 1973—1974; o — total number of bacteria, g — fungi, p — *Actinomycetes*, a — ammonifiers, d — denitrifiers, c — cellulolytic organisms, w% — moisture in %, rb — cellulose decomposition: + — decomposition traces, ++ — weak decomposition, +++ — medium decomposition, ++++ — strong decomposition

Area	Parts		No. of micro-organisms in 1000s per 1 g of forest floor									
			19.IV.		19.VI.		19.VIII.		19.X.		19.XI.	
			1973	1974	1973	1974	1973	1974	1973	1974	1973	1974
		o	15000	9500	15000	15000	9500	20000	11500	20000	9500	11500
		g	400	350	950	750	950	1150	750	1150	400	1150
		p	16	4.5	25	20	20	25	30	35	15	16
	a_1	a	11000	9500	9500	11000	7500	11000	9500	11500	6500	9500
		d	1500	1150	1500	1500	1150	2000	1500	2500	950	950
		c	40	30	95	95	65	95	75	95	35	40
		rb					++++	++++	+++	++++		
		w%	32.26	31.16	35.99	37.15	29.42	35.14	35.57	31.52		29.03
		o	25000	16000	25000	25000	16000	20000	20000	25000	9500	20000
		g	160	250	250	250	200	950	300	750	115	750
		p	4	7	9.5	7.5	16	11	7.5	11	3.5	4.5
3	a_2	a	9500	7500	9500	9500	7500	9500	7500	9500	6500	7500
		d	2500	1150	4500	4000	2500	4000	3500	4500	2000	3000
		c	7.5	9.5	9.5	9.5	9.5	11	11.5	15	6.5	7
		rb					++++	++++	+++	++++		
		w%	35.71	28.73	33.18	38.68	28.37	39.08	34.35	34.89		31.48
		o	40000	40000	45000	65000	35000	45000	40000	45000	16000	25000
		g	200	200	450	350	400	650	450	1150	400	1150
		p	4	3.5	25	9.5	20	25	15	16	11.5	16
	a_3	a	30000	30000	25000	30000	20000	25000	25000	30000	11500	20000
		d	2000	2500	1500	2000	2000	2500	2500	2500	1500	1100
		c	95	115	150	160	95	150	140	150	35	95
		rb					++++	++++	++++	++++		
		w%	41.23	37.05	37.22	37.21	30.01	42.37	36.15	38.53		34.17
		o	4000	3500	4500	4500	3500	4000	4500	3500	2000	3500
		g	950	950	2000	2000	2000	2500	2500	3500	1150	1500
		p	75	70	95	115	95	110	75	95	65	75
	B_1	a	2000	1500	2500	2000	2000	2000	2000	2500	1500	1150
		d	200	150	150	200	150	200	250	300	150	200
		c	0.02	0.095	0.045	0.095	0.02	0.11	0.015	0.095	0.007	0.03
		rb					++	+++	++	+++		
		w%	22.17	23.35	29.95	33.99	24.28	32.11	30.12	31.18		28.09
		o	2500	1500	1500	1500	1500	2500	1500	3000	1150	2000
		g	950	750	1150	1500	1500	2000	1150	2500	750	950
		p	40	35	45	30	65	45	45	65	35	45
4	B_2	a	1500	1150	1500	1500	950	1500	1150	1500	950	1150
		d	150	150	150	150	115	160	160	200	140	140
		c	0.035	0.045	0.025	0.045	0.025	0.075	0.035	0.025	0.011	0.014
		rb					+	++	+	++		
		w%	17.91	19.17	19.04	31.79	16.85	27.49	20.42	27.42		29.06
		o	9500	7500	9500	9500	7500	9500	9500	11000	6500	6500
		g	3000	2500	4500	4500	4500	6500	4500	4500	1500	2000
		p	65	110	250	110	300	250	250	300	300	250
	B_3	a	4500	3000	4500	3500	4000	4500	4500	4500	3500	3500
		d	250	140	200	250	200	250	350	350	150	250
		c	0.15	0.095	0.095	0.14	0.115	0.25	0.07	0.11	0.065	0.075
		rb					+++	+++	++	+++		
		w%	39.68	34.61	31.51	36.12	26.14	30.58	30.72	35.69		32.74

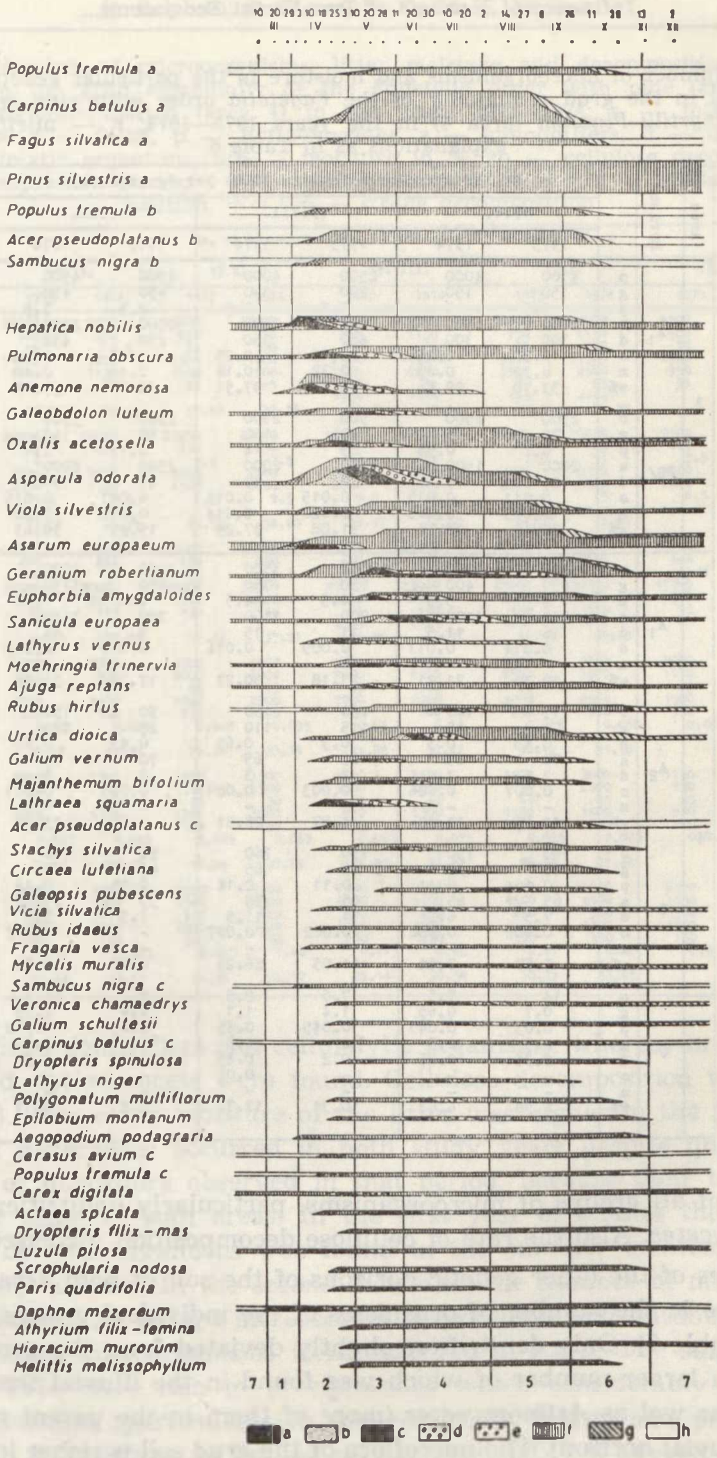
ammonifiers, denitrifiers and cellulolytic organisms, whereas in area 4 — fungi and *Actinomycets* were found. Cellulose decomposition was faster in area 3. Also mean moisture of the litter was higher in the grud. The observed differences occurred in both study years despite quantitative changes of microflora observed in that period, because their tendencies were the same in both areas. In the first year of studies the smallest number of microorganisms was found in the summer months, more in spring and autumn. In the second, however, the number of microorganisms of almost all groups increased in the summer and autumn seasons; a little fewer microorganisms were observed in April. The summer and autumn 1974 were rich in precipitations which considerably increased litter moisture (particularly in the confierous forest) and presumably created in it conditions of limited organic availability of oxygen (5). Water facilitated the use of substrate and contributed to general increase in the

Table 7. Number of microorganisms and moisture in the particular genetic horizons of the soil in the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4) in the years 1973—1974; n — nitrifiers, other explanations as in Table 6

Area	Horizon		No. of micro-organisms in 1000s per 1g of soil					
			19.V.		19.VII.		19.IX.	
			1973	1974	1973	1974	1973	1974
3	A_1	o	4500	4000	2500	4000	4500	4500
		g	150	150	200	350	450	450
		p	3.5	3	3.5	3.5	2.5	3.5
		a	2000	1500	2000	2500	2500	2500
		d	300	300	450	350	250	450
		c	0.3	0.25	0.16	0.25	0.25	0.25
		n	0.32	0.23	0.32	0.18	0.48	0.18
		w%	33.70	29.66	30.74	37.51	16.79	39.18
	/B/	o	2500	2500	900	2500	2500	3500
		g	75	65	90	150	90	140
		p	0.7	0.95	3	4	0.11	1.1
		a	2000	1500	1150	2000	2500	2000
		d	95	75	70	95	45	95
		c	0.011	0.015	0.015	0.015	0.007	0.016
		n	0.023	0.023	0.028	0.014	0.048	0.02
		w%	32.19	28.34	31.08	37.29	19.89	36.63
4	A_1	o	3500	3000	3500	3500	4000	4000
		g	450	400	650	750	950	1150
		p	4	3.5	4.5	4.5	4.5	7.5
		a	950	1100	900	1100	700	1150
		d	16	11.5	11	15	9	14
		c	0.014	0.011	0.009	0.014	0.025	0.025
		n	-	-	-	-	-	-
		w%	19.31	21.21	23.18	30.27	17.37	31.48
	A_2	o	115	140	150	160	90	150
		g	90	45	115	110	25	140
		p	0.45	0.3	0.3	0.65	0.45	0.75
		a	70	65	65	65	70	75
		d	3.5	3	2	3	2	3
		c	0.007	0.006	0.003	0.009	0.005	0.011
		n	-	-	-	-	-	-
		w%	10.66	12.03	14.57	28.81	4.65	23.07
	B	o	160	150	150	160	90	110
		g	45	35	45	65	45	45
		p	0.11	0.11	0.11	0.14	0.15	0.16
		a	65	65	65	75	35	75
		d	7.5	6.5	11	11.5	7.5	9.5
		c	0.002	0.002	0.002	0.007	-	0.007
		n	-	-	-	-	-	-
		w%	7.57	7.54	11.05	26.29	4.57	15.52
	C	o	14	9.5	7.5	9.5	9	11.5
		g	0.7	0.65	1.4	1.1	0.4	0.95
		p	0.035	0.045	0.045	0.45	0.07	0.065
		a	2.5	2.5	2	2.5	3	3.5
		d	0.35	0.25	0.2	0.45	0.15	0.3
		c	-	-	-	0.02	-	-
		n	-	-	-	-	-	-
		w%	6.98	6.83	10.31	17.77	2.83	6.11

number of all groups of microorganisms, particularly denitrifiers, except *Actinomycetes*. Also the rate of cellulose decomposition increased.

Studies of the other genetic horizons of the soil of both areas showed a decrease in the number of organisms of the individual groups with the depth (Table 7). Only denitrifiers slightly deviated from the general tendencies, a larger number of which was found in the illuvial than eluvial horizon, as wel as *Astinomycetes* (more of them in the parent rock than in the illuvial horizon). The microflora of the grud soil is richer in a greater number of nitrifiers. In the pine forest soil only fungi and *Actino-*


III
IV
V
VI
VII
VIII
IX
X
XI
XII
Populus tremula a
Carpinus betulus a
Fagus silvatica a
Pinus silvestris a
Populus tremula b
Acer pseudoplatanus b
Sambucus nigra b
Hepatica nobilis
Pulmonaria obscura
Anemone nemorosa
Galeobdolon luteum
Oxalis acetosella
Asperula odorata
Viola silvestris
Asarum europaeum
Geranium robertianum
Euphorbia amygdaloides
Sanicula europaea
Lathyrus vernus
Moehringia trinervia
Ajuga reptans
Rubus hirtus
Urtica dioica
Galium vernum
Majanthemum bifolium
Lathraea squamaria
Acer pseudoplatanus c
Stachys silvatica
Circaea lutetiana
Galeopsis pubescens
Vicia silvatica
Rubus idaeus
Fragaria vesca
Mycelis muralis
Sambucus nigra c
Veronica chamaedrys
Galium schultesii
Carpinus betulus c
Dryopteris spinulosa
Lathyrus niger
Polygonatum multiflorum
Epilobium montanum
Aegopodium podagraria
Cerasus avium c
Populus tremula c
Carex digitata
Actaea spicata
Dryopteris filix-mas
Luzula pilosa
Scrophularia nodosa
Paris quadrifolia
Daphne mezereum
Athyrium filix-femina
Hieracium murorum
Melittis melissophyllum
7 1 2 3 4 5 6 7
a b c d e f g h
100 90 80 70 60 50 40 30 20 10 5 %

mycetes were found to occur more numerously. Also soil moisture decreased with the depth, which was always higher in the grud during the two study years. The observed regularities were characteristic for both years, despite quantitative differences which occurred in that period. In 1974, the number of microorganisms of almost all groups increased in the soils

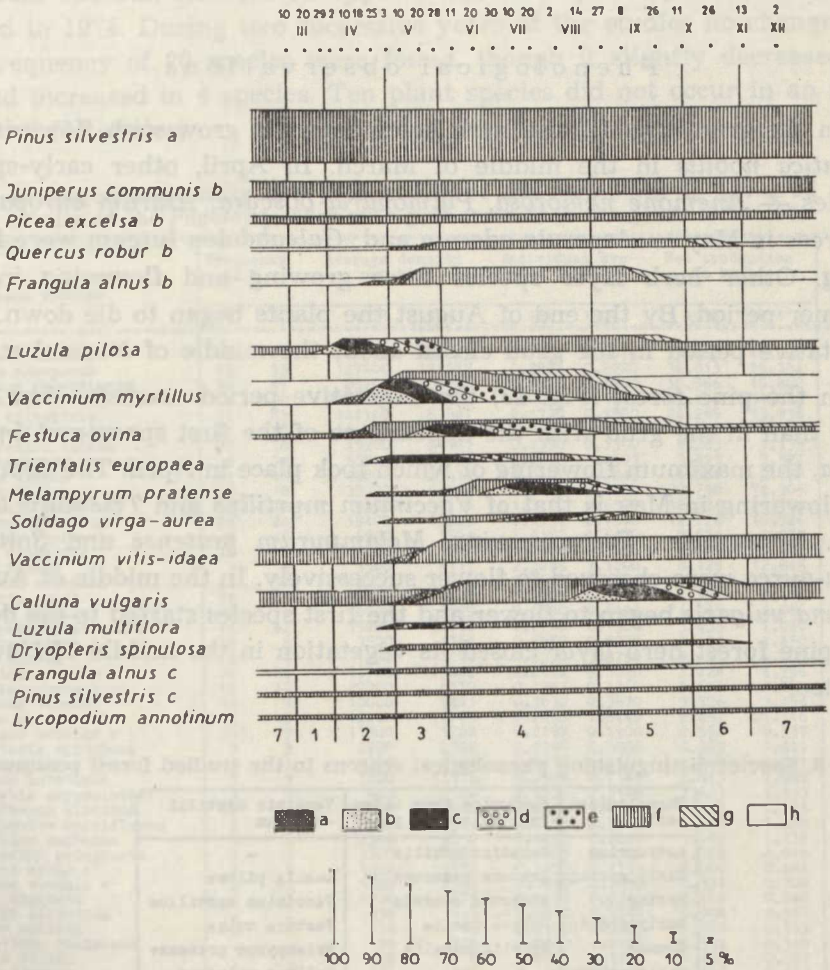


Fig. 13. Phenological spectrum of *Vaccinio myrtilli-Pinetum* (area 4); explanations as in Fig. 12

Fig. 12. Phenological spectrum of the grud community of the *Fagetalia* order with pine (area 3); 1 — young leaves, 2 — flower buds, 3 — flowering, 4 — young fruits, 5 — ripe fruits, 6 — leaves fully developed, 7 — leaf fall, 8 — dormant period of trees and shrubs

of either community. Moisture of the other genetic horizons increased more distinctly than in the litter, twice as much in some of them. This had a negative effect on the growth of nitrifiers the number of which decreased, as compared with the preceding year. In 1974, the largest number of microorganisms was found in July and September, whereas in 1973 — in May and September (Table 7).

Phenological observations

In the grud (Fig. 12) the herb layer began to grow with flowering of *Hepatica nobilis* in the middle of March. In April, other early-spring species — *Anemone nemorosa, Pulmonaria obscura, Asarum europaeum*, whereas in May — *Asperula odorata* and *Galeobdolon luteum* were flowering. Other herb layer species were growing and flowering in the summer period. By the end of August the plants began to die down. The vegetative period in the grud closed about the middle of November.

In the pine forest (Fig. 13) the vegetative period started a few days later than in the grud with the appearance of the first sprouts of *Luzula pilosa*, the maximum flowering of which took place in April. The dominating flowering in May is that of *Vaccinium myrtillus* and *Trientalis europaea*. In summer, *Festuca ovina, Melampyrum pratense* and *Solidago virga-aurea* were observed to flower successively. In the middle of August *Calluna vulgaris* began to flower and the first species started to die down. The pine forest herb layer closed its vegetation in the middle of November, too.

Table 8. Species distinguishing phenological seasons in the studied forest communities

Phenological period	Community from order Fagetalia with pine	Vaccinio myrtilli -Pinetum
Antyspring	Hepatica nobilis	-
Early spring	Anemone nemorosa	Luzula pilosa
Spring	Asperula odorata	Vaccinium myrtillus
Early summer	Urtica dioica	Festuca ovina
Summer	Mycelis muralis	Melampyrum pratense
Early autumn	-	Calluna vulgaris

The present observations resulted in distinguishing 7 periods in either area which approximately correspond to phenological seasons of the year (11). The time of their duration was similar in both study years. Each period was characterized by flowering of definite herb layer species (Table 8). Similar indicatory species were also given by F a l i ń s k a (3).

Productivity of the herb layer and biomass of mosses

In the grud community of the *Fagetalia* order with pine, 48 species of the herb layer were found in 1973, and 49 in the next year (Table 9). The highest frequency (50—100%) of *Oxalis acetosella, Viola silvestris, Asperula odorata, Asarum europaeum* and *Acer pseudoplatanus* was recorded in 1974. During two successive years of the studies no changes in the frequency of 20 species were found, though it slightly decreased in 13 and increased in 4 species. Ten plant species did not occur in an area of 17 m^2 (34 circles).

Table 9. Frequency, density and productivity of the herb layer in the grud community of the *Fagetalia* order with pine (area 3) in the years 1973—1974

Plant species	Frequency in %		Average density per ha		Individual average increase		Net production in kg/ha		Annotations
	1973	1974	1973	1974	1973	1974	1973	1974	
Asperula odorata	85	82	572300	458823	0.1284	0.0970	73.483	44.506	
Asarum europaeum	65	53	127600	114117	0.2885	0.2220	36.813	25.334	
Geranium robertianum	38	47	68200	100000	0.5215	0.1980	35.566	19.800	clump
Oxalis acetosella	100	100	3039400	2948823	0.0096	0.0186	29.178	54.848	
Viola silvestris	97	85	141100	87647	0.1720	0.1590	24.269	13.936	clump
Moehringia trinervia	21	15	141800	34705	0.0525	0.0490	7.445	1.701	
Galeobdolon luteum	18	18	45200	24117	0.1390	0.1300	6.283	3.135	
Anemone nemorosa	35	32	65200	70000	0.0602	0.0503	3.925	3.521	
Galium vernum	21	18	48800	29411	0.0407	0.0945	1.986	2.779	
Urtica dioica	18	18	35900	23529	4.2005	3.1580	150.798	74.305	
Galeopsis pubescens	12	12	9400	41176	1.3760	0.6500	12.934	26.764	
Pulmonaria obscura	24	24	19400	13529	0.6560	0.7780	12.726	10.526	clump
Lathraea squamaria	9	6	5900	1764	1.6160	1.6470	9.534	2.905	
Vicia silvatica	18	9	5800	1764	1.6140	1.5008	9.361	2.647	
Rubus idaeus	3	6	3500	4117	2.3225	3.1200	8.129	12.845	
Sanicula europaea	12	12	5300	4117	0.9690	0.3680	5.136	1.515	clump
Fragaria vesca	24	24	18800	14705	0.2308	0.3140	4.339	4.617	clump
Mycelis muralis	12	12	6500	3529	0.6530	0.6420	4.245	2.266	clump
Acer pseudoplatanus c	44	62	15200	51764	0.2260	0.1360	3.435	7.040	
Sambucus nigra c	12	6	3500	1764	0.8862	0.8220	3.102	1.450	
Rubus hirtus	6	6	1200	1176	2.8590	5.2750	3.431	6.203	
Hepatica nobilis	26	26	15300	15882	0.2110	0.3020	3.228	4.796	
Veronica chamaedrys	12	12	27000	6470	0.1343	0.1362	3.626	0.881	
Lathyrus vernus	12	9	10000	9411	0.3632	0.3670	3.326	3.454	
Galium schultesii	3	3	12900	14705	0.2060	1.8440	2.657	27.116	
Carpinus betulus c	36	9	11800	1764	0.2163	0.1908	2.552	0.337	
Dryopteris spinulosa	3	3	4700	2352	0.4390	0.6000	2.063	1.411	
Lathyrus niger	3	3	2300	1176	0.8435	1.1320	1.940	1.331	
Circaea lutetiana	9	9	7000	11176	0.2590	0.7145	1.813	7.985	
Euphorbia amygdaloides	3	3	600	588	2.6720	2.2160	1.603	1.303	clump
Majanthemum bifolium	18	15	21800	15882	0.0634	0.0740	1.382	1.175	
Polygonatum multiflorum	3	3	3500	3529	0.3450	0.3866	1.208	1.364	
Epilobium montanum	6	6	2300	2352	0.4820	0.4820	1.109	1.134	
Aegopodium podagraria	3	3	3500	10588	0.3125	0.4550	1.094	4.818	
Cerasus avium c	9	6	1800	1176	0.3333	0.4133	0.600	0.486	
Populus tremula c	6	12	1800	2352	0.1840	0.2992	0.331	0.704	
Carex digitata	3	3	1200	1176	0.1450	0.0340	0.174	0.040	clump
Stachys silvatica	.	.	538	116	1.6810	1.2540	0.904	0.146	
Actaea spicata	.	.	116	66	2.3180	2.9280	0.269	0.193	
Dryopteris filix-mas	.	.	198	120	1.9400	1.2100	0.384	0.145	
Luzula pilosa	.	.	400	6	0.0700	0.1100	0.280	0.001	
Ajuga reptans	.	3	356	588	0.3800	0.3104	0.135	0.183	clump
Scrophularia nodosa	.	.	40	10	2.2550	1.3368	0.090	0.013	
Paris quadrifolia	.	.	154	74	0.1693	0.3250	0.026	0.024	
Daphne mezereum	.	.	30	2	1.0428	2.7000	0.031	0.005	
Athyrium filix-femina	.	.	78	160	1.1890	1.0700	0.093	0.171	
Hieracium murorum	.	.	72	66	0.7980	0.5520	0.057	0.036	clump
Melittis melissophyllum	.	.	44	28	1.0020	0.7240	0.044	0.020	
Fagus silvatica	–	12	–	5294	–	0.1340	–	0.709	
Total			4509526	4137686			477.443	382.624	

Plant density in the herb layer of the grud proved to be high; besides, a decrease in 33 species by 371 840 specimens/ha was found in the second year of the studies. Among the dominating species that density decrease concerned mainly *Oxalis acetosella, Asperula odorata, Viola silvestris, Asarum europaeum* and *Urtica dioica*. A slight increase was simultaneously found in *Geranium robertianum*. It is worth stressing that the first 4 dominating species in Table 9 constitute 87 and 89% of all specimens in the two successive years of the studies. In general the density of the herb layer species increased with an increase in their frequency.

The average index of annual increment of individual plants in the grud did not exceed 1 g in 34 and 35 species in two successive years, whereas in the other plants that increase was higher. It was particularly high in *Urtica dioica, Rubus hirtus, R. idaeus, Actaea spicata* and *Euphorbia amygdaloides*. Comparing the annual volume increase of the individual plants in both study years, its slight decrease was found in some species and a slight increase in others.

The total net productivity of the herb layer in the grud of *Fagetalia* order with pine decreased in the second year of the studies by 94.819 kg/ /ha, i.e. by over 19%. In most cases that decrease resulted both from density decrease and individual annual volume increment of the majority of herb layer species. In both study years the productivity value was determined by the dominating plants; the productivity of the first 5 species in Table 9, including *Urtica dioica*, was over 73 and 61% of the total grud herb layer productivity in 1973 and 1974, respectively.

In the subassociation *Vaccinio myrtilli-Pinetum typicum* 13 herb layer species and 5 mosses occurred (Table 10, 11). The highest frequency (50—100%) was recorded in *Entodon schreberi, Dicranum undulatum, Luzula pilosa, Vaccinium myrtillus, Festuca ovina* and *Pinus silvestris* in 1973. Changes in the frequency of the majority of the species were small; they were 15% only in *Dicranum undulatum* and *Pinus silvestris* c.

Plant density in the herb layer of the pine forest increased by over 21% in the second year of the studies. That density increase was found in most herb layer species, particularly distinctly in *Festuca ovina, Vaccinium myrtillus* and *Luzula multiflora*. A slight density decrease was found mainly in *Calluna vulgaris* and *Vaccinium vitis-idaea*.

The index of annual increment of individual species proved to be small and it did not exceed 0.5 g in most cases. An exception was *Solidago virga-aurea* which gained over 1 g in 1974.

The total productivity of the herb layer in the pine forest decreased in the second study year by 38.396 kg/ha, i.e. by over 12% in relation to the state in 1973. That decrease was determined above all by decreased indices of individual increment of the particular species. Similarly

Table 10. Frequency, density and productivity of the herb layer in *Vaccinio myrtilli-Pinetum* (area 4) in the years 1973—1974

Plant species	Frequency in %		Average density per ha		Individual average increase in g		Net production in kg/ha		Annotations
	1973	1974	1973	1974	1973	1974	1973	1974	
Vaccinium myrtillus	65	65	580000	684000	0.3305	0.1650	191.690	112.860	
Calluna vulgaris	40	35	140000	138000	0.2420	0.2541	33.880	35.066	
Vaccinium vitis-idaea	40	35	187000	141000	0.1385	0.0910	25.899	12.831	
Melampyrum pratense	75	80	105000	172000	0.2031	0.1400	21.325	24.080	
Luzula pilosa	65	70	116000	177000	0.1485	0.1750	17.226	30.975	clump
Festuca ovina	50	50	329000	541000	0.0414	0.0885	13.625	47.878	clump
Trientalis europaea	15	15	37000	37000	0.0775	0.0690	2.867	2.553	
Pinus silvestris c	60	35	31000	20000	0.0290	0.0608	0.899	1.216	
Frangula alnus c	25	25	12000	10000	0.0910	0.1240	1.092	1.240	
Solidago virga-aurea	5	5	1000	10000	0.7670	1.0314	0.767	1.031	
Luzula multiflora	5	15	10000	50000	0.0600	0.1000	0.600	5.000	clump
Dryopteris spinulosa	.	.	206	206	0.9520	0.3140	0.196	0.065	
Lycopodium annotinum	.	.	.	.	.	.	5.145	2.016	
Total			1548206	1971206			315.207	276.811	

Table 11. Frequency and biomass of mosses in *Vaccinio myrtilli-Pinetum* (area 4) in the years 1973—1974

Plant species	Frequency in %		Biomass in kg/ha	
	1973	1974	1973	1974
Entodon schreberi	90	95	690.000	829.500
Dicranum undulatum	80	65	266.250	189.250
Hylocomium splendens	10	15	4.000	22.000
Dicranium scoparium i in	5	10	1.790	29.800
Total			962.040	1070.550

as in the grud, the value of total herb layer productivity was determined by the dominating plants; the productivity of the first 6 species in Table 10 was over 96 and 95% of the total herb layer productivity in 1973 and 1974, respectively. A large biomass was found in mosses, which increased by 108.51 kg/ha in the second year of observations. In the two successive years of observations it was respectively 1.3 and 1.9 times higher than the total herb layer productivity in the pine forest. The productivity of mosses (24) was in the two successive study years 320.680 kg//ha and 356.850 kg/ha respectively, i.e. it was higher than that of the herb layer by 5.473 kg/ha and 80.039 kg/ha, respectively.

The productivity values of the herb layer and mosses were effected by weather anomalies which occurred particularly distinctly in 1974. This concerns mainly precipitation and moisture, deficiencies of which occurred in spring and their excess was observed in June, July and September. They resulted in the increase of the biomass and productivity of mosses in the pine forest, but a long lasting cloudiness weakened photosynthesis and presumably caused a general productivity decrease of the herb layer in that year.

The total productivity of the herb layer in both forest ecosystems proved to be higher than that in the grud (5, 7, 10, 18, 23) and pine communities (16, 24, 25), being more closely related from the floristical point of view. However, it was lower than the productivity of the herb layer in similar forest communities at Panasówka in Central Roztocze (6).

Productivity of organic fall

Samples of organic fall were taken in the period from May to December, 1973, and from January to December in the next year. The amount of fall depended on floristic composition and density of the stands. In both areas pine needles dominated decisively; in the grud they constituted 38 and 30% of organic fall in the two successive years of the studies, respectively, and in the pine forest 63 and 58%, respectively (Tables 12—15). The second place with regard to the percentage content was taken by small twigs and bark. The culminating month of organic fall was October. An exception was the year 1973 in the coniferous forest where the highest amount of fall was observed in September.

The amount of organic fall from the second year in the grud was only by 3% smaller than that in a similar forest type, in Central Roztocze, studied in 1972 (6). It was equal to the collection from an oak-hornbeam forest in Slovakia (9) as well as to the mean value from 4-year studies in the beech-fir-hornbeam forest in the reserve at Obrocz (5). However, the organic value obtained in our studies was higher than that in the studied fragments of *Tilio-Carpinetum* (14, 24) and *Fagetum carpaticum* (14).

The amounts of organic fall in the coniferous forest in both years of the studies were respectively smaller by 28 and 36% than those in the grud. The annual organic fall from 1974 studied simultaneously was approximate in its value to the collection obtained in the *Vaccinio myrtilli-Pinetum* from the Kampinos Forest (24) and was by 436.4 kg/ha higher than the organic fall from the pine forest at Panasówka (6).

Chemical composition of the herb layer, mosses and organic fall

The herb layer species of both communities contain much potassium and nitrogen, but considerably lower amounts of other elements. The highest amounts of all the investigated elements were in: *Urtica dioica*, *Galeobdolon luteum*, *Sambucus nigra* c, *Vicia silvatica* in the grud, and in *Melampyrum pratense*, *Solidago virga-aurea* and *Trientalis*

Table 12. Composition of organic fall in the grud community of the *Fagetalia* order with pine (area 3) in 1973

Months	Leaves of pine	Cones of pine	Bark and twigs	Leaves of hornbeam	Leaves of beech	Leaves of asp	Leaves of oak	Leaves of maple	Leaves of cherry	Bud scales of the beech	Fruits of beech	Fruits of maple	Fruits of hornbeam	Other	Total
V	80.5	31.6	121.4	2.8	3.6	0.03	-	-	-	42.3	-	-	-	75.95	358.18
VI	116.3	41.0	127.4	5.8	10.3	1.6	0.9	-	-	1.3	1.0	-	-	41.83	347.43
VII	31.5	5.8	75.9	4.6	2.9	2.6	0.5	-	-	0.4	4.0	-	1.4	10.2	139.80
VIII	80.1	7.4	26.8	26.4	7.1	8.0	0.6	3.6	0.5	0.4	9.5	0.5	1.1	5.8	177.80
IX	328.1	-	78.8	70.1	30.1	24.5	3.1	0.9	3.0	-	12.0	0.8	1.3	5.3	558.00
X	923.9	5.3	107.0	403.3	303.8	277.4	30.6	42.9	18.0	-	32.1	14.1	2.0	5.9	2166.30
XI-XII	270.1	34.1	354.3	80.7	316.5	11.4	34.3	5.5	0.6	-	10.4	6.0	2.9	22.5	1149.30
Total	1830.5	125.2	891.6	593.7	674.3	325.53	70.0	52.5	22.1	44.4	69.0	21.4	8.7	167.48	4896.81

Table 13. Composition of organic fall in the grud community of the *Fagetalia* order with pine (area 3) in 1974

Months	Leaves of pine	Cones of pine	Bark and twigs	Leaves of hornbeam	Leaves of beech	Leaves of asp	Leaves of maple	Leaves of oak	Leaves of cherry	Bud scales of the beech	Fruits of beech	Fruits of hornbeam	Other	Total
I	3.8	17.5	10.5	1.3	0.8	0.3	-	-	-	-	-	-	-	34.2
II	26.5	-	25.9	0.9	3.1	-	0.03	-	-	-	-	-	6.13	62.56
III	38.9	0.9	99.4	2.1	3.0	0.1	-	1.8	-	-	-	0.1	5.7	152.0
IV	84.8	1.7	76.0	3.0	7.9	0.1	1.1	1.0	-	7.5	-	-	17.1	200.2
V	63.1	8.3	60.6	8.3	4.4	2.6	-	-	-	18.1	-	-	20.6	186.0
VI	93.3	203.9	99.0	1.5	4.2	5.1	1.7	0.5	0.8	0.4	1.0	-	2.4	413.8
VII	70.7	53.7	77.9	9.7	8.0	23.2	1.8	1.5	1.7	0.3	-	0.4	7.2	256.1
VIII	26.2	23.1	29.7	5.5	4.8	27.7	0.7	1.1	1.5	-	-	-	0.8	121.1
IX	156.7	-	57.6	44.7	27.1	181.3	0.5	3.3	0.2	-	-	-	1.4	472.8
X	850.2	34.5	366.9	449.7	415.9	73.3	37.6	54.3	-	-	-	-	32.3	2314.7
XI	77.8	5.4	94.8	33.8	82.7	0.8	1.0	12.8	0.3	-	-	-	0.2	309.6
XII	76.9	20.5	549.5	2.6	17.6	0.1	-	-	-	-	-	-	2.1	669.3
Total	1568.9	369.5	1547.8	563.1	579.5	314.6	44.43	76.3	4.5	26.3	1.0	0.5	95.93	5192.36

Table 14. Composition of organic fall in *Vaccinio myrtilli-Pinetum* (area 4) in 1973

Months	Leaves of pine	Leaves of spruce	Leaves of juniper	Cones of pine	Bark and twigs	Leaves of birch	Leaves of oak	Other	Total
V	136.1	1.0	0.3	11.8	110.8	-	-	0.7	260.70
VI	175.8	0.7	0.2	104.0	157.2	0.2	-	67.7	505.80
VII	91.2	0.4	0.3	15.8	128.5	0.3	-	19.5	256.00
VIII	182.3	0.1	-	9.5	134.3	2.5	-	-	328.70
IX	749.6	5.5	0.2	15.7	75.3	1.0	1.9	20.7	869.90
X	625.9	1.1	-	-	76.8	1.5	21.7	1.9	728.90
XI-XII	275.5	1.4	0.5	3.5	282.3	0.2	8.8	6.5	578.70
Total	2236.4	10.2	1.5	160.3	965.2	5.7	32.4	117.0	3528.70

Table 15. Composition of organic fall in *Vaccinio myrtilli-Pinetum* (area 4) in 1974

Months	Leaves of pine	Leaves of spruce	Leaves of juniper	Cones of pine	Bark and twigs	Leaves of birch	Leaves of oak	Other	Total
I	9.5	0.2	0.1	-	52.9	-	-	3.4	66.1
II	21.6	0.1	0.03	-	23.3	-	0.03	3.4	48.46
III	39.6	0.2	0.1	0.3	51.7	-	-	0.7	92.6
IV	76.2	-	0.1	10.1	128.4	0.1	1.2	1.4	217.5
V	91.7	1.1	0.2	13.4	50.9	0.1	-	11.5	168.9
VI	135.4	0.6	0.2	111.2	71.5	0.8	0.1	43.1	362.9
VII	87.9	1.4	1.5	112.1	114.6	0.9	0.2	19.8	338.4
VIII	122.1	-	0.5	18.2	44.4	0.1	0.1	4.5	189.9
IX	424.1	6.4	1.1	8.2	15.6	0.8	3.0	2.4	461.6
X	799.9	1.4	0.1	9.5	117.7	-	21.2	11.9	961.7
XI	66.0	3.9	0.2	12.1	35.1	-	14.0	2.4	133,7
XII	56.1	1.3	0.1	36.4	188.9	-	0.9	3.0	286.7
Total	1930.1	16.6	4.23	331.5	895.0	2.8	40.73	107.5	3328.46

europaea in the pine forest. The lowest amounts of the investigated elements were in *Epilobium montanum*, *Lathraea squamaria* and *Dryopteris spinulosa* in the grud, and *Vaccinium vitis-idaea*, *Calluna vulgaris* and *Festuca ovina* in the pine forest (Table 16).

The organic fall in both investigated areas contained less N, P, K and Mg and more Ca than the species of the herb layer and mosses. The highest percentage of all investigated mineral components was found in the leaves of hornbeam and aspen in the grud, and "various" (mainly cones and pine seeds) and pine needles in the coniferous forest.

In both study years the percentage content of the investigated mineral components in the herb layer, mosses and organic fall of both forest communities was in the main similar. Only iron was found in considerably

Table 16. Content of mineral substances in mg/g of dry matter in the studied forest communities

			N		P_2O_5		K_2O		Na_2O		Fe_2O_3		CaO		MgO	
			a	b	a	b	a	b	a	b	a	b	a	b	a	b
Community from order Fagetalia with pine	Herb layer	Asperula odorata	32.2	24.1	6.1	4.4	55.5	26.8	0.71	0.82	0.39	0.53	11.3	10.3	1.1	2.3
		Asarum europaeum	24.5	24.0	5.9	8.7	56.0	49.0	0.80	0.77	0.39	1.20	14.6	10.6	2.6	2.6
		Geranium robertianum	23.1	32.4	7.7	8.1	50.0	44.8	0.81	0.88	0.26	0.62	12.6	11.7	1.6	3.0
		Oxalis acetosella	25.2	23.6	5.3	4.6	33.5	34.0	0.69	0.65	0.21	0.45	11.7	8.6	2.8	3.4
		Viola silvestris	27.4	21.4	5.9	3.7	58.0	45.5	0.68	0.69	0.43	0.47	8.8	8.2	6.0	5.5
		Moehringia trinervia	21.0	19.2	5.3	4.7	51.5	44.5	0.65	0.59	0.43	0.43	9.5	8.1	2.0	2.0
		Galeobdolon luteum	44.8	40.0	10.5	8.4	61.5	49.0	0.91	0.59	0.65	0.65	9.3	7.7	0.6	4.3
		Anemone nemorosa	27.2	24.2	8.0	3.9	39.0	45.3	0.77	0.86	0.43	0.70	11.4	10.9	2.2	2.8
		Galium vernum	35.7	25.4	8.9	4.1	41.5	36.8	0.89	0.68	0.57	0.45	12.4	9.3	1.2	2.4
		Urtica dioica	40.6	32.0	13.1	6.3	41.5	45.5	0.95	0.95	0.39	1.80	17.0	13.7	5.4	3.4
		Galeopsis pubescens	31.5	19.0	8.9	9.0	49.0	65.5	0.39	0.62	0.52	0.56	10.1	8.0	2.6	3.0
		Pulmonaria obscura	28.7	28.1	7.7	5.3	60.0	61.7	0.81	0.73	0.61	0.74	10.6	10.0	1.1	1.4
		Lathraea squamaria	26.6	24.2	18.5	12.4	37.5	34.5	0.38	0.31	0.26	1.53	2.0	1.9	1.1	1.4
		Vicia silvatica	28.0	28.1	5.6	4.6	27.5	22.7	1.47	0.84	0.31	0.50	17.6	11.7	0.7	2.1
		Rubus idaeus	30.1	17.7	7.0	4.1	28.5	14.0	0.71	0.51	0.57	0.70	9.8	5.6	4.0	2.5
		Sanicula europaea	17.5	18.0	4.2	3.7	70.0	53.0	0.72	0.98	3.12	4.70	10.9	12.2	0.1	0.8
		Fragaria vesca	21.6	17.7	7.5	2.8	31.0	24.9	0.69	0.79	0.31	0.65	10.9	10.8	3.4	2.4
		Mycelis muralis	23.1	19.4	8.6	4.6	44.5	35.8	0.85	0.63	0.17	0.50	10.0	6.6	1.4	2.0
		Acer pseudoplatanus c	23.8	19.9	6.5	4.6	18.5	18.5	0.83	0.65	0.39	0.59	12.2	10.2	3.2	3.2
		Sambucus nigra c	45.5	40.7	8.0	6.5	67.5	55.6	0.72	0.78	0.39	0.62	12.5	10.1	10.8	6.3
		Rubus hirtus	21.0	35.8	5.3	3.7	18.5	15.5	0.59	0.42	1.50	0.30	6.6	5.0	2.4	3.5
		Hepatica nobilis	23.1	19.7	6.5	2.8	47.0	30.8	0.61	0.64	0.39	0.83	8.2	8.1	3.0	3.3
		Veronica chamaedrys	23.1	20.0	6.5	4.4	42.5	34.0	0.66	0.58	0.61	2.98	10.6	7.7	2.0	1.9
		Lathyrus vernus	30.1	30.6	6.7	4.4	36.0	37.8	0.56	0.76	0.74	0.77	8.9	9.3	1.2	2.7
		Galium schultesii	23.1	29.9	5.3	7.3	33.5	35.3	0.67	0.63	0.17	0.41	10.1	8.8	1.2	1.9
		Carpinus betulus c	22.4	18.7	5.9	3.7	10.5	9.0	0.51	0.80	0.31	1.02	15.2	11.2	2.4	2.3
		Dryopteris spinulosa	29.4	24.2	11.5	5.1	32.0	32.6	0.28	0.40	0.21	0.74	5.8	4.4	4.1	4.3
		Lathyrus niger	37.8	36.5	6.1	4.4	26.0	21.5	0.74	0.62	1.20	5.25	10.7	8.7	1.1	0.1
		Circaea lutetiana	29.4	24.0	8.6	5.1	57.5	38.6	0.71	0.79	0.48	0.65	11.4	9.9	3.9	0.8
		Euphorbia amygdaloides	25.9	32.2	9.5	7.8	29.5	29.5	0.73	0.70	3.09	6.15	11.1	9.5	0.9	3.9
		Majanthemum bifolium	28.0	20.3	9.5	4.8	44.0	35.0	0.79	0.53	0.26	0.74	8.7	6.9	2.0	2.1
		Polygonatum multiflorum	28.7	20.4	8.2	4.6	44.5	32.3	1.12	0.65	0.26	1.06	8.9	8.6	0.1	0.6
		Epilobium montanum	16.8	18.2	8.9	6.9	30.0	35.0	1.00	0.63	0.21	0.34	11.2	8.7	2.2	2.2
		Aegopodium podagraria	27.3	37.5	6.7	7.0	84.0	71.8	0.73	0.61	0.26	0.34	10.7	8.5	3.0	5.0
		Populus tremula c	38.5	20.5	18.0	6.5	58.0	28.5	1.21	0.43	0.26	0.25	9.3	5.0	2.2	1.2
		Stachys silvatica	36.4	39.7	9.5	8.4	80.0	49.0	0.59	0.76	0.39	0.50	9.1	10.6	4.1	3.9
		Ajuga reptans	32.2	28.7	11.5	7.0	47.0	42.5	0.72	0.75	0.39	0.65	13.2	10.1	1.8	2.7
		Other herbs	23.8	23.1	7.0	4.8	37.5	25.2	0.73	0.64	0.21	0.45	10.9	8.5	3.0	2.5
	Plant fall	Needles of pine	10.6	13.3	2.0	2.4	3.2	3.5	0.34	0.36	0.50	0.45	6.7	4.6	0.0	0.0
		Leaves of beech	14.2	14.2	2.8	2.5	4.7	2.5	0.57	0.71	1.17	1.25	12.9	10.2	0.0	0.0
		Leaves of hornbeam	20.7	22.7	4.2	3.6	7.0	2.9	0.66	0.89	0.90	1.48	13.9	13.4	0.6	0.1
		Leaves of aspen	13.1	19.6	2.4	3.4	5.6	5.5	0.67	0.82	0.46	0.88	13.8	12.6	0.1	0.4
		Bark and twigs	8.4	8.0	1.7	1.5	2.6	1.5	0.41	0.53	0.56	0.90	8.1	7.4	0.0	0.0
		Other	16.3	16.2	4.2	3.1	5.1	3.8	0.52	0.55	1.00	3.04	9.4	6.4	0.0	0.3
Vaccinio myrtilli-Pinetum	Herb layer	Vaccinium myrtillus	18.2	16.9	5.9	3.0	11.0	8.7	0.52	0.43	0.17	0.30	5.6	4.9	0.5	1.7
		Calluna vulgaris	17.5	16.1	3.7	2.8	10.0	8.3	0.53	0.39	0.65	4.70	3.8	3.8	1.6	0.1
		Vaccinium vitis-idaea	13.3	16.9	3.9	3.7	9.5	7.5	0.45	0.40	0.21	0.39	4.4	4.1	0.7	1.9
		Melampyrum pratense	23.8	22.1	8.6	5.3	19.0	19.0	0.76	0.58	0.09	0.39	11.7	7.0	1.6	4.2
		Luzula pilosa	16.8	16.9	5.0	3.5	31.0	33.9	0.40	0.26	0.26	0.39	2.2	2.1	2.8	3.4
		Festuca ovina	14.0	16.2	4.7	2.6	20.0	15.5	0.39	0.22	0.13	0.36	1.3	0.9	1.1	0.2
		Trientalis europaea	17.5	16.8	4.5	3.0	23.0	24.9	0.78	0.36	0.26	0.30	4.2	3.6	8.5	3.8
		Solidago virga-aurea	21.7	24.0	7.0	5.1	36.0	29.9	0.73	0.78	0.43	0.39	11.5	9.7	1.4	2.3
		Luzula multiflora	16.1	25.9	4.2	4.4	30.0	27.3	0.50	0.24	0.17	0.65	3.2	1.9	0.2	1.2
		Lycopodium annotinum	14.7	14.9	4.2	3.5	9.5	9.5	0.36	0.25	0.21	0.27	0.9	0.7	0.5	1.2
		Other herbs	19.6	20.0	5.6	4.6	14.5	10.0	0.51	0.34	0.31	1.02	5.2	3.4	1.4	1.5
	Moss layer	Entodon schreberi	18.9	15.8	5.0	2.4	9.5	6.0	0.46	0.24	0.43	2.68	1.9	1.1	0.0	0.0
		Dicranum undulatum	16.1	18.3	3.9	2.8	8.0	6.8	0.55	0.51	0.48	3.65	2.5	1.2	0.0	0.0
		Other mosses	16.8	17.7	3.9	2.6	7.0	5.0	0.51	0.25	0.39	4.45	2.1	0.7	0.0	0.0
	Plant fall	Needles of pine	7.8	10.8	1.6	2.0	1.9	1.7	0.31	0.28	0.42	0.79	5.5	3.1	0.0	0.0
		Needles of spruce	11.0	9.9	2.2	1.5	1.8	1.1	0.55	0.71	0.70	0.75	12.2	11.0	0.0	0.0
		Bark and twigs	7.2	7.9	1.2	1.2	1.3	1.0	0.19	0.25	1.20	1.95	2.6	2.4	0.0	0.0
		Other	9.4	11.9	1.9	2.1	1.7	1.3	0.18	0.21	1.30	2.93	1.7	1.2	0.0	0.0

higher amounts, particularly in mosses, in 1974. However, considerable differences in the content of elements were observed between plants of the grud and coniferous forest, in favour of the former (except Fe).

The total amount of mineral components accumulated by plants depends on biomass; therefore the highest content of them was found in the species of the highest annual increment: *Asperula odorata, Urtica dioica, Oxalis acetosella* and *Asarum europaeum* in the grud, and *Vaccinium myrtillus, Melampyrum pratense* and *Calluna vulgaris* in the pine forest

Table 17. Content of mineral substances in kg/ha in the grud community of the *Fagetalia* order with pine (area 3)

		N		P_2O_5		K_2O		Na_2O		Fe_2O_3		CaO		MgO	
		1973	1974	1973	1974	1973	1974	1973	1974	1973	1974	1973	1974	1973	1974
Herb layer	Asperula odorata	2.3661	1.0725	0.4482	0.1936	4.0783	1.1927	0.0521	0.0364	0.0286	0.0235	0.8303	0.4584	0.0808	0.1023
	Asarum europaeum	0.9019	0.6080	0.2171	0.2204	2.0615	1.2413	0.0294	0.0195	0.0143	0.0304	0.5374	0.2685	0.0957	0.0658
	Geranium robertianum	0.8215	0.6415	0.2738	0.1603	1.7783	0.8870	0.0288	0.0174	0.0092	0.0122	0.4481	0.2316	0.0569	0.0594
	Oxalis acetosella	0.7352	1.2944	0.1546	0.2523	0.9774	1.8648	0.0201	0.0356	0.0061	0.0246	0.3413	0.4716	0.0816	0.1864
	Viola silvestris	0.6649	0.2982	0.1431	0.0515	1.4076	0.6340	0.0165	0.0096	0.0104	0.0065	0.2135	0.1142	0.1456	0.0766
	Moehringia trinervia	0.1563	0.0326	0.0394	0.0079	0.3834	0.0756	0.0048	0.0010	0.0032	0.0007	0.0707	0.0137	0.0148	0.0034
	Galeobdolon luteum	0.2814	0.1254	0.0659	0.0263	0.3864	0.1536	0.0057	0.0018	0.0040	0.0019	0.0584	0.0243	0.0035	0.0134
	Anemone nemorosa	0.1067	0.0854	0.0314	0.0137	0.1530	0.1595	0.0030	0.0030	0.0015	0.0024	0.0447	0.0383	0.0086	0.0098
	Galium vernum	0.0709	0.0705	0.0176	0.0113	0.0824	0.1022	0.0017	0.0018	0.0011	0.0012	0.0246	0.0258	0.0023	0.0066
	Urtica dioica	6.1223	2.3777	1.9754	0.4681	6.2581	3.3808	0.1432	0.0705	0.0588	0.1337	2.5635	1.0179	0.8143	0.2526
	Galeopsis pubescens	0.4074	0.5085	0.1151	0.2408	0.6337	1.7530	0.0050	0.0165	0.0067	0.0149	0.1306	0.2141	0.0336	0.0802
	Pulmonaria obscura	0.3652	0.2957	0.0979	0.0557	0.7635	0.6494	0.0103	0.0076	0.0077	0.0077	0.1348	0.1052	0.0139	0.0147
	Lathraea squamaria	0.2536	0.0703	0.1763	0.0358	0.3575	0.1002	0.0036	0.0009	0.0024	0.0044	0.0190	0.0055	0.0104	0.0040
	Vicia silvatica	0.2621	0.0743	0.0524	0.0121	0.2574	0.0600	0.0137	0.0022	0.0029	0.0013	0.1647	0.0309	0.0065	0.0055
	Rubus idaeus	0.2446	0.2273	0.0569	0.0526	0.2316	0.1798	0.0057	0.0065	0.0046	0.0089	0.0796	0.0719	0.0325	0.0321
	Sanicula europaea	0.0898	0.0272	0.0215	0.0056	0.3595	0.0802	0.0036	0.0014	0.0160	0.0071	0.0559	0.0184	0.0000	0.0012
	Fragaria vesca	0.0911	0.0817	0.0316	0.0129	0.1345	0.1149	0.0029	0.0036	0.0013	0.0030	0.0472	0.0498	0.0147	0.0110
	Mycelis muralis	0.0980	0.0439	0.0365	0.0104	0.1889	0.0811	0.0036	0.0014	0.0007	0.0011	0.0424	0.0149	0.0059	0.0045
	Acer pseudoplatanus c	0.0817	0.1400	0.0223	0.0323	0.0635	0.1302	0.0028	0.0045	0.0013	0.0041	0.0419	0.0718	0.0109	0.0225
	Sambucus nigra c	0.1411	0.0590	0.0248	0.0094	0.2093	0.0806	0.0022	0.0011	0.0012	0.0008	0.0387	0.0146	0.0335	0.0091
	Rubus hirtus	0.0720	0.2220	0.0181	0.0229	0.0566	0.0961	0.0020	0.0026	0.0051	0.0018	0.0226	0.0310	0.0082	0.0217
	Hepatica nobilis	0.0745	0.0944	0.0209	0.0134	0.1517	0.1477	0.0019	0.0030	0.0012	0.0039	0.0264	0.0388	0.0096	0.0158
	Veronica chamaedrys	0.0837	0.0174	0.0235	0.0038	0.1541	0.0299	0.0023	0.0005	0.0022	0.0026	0.0384	0.0067	0.0072	0.0016
	Lathyrus vernus	0.1093	0.1056	0.0243	0.0150	0.1307	0.1305	0.0020	0.0026	0.0026	0.0026	0.0323	0.0321	0.0043	0.0093
	Galium schultesii	0.0613	0.8107	0.0140	0.1979	0.0890	0.9571	0.0017	0.0170	0.0004	0.0111	0.0268	0.2386	0.0031	0.0515
	Carpinus betulus c	0.0571	0.0063	0.0150	0.0012	0.0267	0.0030	0.0023	0.0002	0.0007	0.0003	0.0387	0.0037	0.0061	0.0007
	Dryopteris spinulosa	0.0606	0.0341	0.0237	0.0071	0.0660	0.0459	0.0005	0.0005	0.0004	0.0010	0.0119	0.0062	0.0084	0.0060
	Lathyrus niger	0.0733	0.0485	0.0118	0.0057	0.0504	0.0286	0.0014	0.0008	0.0023	0.0069	0.0207	0.0115	0.0021	0.0001
	Circaea lutetiana	0.0533	0.1916	0.0155	0.0403	0.1042	0.3082	0.0012	0.0063	0.0008	0.0491	0.0206	0.0790	0.0070	0.0063
	Euphorbia amygdaloides	0.0415	0.0419	0.0152	0.0101	0.0472	0.0384	0.0011	0.0009	0.0049	0.0008	0.0177	0.0123	0.0014	0.0050
	Majanthemum bifolium	0.0386	0.0238	0.0131	0.0056	0.0608	0.0411	0.0010	0.0006	0.0003	0.0008	0.0120	0.0081	0.0027	0.0024
	Polygonatum multiflorum	0.0346	0.0278	0.0099	0.0062	0.0537	0.0440	0.0013	0.0008	0.0003	0.0014	0.0107	0.0117	0.0000	0.0008
	Epilobium montanum	0.0186	0.0206	0.0098	0.0078	0.0332	0.0396	0.0011	0.0007	0.0002	0.0003	0.0124	0.0098	0.0024	0.0024
	Aegopodium podagraria	0.0298	0.1806	0.0073	0.0337	0.0918	0.3459	0.0007	0.0029	0.0002	0.0016	0.0117	0.0409	0.0032	0.0240
	Populus tremula c	0.0127	0.0144	0.0059	0.0045	0.0191	0.0200	0.0004	0.0003	0.0001	0.0001	0.0030	0.0035	0.0007	0.0008
	Stachys silvatica	0.0329	0.0057	0.0085	0.0012	0.0723	0.0071	0.0005	0.0001	0.0003	0.0001	0.0082	0.0015	0.0037	0.0005
	Ajuga reptans	0.0043	0.0052	0.0015	0.0012	0.0062	0.0077	0.0001	0.0001	0.0001	0.0001	0.0017	0.0018	0.0002	0.0004
	Other	0.0487	0.0425	0.0143	0.0088	0.0768	0.0464	0.0014	0.0011	0.0004	0.0008	0.0223	0.0156	0.0061	0.0046
Plant fall	Leaves of pine	19.3980	20.8623	3.6600	3.7646	5.8560	5.4901	0.6222	0.5646	0.9150	0.7058	12.2610	7.2155	0.0000	0.0313
	Leaves of beech	9.5750	8.2285	1.8880	1.4486	3.1692	1.4486	0.3843	0.4114	0.7889	0.7243	8.6984	5.9106	0.0000	0.0017
	Leaves of hornbeam	12.2885	12.7778	2.4933	2.0264	4.1555	1.6324	0.3918	0.5009	0.5342	0.8330	8.2517	7.5428	0.3561	0.0506
	Leaves of aspen	4.2255	6.1558	0.7741	1.0678	1.8063	1.7274	0.2161	0.2575	0.1483	0.2763	4.4513	3.9573	0.0064	0.1256
	Bark and twigs	7.4890	12.3818	1.5156	2.3215	2.3180	2.3215	0.3655	0.8202	0.4992	1.3929	7.2215	11.4531	0.0000	0.0000
	Other	9.5086	10.0290	2.4500	1.9191	2.9750	2.3524	0.3033	0.3404	0.5833	1.8819	5.4834	3.9620	0.0000	0.1857

Table 18. Content of mineral substances in kg/ha in *Vaccinio myrtilli-Pinetum* (area 4)

		N		P_2O_5		K_2O		Na_2O		Fe_2O_3		CaO		MgO	
		1973	1974	1973	1974	1973	1974	1973	1974	1973	1974	1973	1974	1973	1974
Herb layer	Vaccinium myrtillus	3.4887	1.9073	1.1309	0.3385	2.1085	0.9818	0.0996	0.0485	0.0325	0.0338	1.0734	0.5530	0.0958	0.1918
	Calluna vulgaris	0.5929	0.5645	0.1225	0.0981	0.3388	0.2910	0.0179	0.0136	0.0220	0.1648	0.1287	0.1332	0.0542	0.0001
	Vaccinium vitis-idaea	0.3444	0.2168	0.1010	0.0474	0.2460	0.1218	0.0116	0.0051	0.0054	0.0050	0.1139	0.0526	0.0181	0.0243
	Melampyrum pratense	0.5075	0.5321	0.1833	0.1276	0.4051	0.4575	0.0162	0.0139	0.0019	0.0093	0.2495	0.1685	0.0341	0.1011
	Luzula pilosa	0.2893	0.5234	0.0861	0.1084	0.5340	1.0500	0.0068	0.0080	0.0044	0.0120	0.0378	0.0650	0.0482	0.1053
	Festuca ovina	0.1907	0.7756	0.0640	0.1244	0.2725	0.7421	0.0053	0.0105	0.0017	0.0172	0.0177	0.0430	0.0149	0.0095
	Trientalis europaea	0.0501	0.0428	0.0129	0.0076	0.0659	0.0635	0.0022	0.0009	0.0007	0.0007	0.0120	0.0091	0.0237	0.0097
	Solidago virga-aurea	0.0166	0.0247	0.0053	0.0052	0.0276	0.0308	0.0005	0.0008	0.0003	0.0004	0.0088	0.0100	0.0010	0.0023
	Luzula multiflora	0.0096	0.1295	0.0025	0.0220	0.0216	0.1365	0.0003	0.0012	0.0001	0.0032	0.0019	0.0095	0.0001	0.0060
	Lycopodium annotinum	0.0756	0.0300	0.0216	0.0070	0.0488	0.0191	0.0018	0.0005	0.0010	0.0005	0.0046	0.0014	0.0025	0.0024
	Other	0.0428	0.0504	0.0122	0.0115	0.0317	0.0252	0.0011	0.0008	0.0006	0.0025	0.0113	0.0085	0.0030	0.0037
Moss layer	Entodon schreberi	13.0410	13.1061	3.4500	1.9908	6.5550	4.9770	0.3174	0.1990	0.2967	2.2230	1.3110	0.9124	0.0000	0.0001
	Dicranum undulatum	4.2866	3.4632	1.0383	0.5299	2.1300	1.2869	0.1468	0.0965	0.1278	0.6907	0.6656	0.2271	0.0000	0.0001
	Other	0.0972	0.9168	0.0225	0.1346	0.0405	0.2590	0.0029	0.0129	0.0022	0.2305	0.0121	0.0362	0.0000	0.0001
Plant fall	Leaves of pine	17.4425	20.8431	3.5779	3.8598	4.2488	3.2808	0.6932	0.5403	0.9392	1.5246	12.2992	5.9827	0.0000	0.0000
	Leaves of spruce	0.0929	0.1425	0.0185	0.0216	0.0152	0.0158	0.0046	0.0102	0.0059	0.0108	0.1032	0.1584	0.0000	0.0000
	Bark and twigs	6.9472	7.0693	1.1578	1.0738	1.2543	0.8948	0.1833	0.2237	1.1578	1.7449	2.5087	2.1476	0.0000	0.0000
	Other	2.9955	5.7961	0.6054	1.0228	0.5417	0.6331	0.0573	0.1022	0.4142	1.4271	0.5417	0.5844	0.0000	0.0000

(Table 17, 18). All herb layer species in both areas were observed to accumulate most potassium and nitrogen and considerably less phosphorus, calcium and other elements.

Organic fall accumulates decisively more mineral components than the herb layer because of its considerably higher biomass. It contains the highest amounts of nitrogen and calcium, and slightly less potassium. Pine needles accumulate most of all investigated elements, both in the grud and pine forest area. A quarterly analysis showed that most mineral substances were found in the fall in the third and fourth quarters (Table 19).

Table 19. Content of mineral substances in kg/ha in the organic fall of the studied forest communities (quarterly summary)

Plant community	Quarter	N		P_2O_5		K_2O		Na_2O		Fe_2O_3		CaO		MgO	
		a	b	a	b	a	b	a	b	a	b	a	b	a	b
A	I		3.196		0.554		0.663		0.133		0.312		1.573		0.054
	II	10.065	11.697	2.173	1.993	1.847	2.147	0.275	0.394	0.629	2.066	4.809	4.276	0.000	0.015
	III	10.188	11.223	2.084	1.889	3.674	3.298	0.376	0.540	0.499	0.885	6.974	7,846	0.058	0.141
	IV	42.873	44.261	8.709	7.958	14.805	8.950	1.638	1.827	2.336	2.571	34.640	26.426	0.339	0.198
B	I		1.950		C.322		0.313		0.061		0.190		0.550		0.000
	II	6.806	9.438	1.265	1.513	1.013	1.104	0.145	0.202	0.554	1.830	2.201	1.450	0.000	0.000
	III	10.987	9.753	2.161	1.651	3.251	1.815	01420	0.266	0.815	1.356	6.799	2.768	0.000	0.000
	IV	10.042	12.722	1.964	2.431	1.929	1.566	0.377	0.347	1.178	1.339	6.511	4.121	0.000	0.000

The amount of mineral elements accumulated both by the fall and herb layer during the year was higher in the grud community. Living plants (excluding the fall), however, accumulated more elements in the pine forest (Table 20).

The ratio of the mineral elements contained in the herb layer to their total amount in the herb layer and fall (17) is different and it is from several to 30%. It exceeded the value of 50% only for potassium and magnesium. This accounts for a considerable participation of living plants in the circulation of these elements.

The obtained results were higher than those for the communities studied by other authors (5, 6, 8, 13), mainly because of considerably higher productivity of the herb layer and fall.

Characteristics of the stands, structure and specific composition

The studied forest stands represent a structure typical for forest management which consists in complete periodical cutting down the stands.

Table 20. The amount of mineral substances returned through the herb layer, mosses and organic fall in the studied forest communities

				N		P_2O_5		K_2O		Na_2O		Fe_2O_3		CaO		MgO	
				kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
Community from order Fagetalia with pine	area 3	1973	Herb layer	15.169	19.5	4.254	25.0	22.056	52.1	0.382	14.4	0.205	5.6	6.225	11.8	1.542	80.8
			Plant fall	62.484	80.5	12.781	75.0	20.280	47.9	2.283	85.6	3.469	94.4	46.368	88.2	0.367	19.2
			Total	77.653		17.035		42.336		2.665		3.674		52.593		1.909	
		1974	Herb layer	10.027	12.5	2.258	15.3	15.258	50.5	0.459	13.7	0.376	6.1	3.814	8.7	1.115	73.8
			Plant fall	70.435	87.5	12.548	84.7	14.973	49.5	2.895	86.3	5.814	93.9	40.042	91.3	0.395	26.2
			Total	80.462		14.807		30.231		3.354		6.190		43.856		1.510	
Vaccinio myrtilli Pinetum	area 4	1973	Herb layer	5.608	11.1	1.745	15.0	4.100	21.7	0.163	10.4	0.071	2.3	1.660	8.7	0.296	100.0
			Moss layer	17.425	34.5	4.511	38.8	8.725	46.2	0.467	29.8	0.427	14.2	1.989	10.4	0.000	0.0
			Plant fall	27.478	54.4	5.359	46.2	6.061	32.1	0.939	59.8	2.516	83.5	15.452	80.9	0.000	0.0
			Total	50.511		11.615		18.886		1.569		3.014		19.101		0.296	
		1974	Herb layer	4.797	8.5	0.898	9.4	3.919	25.6	0.104	8.1	0.249	3.1	1.054	8.7	0.456	99.9
			Moss layer	17.486	31.2	2.655	27.9	6.523	42.7	0.308	23.9	3.144	38.8	1.176	9.7	0.001	0.1
			Plant fall	33.851	60.3	5.978	63.7	4.825	31.7	0.877	68.0	4.708	58.1	9.873	81.6	0.000	0.0
			Total	56.134		9.531		15.267		1.289		8.101		12.103		0.457	

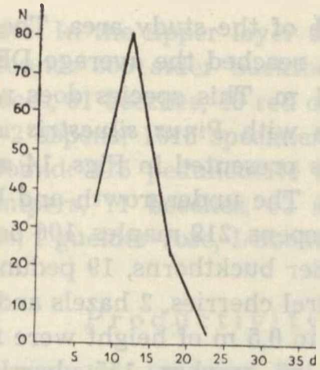


Fig. 14. Structure of the thickness of hornbeam in the grud community of the *Fagetalia* order with pine (area 3)

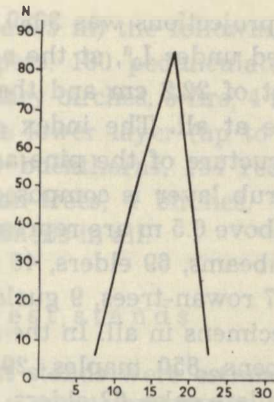


Fig. 15. Structure of hornbeam height in the grud community of the *Fagetalia* order with pine

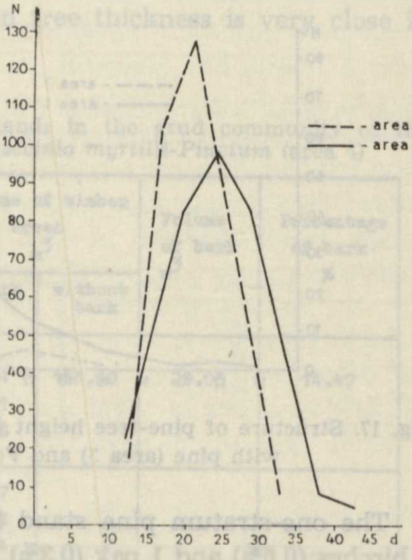


Fig. 16. Structure of the thickness of pine-tree in the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4)

In area 3 two substrata can be distinguished. The upper sublayer is composed of pines (334 trees — 93.3%) with a small admixture of aspen (13 trees — 3.6%) and beech (11 trees — 3.0%). The poorly developed lower sublayer (about 17% of the upper sublayer volume) is composed of hornbeam (141 trees — 63.5%) with an addition of beech (54 trees — 24.3%), pedunculate oak (17 trees — 7.6%), sporadic maple (8 trees — 3.6%), and cherry (2 trees — 0.9%). In all, 580 trees were found in this area. The volume of the stand at an average tree height of 23.1 m was 80 130 m³, and that of the undercanopy space reached 52 092 m³ at an average stem height of 13.6 m up to the base of the crown. The area of crown projections was 3830.3 m², i.e. 76.6% of the study area. The pines classified under I_0^a, at the age of about 53, reached the average DBH increment of 22.2 cm and the height of 23.1 m. This species does not reproduce at all. The index of afforestation with *Pinus silvestris* is 0.76. The structure of the pine and hornbeam is presented in Figs. 14 and 15. The shrub layer is composed of 17 species. The undergrowth and brushwood above 0.5 m are represented by: 271 aspens, 219 maples, 106 beeches, 83 hornbeams, 69 elders, 46 cherries, 23 alder buckthorns, 19 pedunculate oaks, 17 rowan-trees, 9 guelder-roses, 6 laurel cherries, 2 hazels and 1 fir; 871 specimens in all. In the same layer up to 0.5 m of height were found: 854 aspens, 850 maples, 291 hornbeams, 168 beeches, 155 cherries, 74 pedunculate oaks, 62 elders, 31 firs, 30 guelder-roses, 23 alder buckthorns, 10 laurel cherries, 9 dogwoods, 4 pear trees, 2 spindle trees, 1 hazel, 1 rowan-tree and 1 maple; 2,566 specimens in all.

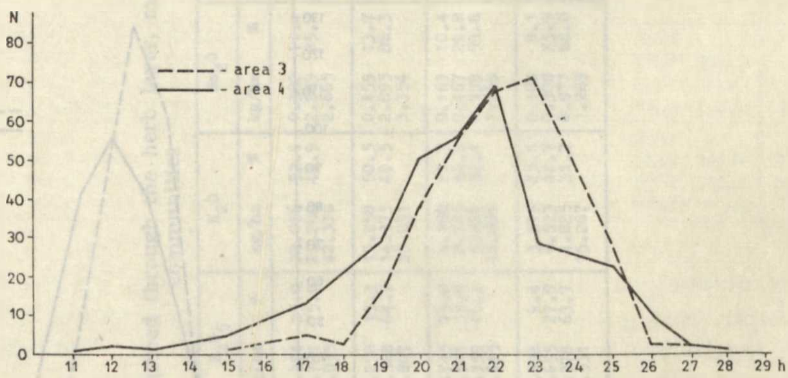


Fig. 17. Structure of pine-tree height in the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4)

The one-stratum pine stand in area 4 consists of 343 pines (99.1%), 2 birches (0.6%) and 1 oak (0.3%). The volume of the stand was 53 509 m³ at an average tree height of 22.2 m and that of the undercanopy space was 36 314 m³ at an average stem height of 15.1 m up to the base of the crown. The area of crown projection was 2404.9 m², i.e. 48.0% of the study area. The pine trees classified under I_8^a were on the average 7 years older than those in area 3. *Pinus silvestris* stems are not well cleaned of dry branches, frequently down to mid-height of the trees. The average increment of DBH and the height they reach are 24.8 cm and 22.2 m, respectively. The average DBH of *Pinus silvestris* trees is 2.6 cm higher than that in the grud, whereas the average height is by 0.9 m lower. The structure of the forest stand is presented in Figs. 16 and 17. Among the 13 species of the undergrowth alder buckthorn and pedunculate oak predominate. In the upper layer of shrubs (above 0.5 m) the following trees were found: 359 alder buckthorns, 275 junipers, 180 pedunculate oaks, 79 spruces, 61 beeches, 46 red oaks, 5 mammillary birches, 5 firs, 4 rowan-trees, 2 aspens; 1016 specimens in all. In the lower layer (up to 0.5 m) were found: 315 pedunculate oaks, 193 alder buckthorns, 184 red oaks, 134 junipers, 71 beeches, 62 spruces, 6 rowan-trees, 4 birches, 3 firs, 1 maple, 1 guelder-rose, 1 buckthorn; 977 specimens in all.

Productivity of the forest stands

The actual yields of the investigated forest stands were estimated by means of stem thickness with and without bark (Table 21). The presented summary indicates that total yields of the forest stands in both areas are approximate. The yields of the grud community with pine are hardly 10% higher. The participation of bark in tree thickness is very close in both areas.

Table 21. Actual wood yields of the pine stands in the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4)

No of area	Layer	Species	Volume of timber trees m^3 of bark	Volume of timber trees m^3 without bark	Volume of bark m^3	Percentage of bark %
3	I	Pinus silvestris	138.44	118.40	20.03	14.47
		Fagus silvatica	3.81			
		Populus tremula	9.28			
	II	Carpinus betulus	12.57			
		Fagus silvatica	6.82			
		Quercus robur	3.54			
		Acer pseudoplatanus	1.44			
		Cerasus avium	0.93			
			176.82			
4	I	Pinus silvestris	161.78	137.53	24.25	14.99

The value of wood production of the studied forest stands, based on current volume increment was very approximate in the last periods of 2, 5 and 10 years (Table 22). Its slightly higher values in the grud (by 5.6%, 8.7%, 6.1%, respectively) do not constitute significant differences.

It follows from the comparison of the production of the discussed forest stands that in both cases the current volume increment in the last 5-year period was slightly higher than that in the preceding 5-year period — by 7.4% in the pine forest and 13% in the grud. It can thus be assumed that both forest stands were close to the culmination of volume increment, which has not occurred yet.

Table 22. Wood production of the pine stands in the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4) in the last 2-, 5-, and 10-year periods

No. of area	Current increment production of timber in m^3					
	of bark			without bark		
	2-years	5-years	10-years	2-years	5-years	10-years
3	10.8741	24.2222	45.6620	9.5874	22.3219	41.7654
4	10.2936	22.2901	43.0472	9.2115	20.5317	39.5235

Table 23. Total wood production (big timber and small timber) of the pine stands in the grud community of the *Fagetalia* order with pine (area 3) and *Vaccinio myrtilli-Pinetum* (area 4)

Period /years/	Mean site class /of period/		Total production of timber in m^3 /of period/		Age of trees	Total together production of timber in m^3	
	area no. 3	area no. 4	area no. 3	area no. 4		area no. 3	area no. 4
0 - 30	I_0^a	I_9	156	114	30	156	114
30 - 40	I_0^a	I_6	66	53	40	222	167
40 - 50	I_0^a	I_2	66	54	50	288	221
50 - 60	-	I_8^a	-	52	60	-	273

The analysis of the maximal height growth of the studied forest stands showed that each of them represents a different type of growth (20). The stand in the grud area with pine shows type 2 of normal growth. In the last 20 years, the classification of the stand was on the same level I_0^a (Table 23). The stand in the pine forest community shows type 3 of extended growth. It is characterized by an improvement of the class with age; in the last 30 years (at the age of 30—60 years), the classification improved by over one class (at the age of 32 years — class I_9, at the age of 60 years — class I_0^a).

The estimation results of the total volume production (timber and smallwood) of the studied pine stands, which were obtained by means of yield tables (22), on assuming complete afforestation are presented in Table 23.

DISCUSSION

The studies were carried out in two forest ecosystems of the Zwierzyniec forest district in Central Roztocze. One represents a grud community of the *Fagetalia* order, the other — used as the control — represents an eutrophic pine forest *(Vaccinio myrtilli-Pinetum typicum)*; undergrowing pines dominate in both communities. With regard to physiognomy, floristic composition and habitat these communities are representative of Roztocze and they cover a large area of this region.

The studied forest ecosystems cover areas of different land relief. The grud community appears in the upper and top parts of a high elevation at a small inclination of the slopes, where considerable differences in relative height have occurred. The pine forest covers the lower part of the slope, which is slightly undulated (with dunes) with slight differences in relative height.

The grud community was cooler and moister than the pine forest one because of 2—3 times lower insolation intensity and almost 4 times lower brightness of daylight. Lower diurnal amplitudes of soil and air temperature, and humidity as well as more equalized diurnal courses of these elements (lower maxima and higher minima) characterized the grud. Inverse temperature system and the wet type of moisture stratification were recorded more often in the grud than in the pine forest. Microclimatic differences between the grud and pine forest were particularly distinct in summer, and the highest during anticyclonic weather.

More favourable climatic conditions in the grud presumably affected the extension of the vegetation period in relation to the pine forest. Besides, the most intensive growth of the herb layer in the grud was observed in the period from April to July, whereas in the pine forest it lasted at the same intensity till early autumn.

The soil conditions in the grud also proved to be more favourable, where shallow brown soil, formed of cretaceous gaizes, had developed, whereas in the pine forest podzolic soil formed of loose sand occurs. The soil in th grud is moister and more fertile. This is indicated by: humus of the mull type, more rarely that of the moder type, lower soil acidity ($CaCO_3$ occurred in some sites), higher sorptive capacity and content of exchangeable cations (except H) and nutritional components. In addition, it was found that the organic fall in the grud returns to the soil much greater amounts of mineral substances every year than those in the pine forest.

The grud habitat effects also more favourably the development of soil microflora. As compared with the pine forest, the litter and other genetic horizons of the grud soil were found to contain a higher number of microflora being richer by nitrifiers. The effect of higher *pH* of the grud litter is that the decomposition rate of cellulose, which is higher than that in the pine forest, is mainly supported by cellulolytic bacteria, whereas higher acidity and smaller amount of nitrogen substances in the pine forest litter were observed to favour fungi which were found here in a much greater number than in the grud.

In the above presented different habitats the herb layers varied with regard to the floristic composition. In the grud 4.5-time greater number of species was found. Mesophilic plants constitute the dominating group, whereas in the pine forest — species with xeromorphic structure dominate. Also plant density in the grud was almost 3 and 2 times higher than in the pine forest in the two successive study years. The total productivity of the herb layer proved 1.5 and 1.4 times higher than that in the pine forest, respectively. Mosses, of course, constitute a recompense, which reach a large cover, and high increment of biomass (productivity). They were not found in the grud. In each case the productivity of the herb layer and mosses was determined by the dominating herb layer species in both forest communities.

The organic fall was higher in the grud than in the coniferous forest in both study years. Moreover, a much greater participation of leaves was found in the grud community. Pine needles and, to a lesser extent, small twigs dominated in the fall of both ecosystems.

The stands of both forest ecosystems with a structure typical for their periodical cutting down differed with regard to floristic composition, density and classification. The differences in wood yields in both areas were small and did not exceed 10% in favour of the grud community. The pine stands of both communities are close to the culmination of volume increment.

The seven-year younger pines in the grud show a higher class and slightly higher wood production in the particular growth periods. Furthermore, their stand represents type 2 with normal growth, whereas that in the pine forest — type 3 with extended growth. In a 50-year period the total wood volume production of *Pinus silvestris* in the grud area was by over 30% higher than that in the pine forest.

CONCLUSION

The ecological analysis proved that more favourable habitat conditions for 53-year-old pines are found in the grud community of the *Fagetalia* order. This is shown by slightly higher wood yields of the grud forest and higher classes and wood production of *Pinus silvestris*.

The above conclusion indicates that pine should be introduced into the habitats of deciduous and mixed forest of the grud type in Roztocze. The authors' attitude towards this problem was already critical in the first part of the paper and particularly in the third one summing up the four-year studies.

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STRESZCZENIE

Badania przeprowadzono w dwóch ekosystemach leśnych nadleśnictwa Zwierzyniec na Roztoczu Środkowym (ryc. 1). Pierwszy reprezentuje zbiorowisko grądowe z rzędu *Fagetalia*, drugi — kontrolny — przedstawia bór sosnowy świeży *Vaccinio myrtilli-Pinetum;* w obu dominuje podsadzona sosna. Pod względem fizjonomii (ryc. 3, 5), składu florystycznego i siedliska ekosystemy te są reprezentatywne dla Roztocza i zajmują na jego terenie duże powierzchnie.

Badane ekosystemy leśne zajmują tereny o odmiennej rzeźbie. Zbiorowisko grądowe występuje w górnej i szczytowej partii wysokiego wzniesienia o połogim upadzie zboczy i dość dużych różnicach wysokości względnej na powierzchni badawczej (ryc. 2). Bór sosnowy zajmuje tereny obniżone, lekko faliste (zwydmione) o niewielkich różnicach wysokości względnej (ryc. 4).

W związku z 2—3-krotnie mniejszą intensywnością insolacji i prawie 4-krotnie mniejszą jasnością światła dziennego, zbiorowisko grądowe było chłodniejsze i bardziej wilgotne od borowego (tab. 2). Grąd posiadał mniejszą amplitudę dobową temperatury gleby, powietrza i wilgotności oraz bardziej wyrównane przebiegi dobowe tych elementów (niższe maksima i wyższe minima). W grądzie częściej niż w borze notowano inwersyjny układ temperatury i mokry typ stratyfikacji wilgotnościowej. Różnice mikroklimatyczne między grądem a borem były szczególnie wyraźne w lecie, a największe w czasie pogody antycyklonalnej. Charakterystykę mikroklimatu w okresie badań przedstawia tab. 1.

Korzystniejsze warunki klimatyczne w grądzie wpłynęły prawdopodobnie na wydłużenie okresu wegetacji w stosunku do boru. Poza tym w zbiorowisku grądowym największy rozwój runa następował w okresie kwiecień—lipiec, natomiast w borze trwał w jednakowym nasileniu do wczesnej jesieni (tab. 8, ryc. 12, 13).

Warunki glebowe również okazały się korzystniejsze w zbiorowisku grądowym, gdzie wykształciła się płytka gleba brunatna wytworzona z gez formacji kredowej, w borze natomiast — gleba bielicowa wytworzona z piasku luźnego (ryc. 7). Gleba w grądzie jest wilgotniejsza i żyźniejsza. Wskazują na to: próchnica typu insektowego, rzadziej grzybowo-insektowego, mniejsze zakwaszenie (miejscami wystąpił $CaCO_3$), większa pojemność sorpcyjna oraz zasobność w kationy wymienne (z wyjątkiem H^+) i składniki pokarmowe (tab. 3, 4, 5, ryc. 8, 9, 10).

Stwierdzono poza tym, że w zbiorowisku grądowym wraca do gleby corocznie wraz z opadem organicznym znacznie więcej składników mineralnych niż w borze (tab. 16, 17, 18, 19, 20).

Siedlisko grądowe wpływa również korzystniej niż borowe na rozwój mikroflory glebowej (ryc. 11, tab. 6, 7). Ściółkę i pozostałe poziomy genetyczne gleby grądu zasiedla liczniejsza i bogatsza o nitryfikatory mikroflora. Wyższe *pH* ściółki grądowej powoduje, że większe niż w borze tempo rozkładu błonnika podtrzymywane jest głównie przez bakterie celulolityczne, natomiast większe zakwaszenie i mniejsza zasobność ściółki borowej w substancje azotowe preferuje grzyby, których wykryto tu znacznie więcej niż w grądzie.

W odmiennych na obu powierzchniach warunkach siedliskowych rozwija się różne pod względem składu florystycznego runo. W zbiorowisku grądowym stwierdzono 4.5-krotnie większą liczbę gatunków. Z ilości tej przeważającą grupę stanowią rośliny mezofilne, podczas gdy w borze dominują gatunki o budowie kseromorficznej. Również zagęszczenie roślin w grądzie było w obu kolejnych latach badań prawie 3 i 2 razy większe niż w borze. W rezultacie globalna produkcyjność runa grądowego okazała się 4,5 i 1,4 raza większa niż borowego (tab. 9, 10). Oczywiście pewną rekompensatę stanowią mchy, które w borze osiągają duże pokrycie, biomasę i produkcyjność (tab. 11). W grądzie mchy nie wystąpiły. W każdym przypadku o produkcyjności runa i mchów decydowały w obu zbiorowiskach gatunki panujące.

Opad organiczny w grądzie był w obu latach badań większy niż w borze. Ponadto w zbiorowisku grądowym zaznaczył się o wiele większy udział liści. W opadzie obu ekosystemów przeważały szpilki sosny i w mniejszym stopniu drobne gałązki (tab. 12, 13, 14, 15).

Drzewostany obu ekosystemów leśnych, o strukturze charakterystycznej dla zrębowego sposobu zagospodarowania (ryc. 14, 15, 16, 17), różniły się składem florystycznym, zagęszczeniem i bonitacją. Różnice zasobów drzewnych na obu powierzchniach były niewielkie i nie przekroczyły 10% na korzyść zbiorowiska grądowego (tab. 21). Drzewostany sosnowe obu zbiorowisk znajdują się w pobliżu kulminacji przyrostu miąższości (tab. 22).

Młodsza o 7 lat sosna w grądzie wykazuje wyższą bonitację i nieco wyższą produkcję drewna w poszczególnych okresach wzrostu. Ponadto drzewostan jej reprezentuje typ 2 o wzroście normalnym, podczas gdy w borze typ 3 o wzroście przedłużonym. W okresie 50-letnim całkowita produkcja miąższości drewna *Pinus silvestris* na powierzchni grądowej była o ponad 30% wyższa niż na borowej (tab. 23).

W wyniku przeprowadzonej analizy ekologicznej stwierdzono korzystniejsze dla 53-letniej sosny warunki siedliskowe w zbiorowisku grądowym z rzędu *Fagetalia*.

Odzwierciedleniem tego jest nieco większy stan zasobów drzewnych grądu oraz wyższa bonitacja i produkcyjność drewna *Pinus silvestris*.

Stwierdzenie powyższe sugeruje, że na Roztoczu sosny należałoby podsadzać na siedlisku lasów liściastych lub mieszanych typu grądowego. Do zagadnienia tego ustosunkowaliśmy się krytycznie już w części I, a zwłaszcza w III, podsumowującej 4-letnie badania.

РЕЗЮМЕ

Исследования проводились в двух лесных экосистемах надлесничества Звежинец в Центральном Розточе (рис. 1). Представителем первой из них является грудовое сообщество ряда *Fagetalia*, а второй (контрольной) — бор сосновый свежый *Vaccinio myrtilli-Pinetum*. В обеих экосистемах доминирует сосна. По своему флористическому составу (рис. 3, 5) и местообитанию эти экосистемы являются типичными для Розточе и занимают на его территории большие поверхности.

Изучаемые лесные экосистемы занимают территории с разным рельефом. Грудовое сообщество распространено в верхней и вершинной партиях высокой возвышенности с пологим склоном и довольно большими разницами относительной высоты на исследуемой территории (рис. 2). Сосновый бор занимает пониженные холмистые территории с небольшими разницами относительной высоты (рис. 4).

По сравнению с боровым сообществом грудовое было холоднее и влажнее (табл. 2). Суточная амплитуда температуры почвы, воздуха и влажности у груда были меньше, а суточный ход этих элементов более ровный (низшие максимальные и высшие минимальные). В груде чаще, чем в боре констатировались инверсионные соотношения температуры и мокрый тип влажностной стратификации. Микроклиматические разницы между грудом и бором были особенно отчетливы летом, а наибольшими — во время антициклонной погоды. Характеристика микроклимата в период исследований представлена в табл. 1.

Возможно, что более благоприятные климатические условия в груде повлияли на удлинение периода вегетации. Кроме того, наибольшее развитие травянистого покрова в грудовом сообществе приходилось на период апрель—июль, а в боре продолжалось с одинаковой интенсивностью до ранней осени (табл. 8, рис. 12, 13).

Также и почвенные условия оказались более благоприятными в грудовом сообществе, где формировалась неглубокая коричневая почва, образованная из гез меловой формации, а в боре — подзолистая почва, образованная из рыхлого песчаника (рис. 7). Почва в груде более влажна и плодородна, чем в боре. Об этом свидетельствуют: гумус инсектового, реже грибо-инсектового типа, меньшее закисление (местами выступала $CaCO_3$), большая емкость поглощения, а также богатое содержание обменных катионов (за исключением H^+) и питательных веществ (табл. 3, 4, 5, рис. 8, 9, 10).

Кроме того, было установлено, что ежегодно в грудовом сообществе вместе с органическим опадом в почву возвращается значительно больше минеральных компонентов, чем в боре (табл. 16, 17, 18, 19, 20).

Также более благоприятным было влияние грудового местообитания на развитие почвенной микрофлоры. По сравнению с бором, подстилку и остальные генетические горизонты почвы груда заселяет более многочисленная и более

богатая интрофикаторами микрофлора. Высшие pH грудовой подстилки приводят к тому, что быстрейший, чем в боре темп разложения клетчатки поддерживается в основном целлюлолитическими бактериями, зато большее закисление и меньшее содержание азотных веществ в подстилке дают преимущество грибам, которых здесь значительно больше, чем в груде.

В этих разных условиях местообитания развивается различный по своему флористическому составу травянистый покров. В грудовом сообществе обнаружено в 4—5 раз больше видов, чем в боре. В первом сообществе преобладают мезофильные растения, а во втором — виды с ксероморфным строением. Также и густота стояния растений во все годы исследований в груде была почти в 2—3 раза больше, чем в боре. В результате валовая продукция грудового травянистого покрова оказалась в 1,4—4,5 раза больше, чем борового (табл. 9, 10). Конечно, некоторой компенсацией являются мхи, занимающие в боре большую поверхность и обладающие большей биомассой и продуктивностью (табл. 11). В груде мхи не наблюдались. О продуктивности мхов и травянистого покрова решали господствующие виды.

Органический опад в груде в годы исследований был больше, чем в боре. Кроме того, наблюдалось значительно большее участие листьев в грудовом сообществе. В листопаде обоих экосистем преобладали прежде всего сосны и в меньшей степени небольшие ветки (табл. 12, 13, 14, 15).

Древостои обеих лесных экосистем, структура которых является характерной для вырубного способа освоения (рис. 14, 15, 16, 17), отличались флористическим составом, плотностью и бонитацией. Древесные ресурсы на обеих поверхностях были почти одинаковые (преобладание грудового сообщества не превышало 10%, табл. 21). Сосновые древостои обоих сообществ расположены вблизи кульминационного пункта прироста древесины (табл. 22).

Несмотря на то, что сосна в груде моложе сосны второй экосистемы на 7 лет, в отдельные периоды роста она проявляет более высокую бонитацию и дает несколько большую продукцию древесины. Кроме того, ее древостой представляет собой типичный древостой 2-го типа с нормальным ростом, а в боре — тип 3 с удлиненным ростом. В течение всего 50-летия полная продукция объема древесины *Pinus silvestris* на грудовой поверхности была на 30% выше, чем на боровой (табл. 23).

В результате проведенного экологического анализа лучшие условия местообитания для 53-летней сосны обнаружены в грудовом сообществе ряда *Fagetalia*. Отражением этого является несколько высшее состояние древесных ресурсов груда, более высокая бонитация и древесная продуктивность *Pinus silvestris*.

Из всего сказанного выше следовало бы сделать вывод о необходимости подсаживания сосны на местообитания лиственных или смешанных лесов грудового типа в Розточе. Свое критическое отношение к этому авторы высказали уже в I части работы, развернув его затем в III части, посвященной подведению итогов четырехлетних исследований.

богатой эпитрофической микрофлоры. Все это [illegible] приводит к тому, что быстрее, чем в боре [illegible]

[illegible] которые [illegible] больше, чем в груде.

В этих разных условиях местообитания различается [illegible] по фитоценотическому составу травянистый покров. В грудовом сообществе обнаружено в 4—5 раз больше видов, чем в боре. В первом сообществе преобладают мезофильные растения, а во втором — [illegible] с ксероморфным строением. Также и густота стояния растений во все годы исследований в груде была почти в 2—3 раза больше, чем в боре. [illegible]

Органический опад в груде в годы исследований был больше, чем в боре. [illegible]

Древостой обоих [illegible]

В результате проведенного [illegible]

Из всего сказанного выше следовало бы сделать вывод о необходимости [illegible] уже в I части работы, [illegible] III часть, [illegible] итогов [illegible] исследований.

[illegible] тельных явлений (табл. 3, 4, 5, рис. 8, 9, 10).

Кроме того, было установлено, что дождевые в грудовом сообществе вместе с [illegible] в почву возвращается значительно больше минеральных элементов, чем в боре (табл. 16, 17, 18, 19, 20).

Также более благоприятным было влияние грудового местообитания на развитие почвенной микрофлоры. [illegible]