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SPECIES COMPOSITION AND STRUCTURE OF FOREST STANDS IN PHYLLITIDO-ACERETUM COMMUNITY

ABSTRACT: This study is based on data taken from literature and on our own research conducted in Pieniny National Park. The sycamore maple is one of the main tree species in Phyllitido-Aceretum, but very seldom the most abundant one. Spatial distribution of trees, ascertained using the Ripley's K function, follows the random pattern. Negative spatial relationship between tree species at local spatial scales probably reflects site patchiness. The size structure of tree stands in Phyllitido-Aceretum is similar to that of beech forests, but the stand density is two times lower. Slope instability can be a plausible explanation of this phenomenon.

KEY WORDS: size distribution, spatial patterns, tree stand density.

1. INTRODUCTION

The Phyllitido-Aceretum (P–A) community in Poland is restricted only to relatively small areas, occurring in patches on calcium-rich soils (mainly limestone, but sometimes also Carpathian flysh) in mountainous and upland areas (Kozłowska and Matuszkiewicz 1993). The total area covered by this community does not exceed 40 ha, and most of it is protected within national parks and nature reserves (Bodziarczyk 1996). The Pieniny National Park is the place, where patches of P–A are most numerous and cover largest areas in Poland (Pancer-Kotejowa 1973).

Forest stands in Phyllitido-Aceretum community are among the most diverse in Poland, and have a big share of tree species which in other forest communities play only a minor role (sycamore maple *Acer pseudoplatanus*, mountain elm

Ulmus scabra and bigleaf linden *Tilia platyphyllos*). Data concerning species composition of tree stands are quite numerous (Medwecka-Kornaś 1952, Pancer-Kotejowa 1973, Staszkiewicz 1973, Wika 1978, Święs 1982, Michalik and Mazur 1991), but they are usually just cover-abundance estimations in phytosociological releves. Detailed quantitative data are scarce (Bodziarczyk 1992), and practically nothing is known about the size and spatial structure of forest stands in Phyllitido-Aceretum community.

In our work we tried to determine, what is the proportion of tree species constituting forest stands in Phyllitido-Aceretum community, how it varies among different localities and among different stands in one area, and what is the actual difference in stand composition between this community and surrounding forest stands. We want also to answer, what is the density and size structure of tree stands in Phyllitido-Aceretum, and whether it is significantly different from density and size structure in other forest communities, i.e. in Dentario glandulosae-Fagetum and Carici-Fagetum (Jaworski and Karczmarski 1991). By analyzing spatial structure in a quantitative way, we tried to determine, what are the patterns of tree distribution in Phyllitido-Aceretum, and what are the spatial relationships between main tree species occurring in that community.

2. MATERIALS AND STUDY AREA

2.1. MATERIALS

Materials for comparisons were taken from literature (Pancer-Kotejowa 1973, Staszkiewicz 1973, Wika 1978, Święs 1982, Michalik and Mazur 1991, Kozłowska and Matuszkiewicz 1993), and they came from almost all areas of occurrence of Phyllitido-Aceretum community in southern Poland – from Bieszczady Mountains, Beskid Niski Range, Pieniny Mountains and Cracow-Częstochowa Upland (Fig. 1, Table 1). Unpublished materials had been collected in Carpathian Foothills, in Beskid Wyspowy Range, in Ojców National Park and in Pieniny National Park. The elevation of patches of Phyllitido-Aceretum community ranged from 230 m a.s.l. (Bodziarczyk and Kucharzyk 1991) to 1000 m a.s.l. (Winnicki and Zemanek 1987). Most of them occurred in northern slopes, some also in eastern and western slopes (Kozłowska and Matuszkiewicz 1993). The slope inclination was different, varying from 5 to 65°. All localities in Pieniny Mountains and in Cracow-Częstochowa Upland were in limestone areas (Wika 1978), whereas patches of Phyllitido-Aceretum from Bieszczady and Beskidy Mountains developed on Carpathian flysh rich in calcium (Staszkiewicz 1973, Michalik and Mazur 1991).

Table 1. Species composition (in %) of forest stands in Phyllitido-Aceretum community

Species	1*	2	3	4	5	6	7	8	9	10
Abies alba			2.9	9.8	30.7	7.7			11.5	13.0
Picea abies				3.2	3.3					
Larix decidua				3.2						
Fagus sylvatica	14.7	6.7	55.5	16.1	38.4	23.1	41.9	44.8	30.8	39.2
Acer pseudoplatanus	26.5	66.7	23.5	22.6	10.3	42.3	48.4	22.4		47.8
Ulmus glabra	26.5		2.9	19.4	6.3	11.5				
Tilia platyphyllos	32.3	13.3	14.7		5.3			7.5		
Tilia cordata					1.0			11.8	7.7	
Acer platanoides					3.3	7.7		9.0		
Fraxinus excelsior					0.4	7.7				
Carpinus betulus		13.3			0.7		9.7	4.5	46.2	
Alnus incana				16.1					3.8	
Betula verrucosa				3.2						
Padus avium				3.2						
Cerasus avium				3.2						
Sorbus aucuparia					0.3					
Total	100	100	100	100	100	100	100	100	100	100

*1–10 numbers of localities like in Figure 1.

For comparisons of species composition and size structure of tree stands in Phyllitido-Aceretum community we used data collected in Pieniny National Park, published by Dziewolski (1991) and Jaworski and Karczmarski (1991). Despite the fact, that those data were gathered from plots of different size, chosen using different criteria, they provide a good background for comparison of Phyllitido-Aceretum community with other forest communities, and especially with beech forests which predominate in those areas.

2.2. STUDY AREA

The area, where we conducted our field work is located in the north-eastern part of the Pieniny National Park (Fig. 2). The detailed description of plots' locations was given in the paper by Bodziarczyk (1992). Plot A was situated in Pieniński Potok valley, plots B (Sokolica) and C (Ociemny Potok) in northern slopes of the Pieninki range. The elevation of plots ranged from 500 m a.s.l. (plot C) to 650 m a.s.l. (plot B). Two plots (A and C) were located just below tall limestone cliffs, while the plot B was situated in the steep slopes of Sokolica, with many smaller limestone rock outcrops, but without any real cliff. Tree stands in plots B and C retained their semi-natural character and are dominated by large

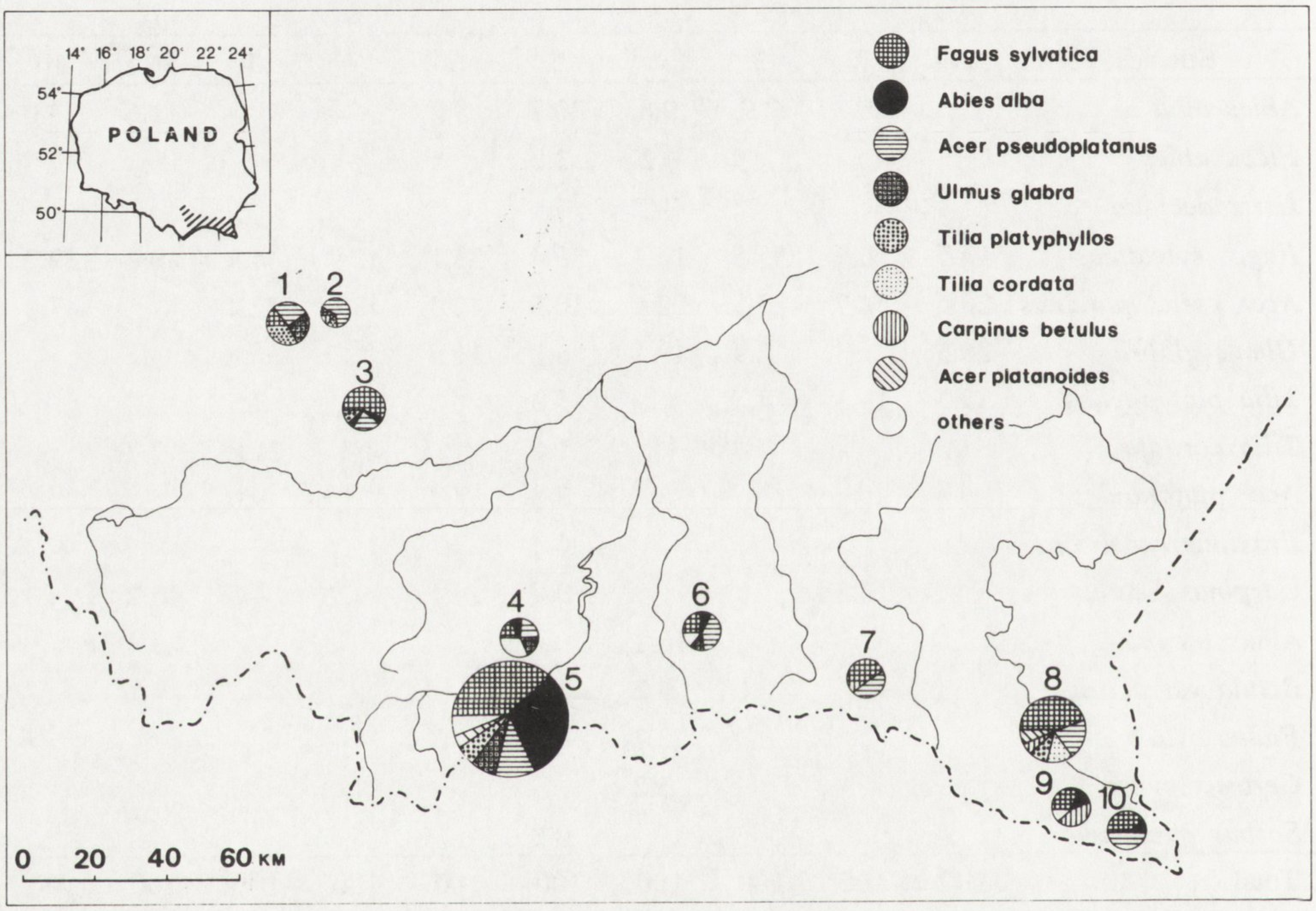

Fig. 1. Share of tree species in forest stands of Phyllitido-Aceretum in different regions
1 – Cracow-Częstochowa Upland I, 2 – Cracow-Częstochowa Upland II, 3 – Ojców National Park, 4 – Western Beskidy Mountains, 5 – Pieniny National Park, 6 – Beskid Niski Range I, 7 – Beskid Niski Range II, 8 – Lower Bieszczady Mountains I, 9 – Lower Bieszczady Mountains II, 10 – High Bieszczady Mountains. The area of each circle is propotional to the number of releves in given locality

trees; plot A at the beginning of the century was subjected to intense cuttings, and most of the stands originated about 60 years ago in a process of natural forest regeneration in clear-cut areas.

3. METHODS

3.1. METHODS OF DATA COLLECTING

To obtain exact data of forest stand structure, we established 3 nested rectangular plots in Phyllitido-Aceretum community in the Pieniny National Park. Each tree within the plot was mapped using a theodolite and measuring tape, and its diameter at breast height (DBH) measured. The size of each plot was: 16 x 32 m for shrubs and tree saplings, 32 x 52 m for trees over 7 cm DBH and 56 x 72 m for trees over 35 cm DBH.

3.2. METHODS OF DATA ANALYSIS

Detailed comparisons of species composition of tree stands between Phyllitido-Aceretum community and adjacent forests stands were made for Pieniny Mountains in two ways. First, we compared the share of various tree species in data collected by Dziewolski (1991) in forest stands of the north-eastern part of the Trzy Korony massif with the share of tree species in phytosociological releves, made in the same area (Bodziarczyk – unpublished data). Then, we compared the share of tree species in four permanent plots established by Jaworski and Karczmarski (1991) in Dentario glandulosae-Fagetum and Carici albae- -Fagetum with the share of tree species in our plots established in Phyllitido- -Aceretum community. Both comparisons took into account only the numbers of trees, and not their sizes.

For determining forest stand density, three measures were calculated: number of trees per area unit (1 ha), sum of diameters at breast height per 1 ha, and sum of stems cross-sections per 1 ha (basal area). The sum of DBH is considered a good approximation of the forest canopy closure (Kozlowski et al. 1991), and basal area is the most commonly used estimator of tree stand density in forestry research (Oliver and Larson 1990).

While comparing size distributions between plots, we have grouped trees in 4-cm size classes, to make our data comparable with results published by Jaworski and Karczmarski (1991). For ascertaining the statistical significance of differences between size distributions, the Kolmogorov-Smirnov test (Sokal and Rohlf 1981) was employed. To see, how large are the differences in results obtained by using exact data on size structure, and simplified data (trees grouped in 4-cm size classes) we compared our 3 plots using Kolmogorov-Smirnov tests in both ways; the differences were negligibly small.

To determine the spatial patterns of trees we used Ripley's K function (Ripley 1981). This function compares the distribution of distances among trees within the plot with the distribution of distances in an ideally random pattern (CSR – complete spatial randomness) and determines, whether the local-scale pattern of trees is random, aggregated or regular (Diggle 1983). Ripley's K function was used in a modified version; instead of making edge corrections, each plot was divided into two nested circles. The outer circle served as a buffer zone: thus the distance, up to which the results were fully reliable, was equal to the difference between the radii of the outer and inner circles (Szwagrzyk and Ptak 1991). In our study, the radii were: 33 and 23 m for trees of DBH larger than 35 cm; 16 and 8 m for trees of DBH equal to or larger than 7 cm.

For analyzing spatial relationship between different tree species, different size classes or between live and dead trees we employed the Ripley's K method for bivariate processes (Diggle 1983, Szwagrzyk and Ptak 1991). This indicates, whether two analyzed components are distributed independently of each other, or is there any kind of spatial relationships between them. The relationships can be either a positive (attraction) or a negative one (repulsion).

4. RESULTS

4.1. SPECIES COMPOSITION

Species composition of forest stands in Phyllitido-Aceretum is very diverse; we found 16 tree species occurring in the tree layer of analyzed releves, compared with 40 tree species native to the flora of Poland. Results are given in Figure 1 and in Table 1.

The dominant tree is beech (more than 36% of tree stands in the whole area), and its share varies from almost 56% in Ojców National Park to 12% in northern part of Cracow-Częstochowa Upland. Silver fir and sycamore maple are almost equally abundant – the share of fir is 18%, and of sycamore maple – less than 20%. It is essential to note, that the big proportion of fir is due to its abundance in Pieniny Mountains – in other areas its proportion is less than 10%, while in Pieniny Mts it exceeds 30%. Sycamore maple is abundant in Beskid Niski (over 45%) and in northern part of Cracow-Częstochowa Upland (39%), and least numerous in Pieniny Mts (10%).

Other tree species are less abundant in tree stands. Two of them – mountain elm *Ulmus scabra* and big leaf linden *Tilia platyphyllos* attain around 6% in the whole area, and more than 10% in certain localities. Mountain elm is quite numerous in Western Beskidy Mountains (19%) and in northern part of Cracow-Częstochowa Upland (18%), while big leaf linden is common in northern part of Cracow-Częstochowa upland (over 26%) and in Ojców National Park (almost 15%). Hornbeam *Carpinus betulus* and small leaf linden *Tilia cordata* occur mainly in lower elevations of Bieszczady Mountains, and their mean proportion in the whole community is well below 5%; Norway maple *Acer platanoides* is equally abundant, but more widely distributed. Other species – like ash (*Fraxinus excelsior*), Norway spruce (*Picea abies*) and cherry (*Prunus avium*) occur sporadically, some of them only in single localities. Some other species have been probably planted by foresters – like european larch *Larix decidua*, or are pioneer species, established naturally after cuttings – like grey alder *Alnus incana*.

Comparison of species composition of tree stands between Phyllitido-Aceretum community and the average for all forests growing in north-eastern part of Trzy Korony massif, Pieniny National Park (data from Dziewolski 1991) was presented in Table 2. Tree stands in Phyllitido-Aceretum community displayed much lower proportion of silver fir and beech than the average for that area. The share of sycamore maple, mountain elm and Norway maple in Phyllitido-Aceretum was substantially higher than the average, and the share of linden only slightly lower.

Table 2. Comparison of species composition of Phyllitido-Aceretum community with the average for forest stands in all forest communities in north-eastern part of Trzy Korony massif

Species	Share in tree stands (%)	
	all forests (Dziewolski 1991)	Phyllitido-Aceretum (Bodziarczyk – unpublished)
Fagus sylvatica	48.3	36.9
Abies alba	33.0	24.5
Acer pseudoplatanus	7.7	12.3
Tilia sp.	4.5	4.1
Ulmus glabra	3.6	10.7
Picea abies	1.6	4.9
Acer platanoides	1.1	6.6
Sorbus aucuparia	0.2	0.0
Total	100.0	100.0

Table 3. Comparison of species composition between plots located in Phyllitido-Aceretum community and plots located in beech forests (from: Jaworski and Karczmarski 1991) A – Pieniński Potok, B – Sokolica, C – Ociemny Potok, Dg-F – Dentario glandulosae-Fagetum, Ca-F – Carici albae-Fagetum

Community	Phyllitido-Aceretum				Beech forests		
species	A	B	C	total	Dg-F	Ca-F	total
Abies alba	5.6	50.0	72.6	45.0	44.8	76.6	60.8
Picea abies	1.1		1.2	0.8	0.8	0.8	0.8
Fagus sylvatica	56.7	36.8	14.3	36.4	52.9	17.8	35.2
Acer pseudoplatanus	23.3		3.6	9.9	1.5	3.3	2.4
Ulmus scabra	2.2	8.8		3.3			
Tilia platyphyllos		1.5	8.3	3.4		1.5	0.8
Acer platanoides	1.1			0.4			
Sorbus aucuparia		2.9		0.8			
Total	100	100	100	100	100	100	100

The other comparison made was the one between plots located in Phyllitido-Aceretum and in beech forests in Pieniny Mts (Table 3). Forest stands of Dentario glandulosae-Fagetum (Jaworski and Karczmarski 1991) were dominated by beech and silver fir, and the share of sycamore maple is very small. In Carici albae-Fagetum silver fir was a dominant species, beech was much less abundant, and the share of sycamore maple, big leaf linden and Norway spruce was higher than in the Carpathian beech forest, although still rather low. Our three plots differed from both beech forest communities: the share of beech was almost the same as the average for beech forest, but the share of fir was significantly lower. At the expense of silver fir, broadleaf species (sycamore maple, big leaf linden and mountain elm) were more abundant, although their proportion was lower than in phytosociological releves representing Phyllitido-Aceretum community (Table 2).

4.2. DENSITY

Number of trees over 7 cm DBH in Phyllitido-Aceretum community ranged from 246 trees · ha^{-1} in Sokolica plot to 342 trees · ha^{-1} in Pieniński Potok plot. The average for three plots was equal to 290 individuals · ha^{-1} (Table 4).

Table 4. Comparison of density, sum of DBH and basal area between plots located in Phyllitido-Aceretum community (A, B and C) and in beech forests (D, E, F and G)

Plots*	Number of trees · ha^{-1}	Sum of basal area per 1 ha (m2)	Sum of DBH per 1 ha (cm)
A	342	19.51	9001
B	246	32.39	8461
C	283	28.45	8605
D	448	36.12	12406
E	440	42.62	12817
F	509	46.20	15021
G	536	46.75	16220

*Plots: A–C – like in Figure 2, D – Gródek (Jaworski and Karczmarski 1991), E – Walusiówka (Jaworski and Karczmarski 1991), F – Sosnów (Jaworski and Karczmarski 1991), G – Facimiech (Jaworski and Karczmarski 1991).

According to data presented by Jaworski and Karczmarski (1991), tree density per 1 ha in beech-fir forests was almost twice as big as in Phyllitido-Aceretum, ranging from 440 trees ha^{-1} in Walusiówka plot to 536 trees ha^{-1} in Facimiech plot, with the mean value of 483 trees ha^{-1}.

Sum of DBH per 1 ha, which is a good estimator of canopy density, amounted to 9000 cm ha^{-1} in Pieniński Potok plot; in two other plots it was slightly lower, so the average for three plots was 8689 cm ha^{-1}. Sums of DBH for plots located in beech-fir forests (Jaworski and Karczmarski 1991) ranged from 12406 cm ha^{-1} to 16220 cm ha^{-1}, with the average amounting to 14116 cm ha^{-1} (Table 4).

Similar results were obtained while comparing stand basal area in Phyllitido-Aceretum with plots located in beech-fir forests. The lowest basal area was ascertained for Pieniński Potok plot (19.50 m^2 ha^{-1}), the average one – 28.45 m^2 ha^{-1} in Ociemny Potok, and the largest one – 32.39 m^2 ha^{-1} in Sokolica plot. Respective values for beech-fir forest (Jaworski and Karczmarski 1991) were much higher, from 36.12 m^2 ha^{-1} in Gródek plot to 46.75 m^2 ha^{-1} in Facimiech plot (Table 4).

4.3. SIZE STRUCTURE

Size structure of Phyllitido-Aceretum stands was very similar in two plots: Ociemny and Sokolica (Fig. 2A, 2B). Results of comparisons made with K-S test (DN = 0.1447, SL = 0.99975) indicated, that the structure of both stands was almost identical (Table 5). Both distributions were significantly different from normal distribution. On the other hand, the size structure in Pieniński Potok plot differed significantly both from Ociemny and from Sokolica plots (Fig. 2C), and was practically a normal distribution (DN = 0.07705, SL = 0.99999).

Comparisons with data from research plots established in Carpathian beech forest and in thermophilous beech forest (Jaworski and Karczmarski 1991) indicated, that the difference between those three communities (Phyllitido-Aceretum, Dentario glandulosae-Fagetum and Carici albae-Fagetum) were not larger, than the differences between plots located in the same community (Table 5). Because

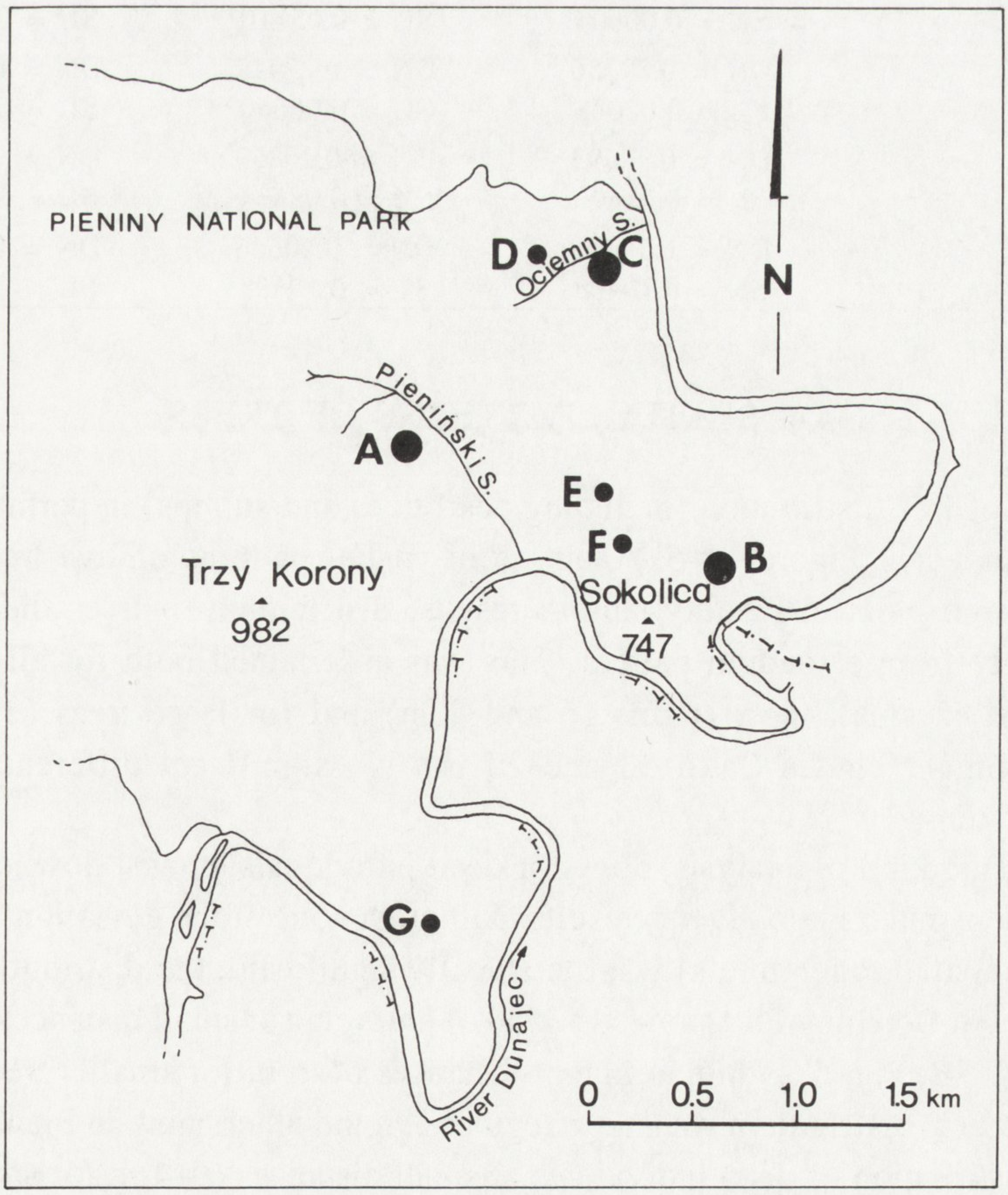

Fig. 2. Location of research plots in Pieniny National Park
A – Pieniński Stream, B – Sokolica, C – Ociemny Stream, D – Gródek (Jaworski and Karczmarski 1991), E – Walusiówka (Jaworski and Karczmarski 1991), F – Sosnów (Jaworski and Karczmarski 1991), G – Facimiech (Jaworski and Karczmarski 1991)

plots in beech forests had been measured twice, we had the opportunity to compare size structure in the same plots in years 1974 and 1987: the differences between two censuses in the same plot were statistically significant in three cases, while non-significant only in one case (Facimiech plot – DN = 0.14213, SL = 0.12086).

Table 5. Results of Kolmogorov-Smirnov tests between size distributions of trees in given plots
All explanations like in Table 4

Plots	A	B	C
A	–	DN = 0.33831 SL = 0.00436	DN = 0.30631 SL = 0.00868
B	DN = 0.33831 SL = 0.00436	–	DN = 0.14479 SL = 0.99975
C	DN = 0.30631 SL = 0.00868	DN = 0.14479 SL = 0.99975	–
D	DN = 0.26645 SL = 0.00604	DN = 0.23682 SL = 0.05110	DN = 0.25613 SL = 0.01758
E	DN = 0.29756 SL = 0.00046	DN = 0.27922 SL = 0.00660	DN = 0.19350 SL = 0.09319
F	DN = 0.22693 SL = 0.01690	DN = 0.20859 SL = 0.08634	DN = 0.20833 SL = 0.06055
G	DN = 0.18449 SL = 0.10408	DN = 0.20666 SL = 0.10688	DN = 0.19357 SL = 0.11542

4.4. SPATIAL PATTERNS OF TREES

Maps of tree distribution (including dead trees and stumps) in permanent plots were presented in Figures 3–5. Analyses of spatial patterns of live trees gave in three research plots in Pieniny similar results: distribution of trees did not differ significantly from a random pattern. This was ascertained both for all trees over 7 cm DBH in small plots (radii: 16 and 8 m) and for large trees (over 35 cm DBH) in bigger circles (radii 33 and 23 m). No significant difference between plots was found.

The same kind of analysis, done for dead individuals (snags, downed logs and stumps) gave much more diverse results. Although none of the deviations from CSR (complete spatial randomness) was statistically significant, the distribution of dead individuals in Ociemny Plot showed a kind of clumping at small distances (up to 1 m – Figs. 7A, 7B, Fig. 6), while at bigger distances (4–6 m for smaller trees, 8–10 m for larger trees) distribution was more regular. On the other hand, in Pieniński Potok plot the distribution of dead individuals at small distances (0–4 m for smaller trees, up to 10 m for larger trees) turned out to be quite regular (Fig. 3), although the "regularity" was not statistically significant. Similar distribution – close to regular at small distances – was ascertained for dead trees in Sokolica plot (Fig. 5, Figs. 8A, 8B).

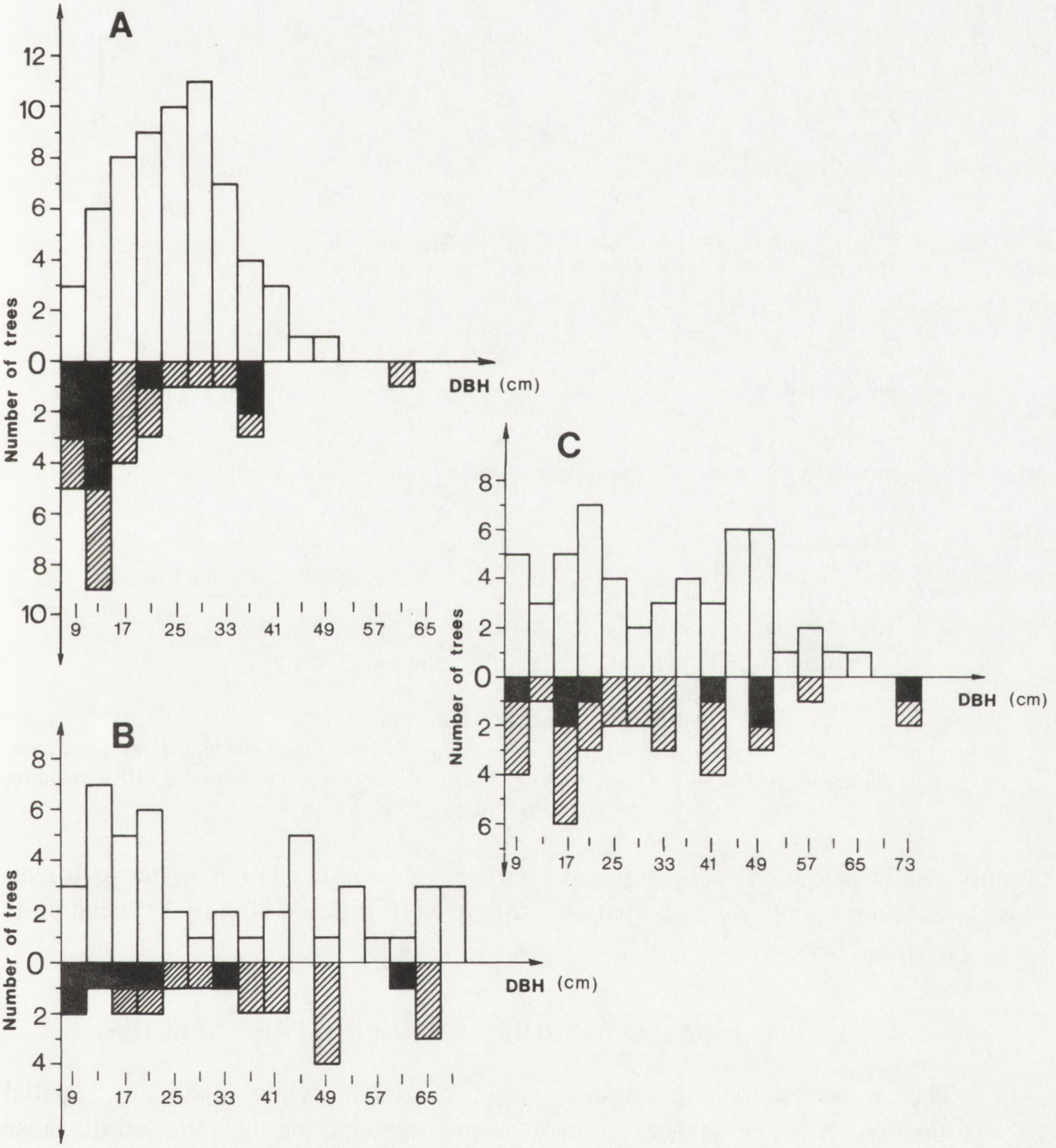

Fig. 3. Size structure of trees in plots A, B and C
Open bars above x-axis – live trees, solid bars below x-axis – snags, shaded bars below x-axis – stumps, DBH – diameter at breast height

When both live and dead trees were analyzed together, the results were very close to CSR in most cases. Only in Ociemny the pattern for small and large trees was almost identical, while in Sokolica and Pieniński Potok plots the deviations from CSR for small and large trees had opposite direction (Figs. 9A, 9B).

In Sokolica plot, beech and fir were the only tree species numerous enough to permit separate computations for each species. In Pieniński Potok, the two species numerous enough were beech and sycamore maple, while in Ociemny –

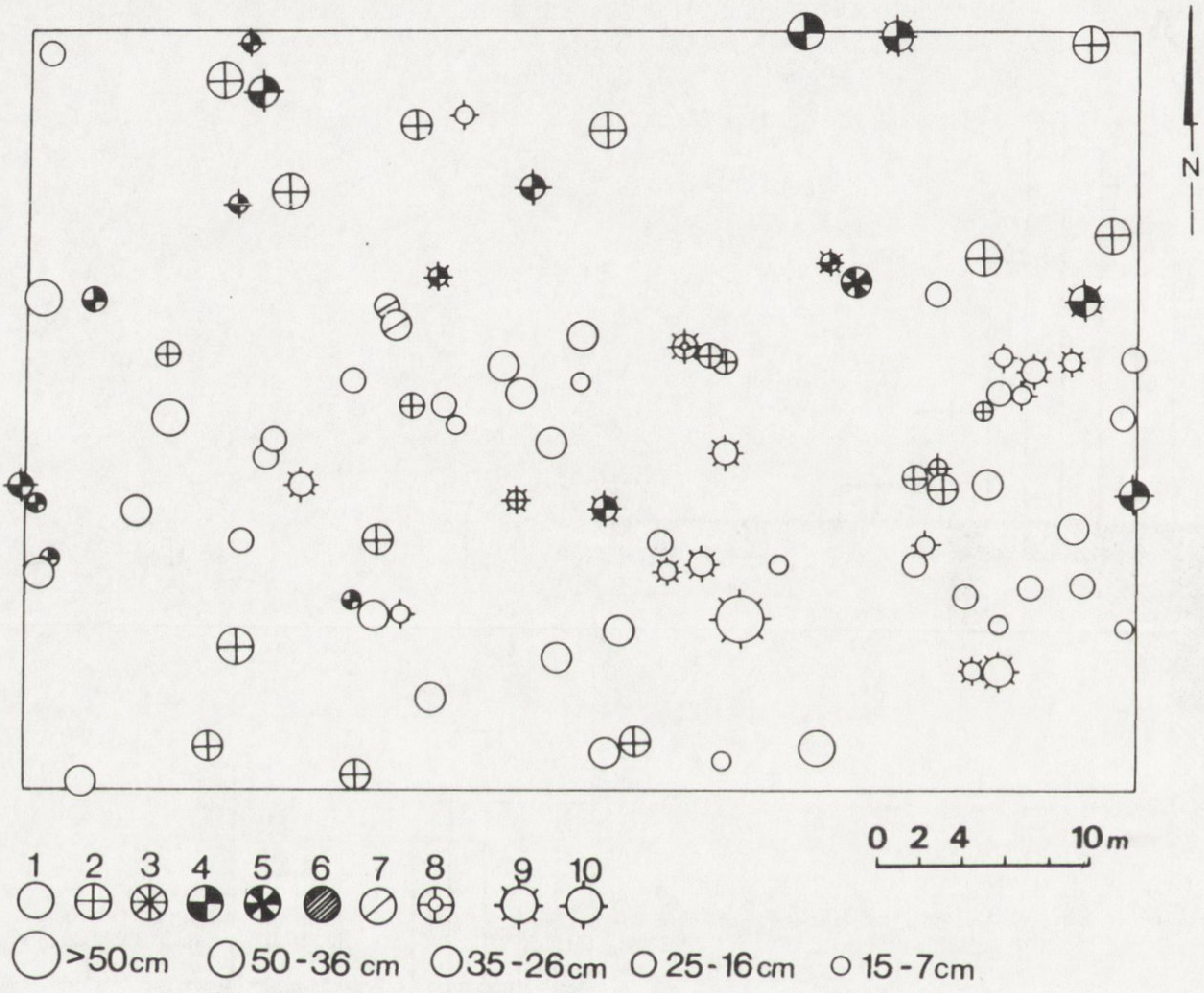

Fig. 4. Stem map of the plot A
1 – *Fagus sylvatica*, 2 – *Acer pseudoplatanus*, 3 – *Tilia platyphyllos*, 4 – *Abies alba*, 5 – *Picea abies*, 6 – *Sorbus aucuparia*, 7 – *Ulmus glabra*, 8 – *Acer platanoides*, 9 – stumps, 10 – standing dead trees

only fir. Distributions for single species were generally similar to those for all species taken together. Spatial patterns for silver fir differed slightly between plots (Figs. 10A, 10B).

4.5. SPATIAL RELATIONSHIPS BETWEEN TREE SPECIES

The most interesting results were obtained, while analyzing spatial relationships between species, which were abundant enough to permit those calculations. That was done for beech and fir in Ociemny and Sokolica plots, and for beech and sycamore maple in Pieniński Potok. The results were quite consistent: no matter what the size of trees, spatial relationships between species were always negative, indicating a kind of "repulsion" at small distances (2–12 m). However, none of those results was statistically significant (Figs. 11A, 11B).

4.6. DISTRIBUTION OF TREES IN RELATION TO GRUSS COVER

As we supposed, that the distribution of trees in Phyllitido-Aceretum can be affected by gruss cover, we compared the stem maps for Ociemny and Pieniński Potok with data on percentage of gruss in 1 x 1 m square grids of area 512 m^2

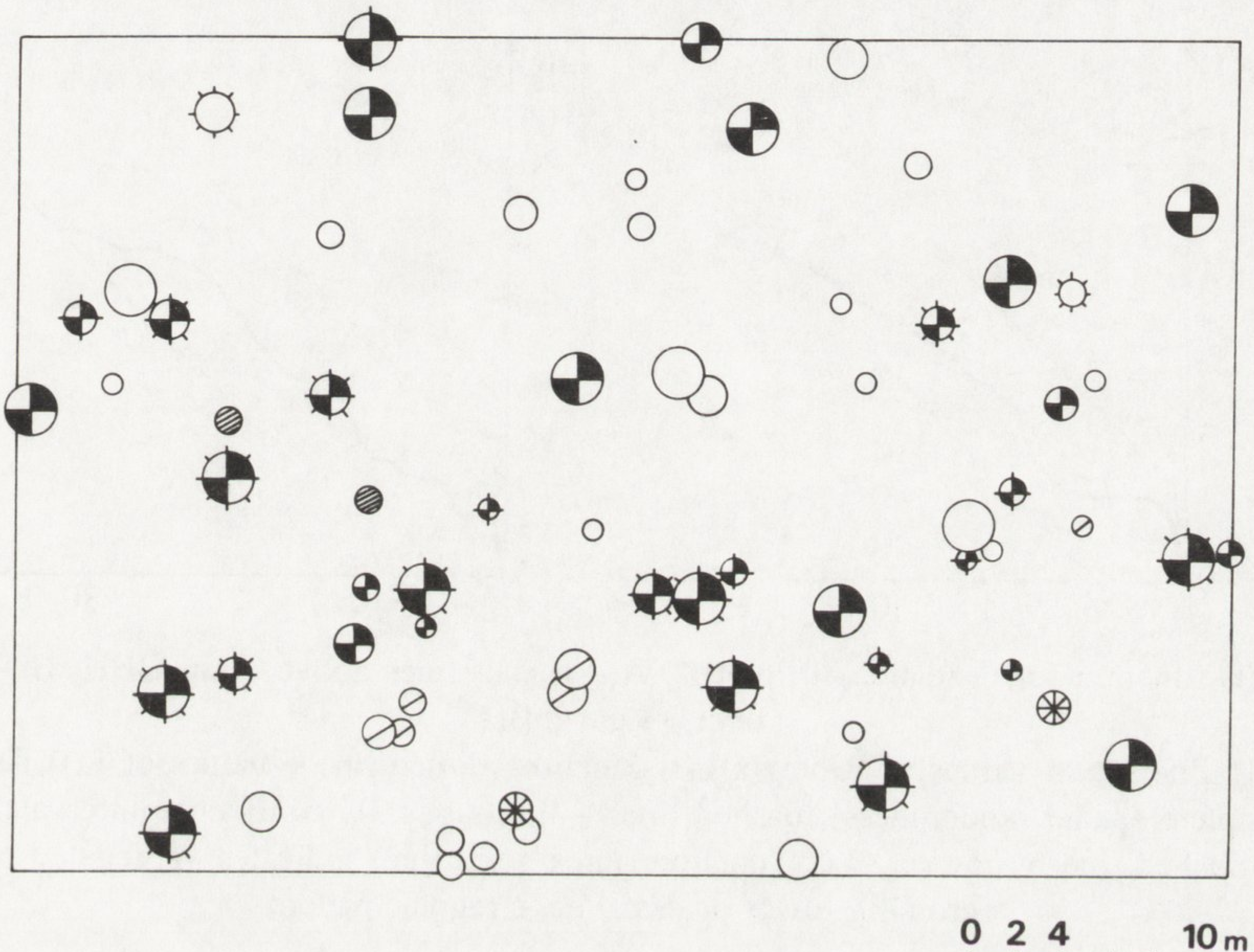

Fig. 5. Stem map of the plot B
All explanations like in Figure 3

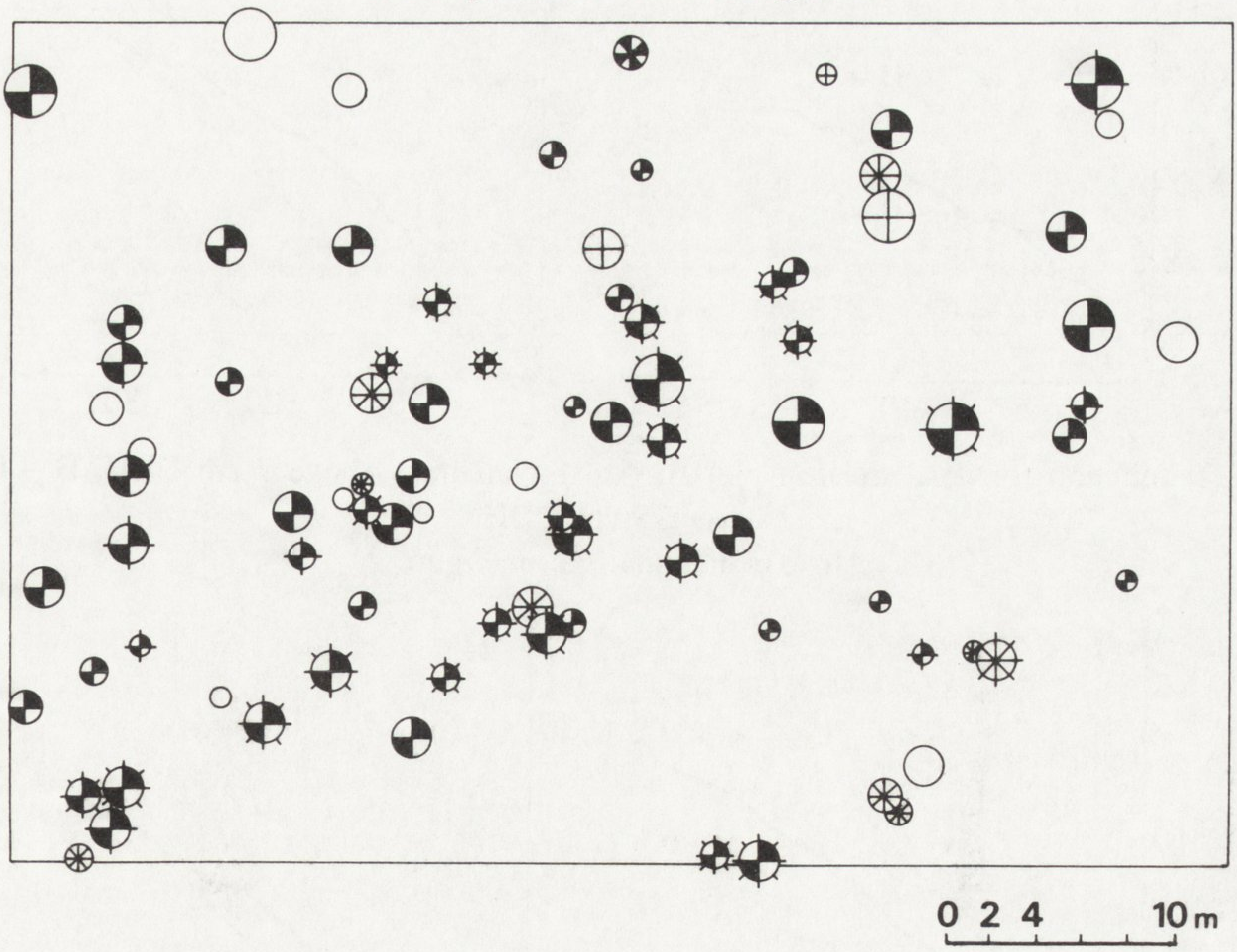

Fig. 6. Stem map of the plot C
All explanations like in Figure 3

(Bodziarczyk 1992). Results are presented in Tables 6 and 7. The very dense gruss cover (over 75%) occurred only in Ociemny plot, and both in Pieniński Potok and Ociemny plots the medium gruss cover class (26–50%) dominated. Quadrats with very dense gruss cover in Ociemny turned out to have the lowest

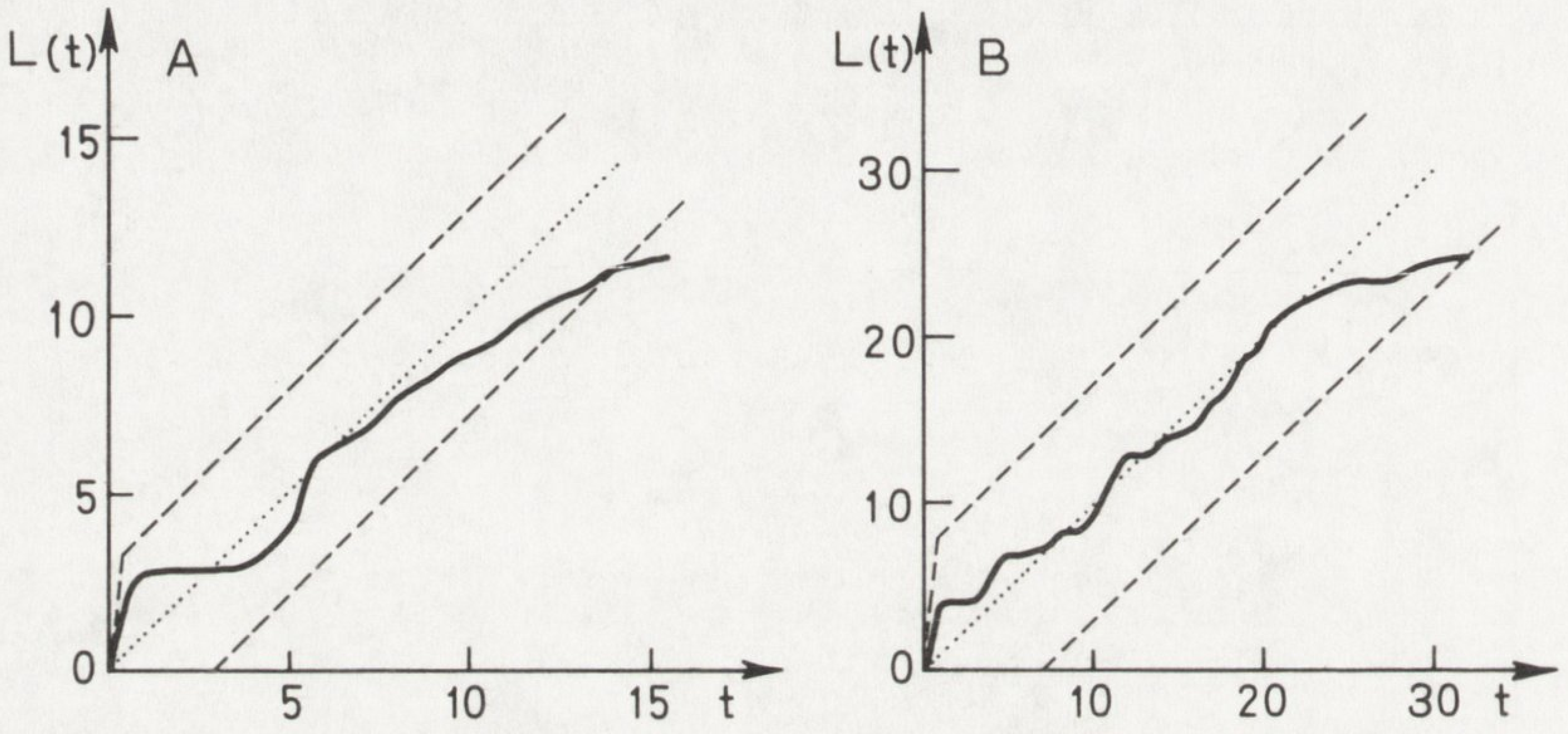

Fig. 7. L(t) function for dead trees in plot C, A – for all trees above 7 cm DBH, B – for trees over 35 cm DBH

Thick solid line – real values of Ripley's L(t) function; dotted line – values of L(t) function for CSR (complete spatial randomness); dashed lines – limits of 0.05 confidence intervals. Crossing upper dashed line by the real L(t) function (thick solid line) indicates aggregated pattern, crossing lower dashed line – regular pattern

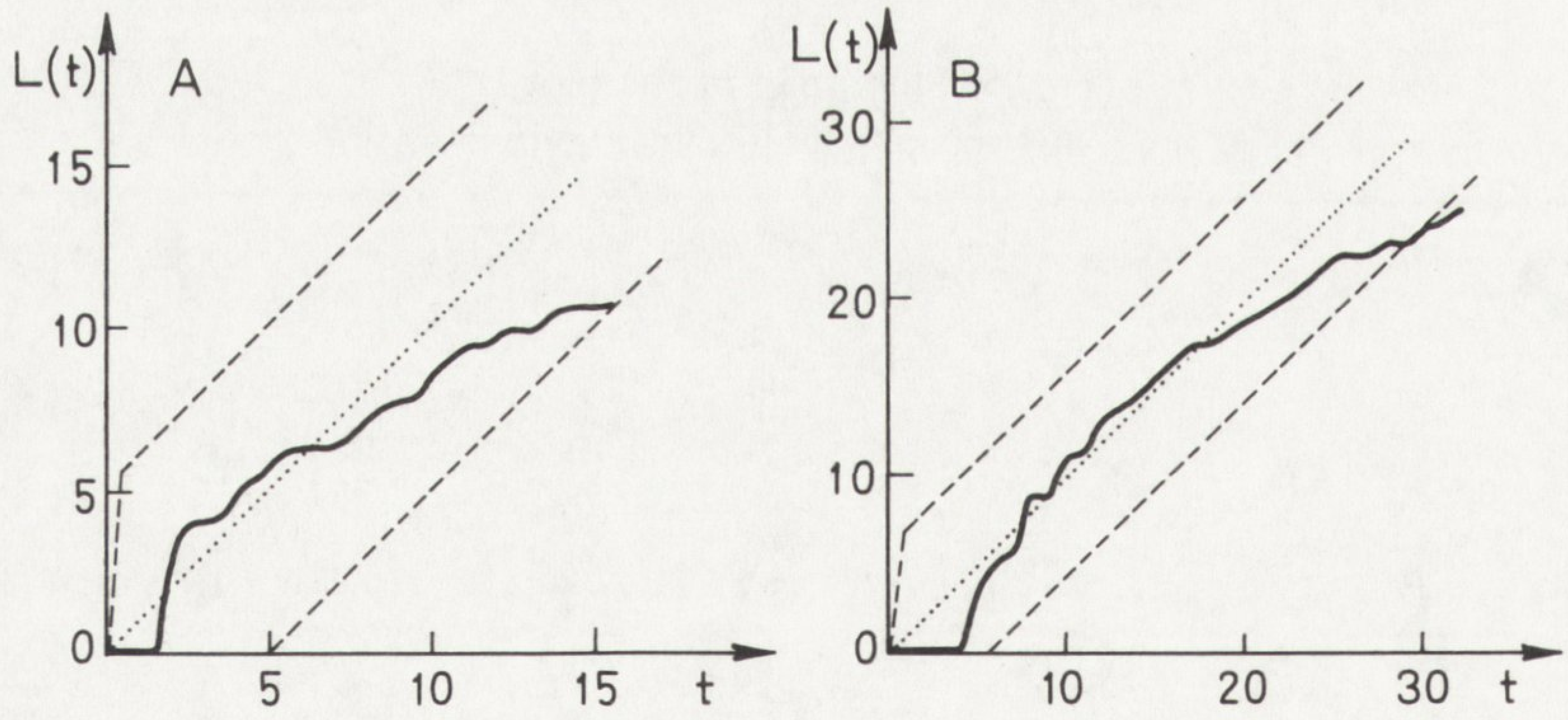

Fig. 8. L(t) function for dead trees in plot B; A – for all trees above 7 cm DBH, B – for trees over 35 cm DBH

All explanations like in Figure 7

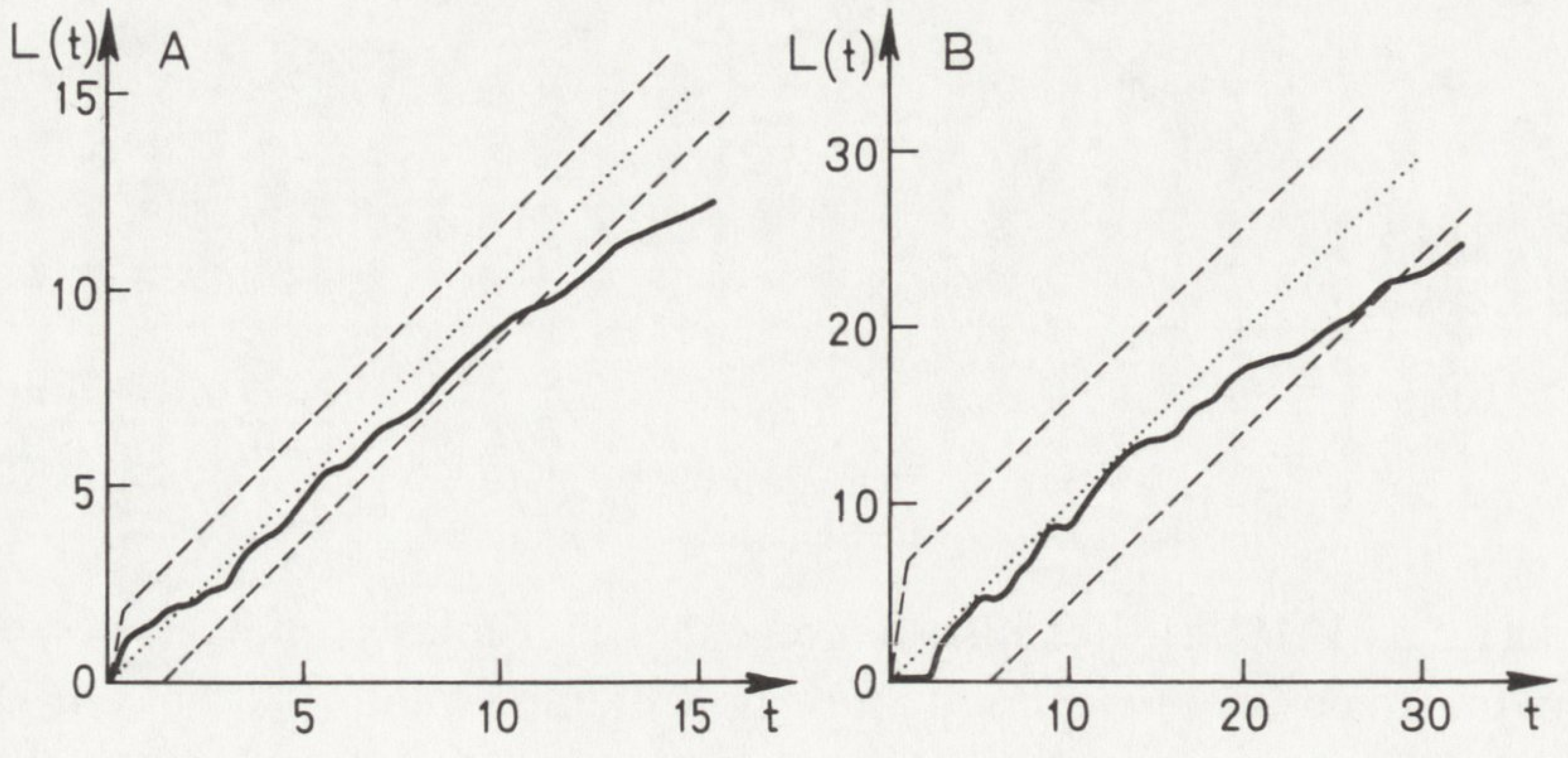

Fig. 9. L(t) function for live and dead trees together in plot A; A – for all trees above 7 cm DBH, B – for trees over 35 cm DBH

All explanations like in Figure 7

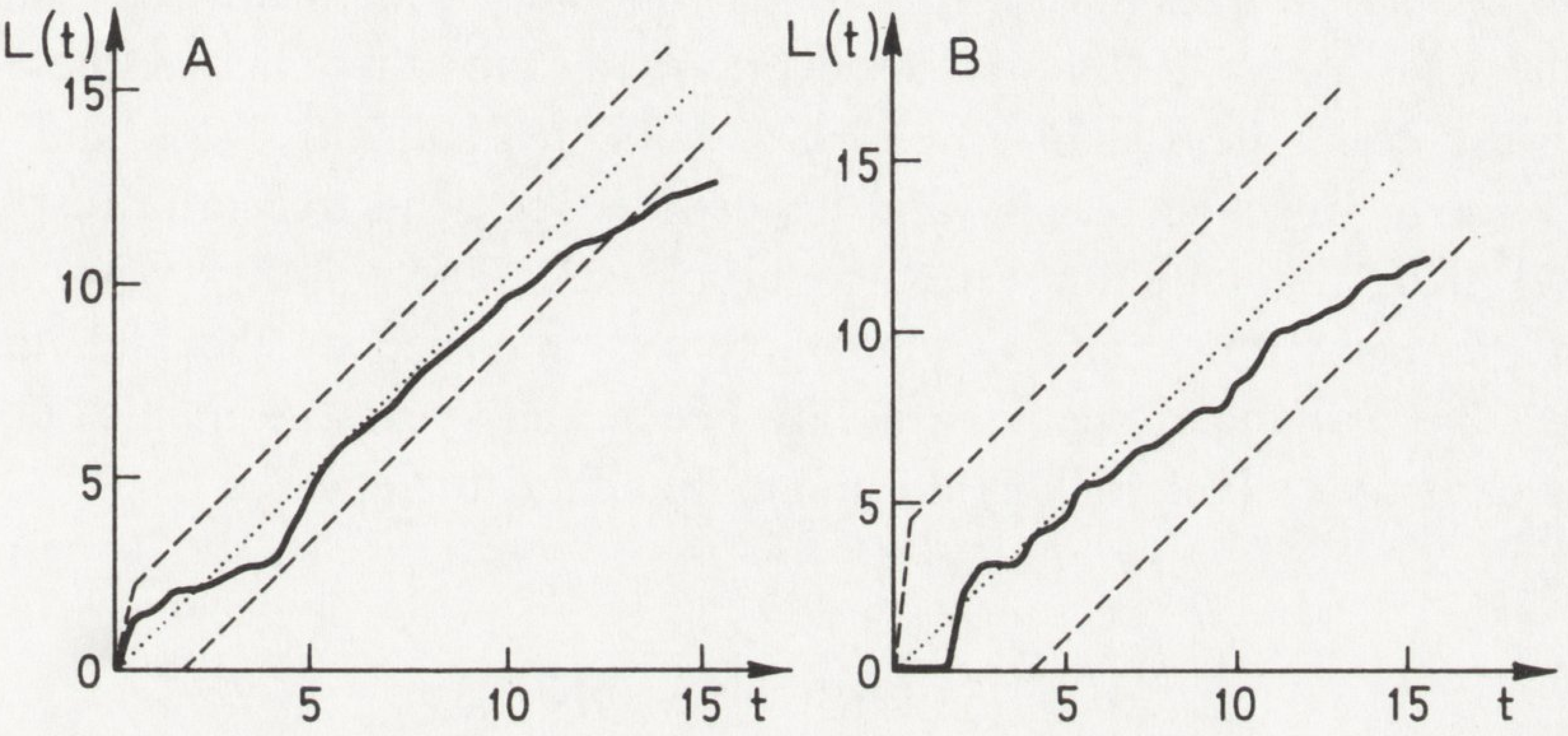

Fig. 10. L(t) function for live and dead silver firs above 7 cm DBH; A – in plot C, B – in plot B
All explanations like in Figure 7

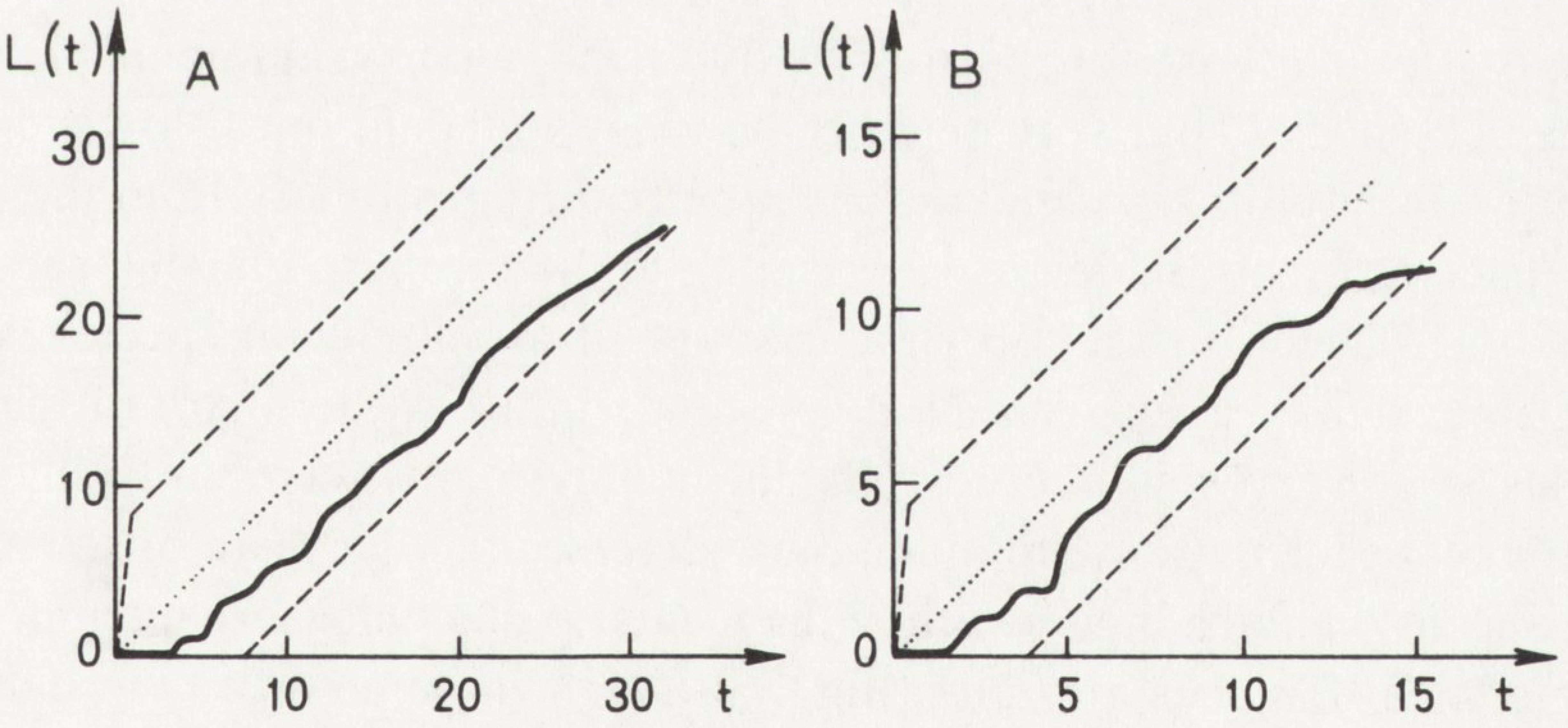

Fig. 11. Spatial relationships between: A – beeches and firs in Ociemny plot, B – beeches and sycamore maples in Pieniński Potok plot
All explanations like in Figure 6

Table 6. Distribution of trees in various gruss cover classes in the plot C

Gruss cover class (%)	Percent of area covered	Live trees $\cdot$ 100 m^{-2}	Dead trees and stumps $\cdot$ 100 m^{-2}	Live trees : dead trees ratio
100–76	29.3	2.0	3.3	0.6 : 1
75–51	17.0	5.7	3.4	1.6 : 1
50–26	32.4	5.4	2.4	2.3 : 1
25–1	21.3	3.7	3.7	1 : 1

Table 7. Distribution of trees in various gruss cover classes in the plot A

Gruss cover class (%)	Percent of area covered	Live trees $\cdot$ 100 m^{-2}	Dead trees and stumps $\cdot$ 100 m^{-2}	Live trees : dead trees ratio
75–51	20.1	3.9	1.0	3.9 : 1
50–26	56.7	4.8	2.4	2 : 1
25–1	23.2	3.4	1.7	2 : 1

live tree density (2 trees · 100 m^{-2}), while the density of dead trees and stumps was higher (3.3 trees · 100 m^{-2}). However, among the other classes, the class with lowest gruss cover (less than 25%) has – both in Pieniński Potok and Ociemny plots – a lower live tree density and lower live tree/dead tree ratio (especially in Ociemny) than the medium gruss cover classes. The validity of comparisons between Pieniński Potok and Ociemny plots is impaired by the fact, that in the first one silver broadleaf species (mainly beech and sycamore maple) dominated, while in Ociemny silver fir was the most abundant tree species.

5. DISCUSSION

Although the common name of Phyllitido-Aceretum is "mountain sycamore maple forest", sycamore maple is not – in general – the dominant tree species in this community. In fact, those forests are usually mixed, with sycamore maple as one of the main tree species, but very seldom the most abundant one. However, species composition in Phyllitido-Aceretum community differs strongly from the composition in adjacent forests, which usually belong to the Dentario glandulosae-Fagetum community. In beech forests beech and silver fir are dominant species, while the share of other trees – apart from Norway spruce in the western part of the Beskidy Mountains – is very small. Forest stands in Phyllitido-Aceretum, although also dominated by beech and fir, are much more diverse, and the share of several broadleaf tree species is much bigger than in the Dentario glandulosae-Fagetum.

Regional differences are interesting, although in some areas the data are too sparse to permit reliable comparisons. The most striking feature is the very big proportion of silver fir in the Pieniny Mountains, where – in some releves – it was the main tree species in Phyllitido-Aceretum. That was observed exclusively in Pieniny – in other areas silver fir was a minor species, or even it was absent in that community. The latter situation refers especially to the eastern part of the Carpathian Mountains and to the Cracow-Częstochowa Upland.

The abundant occurrence of bigleaf linden in Pieniny and in Cracow-Częstochowa Upland confirms the opinion, that this species is confined to limestone rock outcrops or to their immediate neighbourhood. The occurrence hornbeam and small leaf linden in Bieszczady Mts is in agreement with the opinion, that in eastern parts of the Beskidy Mountains the 'lowland' plant species (not only trees) tend to enter the mountain zone.

A very interesting thing is the occurrence of grey alder (*Alnus incana*) in tree stands of Phyllitido-Aceretum community. Grey alder is considered an early successional trees species, and it usually occurs either on river banks, or in relatively young, secondary forest stands. The quite big proportion of grey alder – especially in the lower part of Bieszczady Mountains – indicates, that the Phyllitido-Aceretum community comprises not only natural or semi-natural old growth forest stands, but also forests which have been cut in the past, or even typical secondary forest stands.

Comparisons of size structure and spatial patterns of trees between Phyllitido-Aceretum and beech forests revealed no substantial differences. Size structure varied between plots both in beech forests (Dentario glandulosae-Fagetum, Carici albae-Fagetum) and in Phyllitido-Aceretum no less than between communities. Thus it cannot be considered a characteristic feature of any forest community. Spatial patterns of trees – in general – were not significantly different from the random distribution. Similar results for beech and mixed beech-fir forests were obtained while analyzing spatial structure of forest stands in other parts of the Western Carpathian Mountains (Szwagrzyk 1990, Szwagrzyk and Czerwczak 1993).

The very interesting feature of the tree stands in Phyllitido-Aceretum community turned out to be the negative spatial relationship between tree species constituting forest stands: between beech and fir in Ociemny plot, and between beech and sycamore maple in Pieniński Potok. In other studies of this kind, tree species were usually randomly mixed at local spatial scales (Szwagrzyk and Czerwczak 1993). The negative relationship at small distances can suggest a kind of microsite separation between those species: probably certain patches within community are usually occupied by a single species. Probably, the local-scale tree species segregation is a typical feature of Phyllitido-Aceretum, reflecting its habitat patchiness, much more pronounced than in Carpathian beech forests.

There is a significant difference in stand density between Phyllitido-Aceretum and beech forests. No matter which measure was taken into account (number of trees, sum of DBH or basal area), the density of tree stand in Phyllitido-Aceretum was substantially lower. It was also lower than the data reported in literature for most of the natural, mixed broadleaf stands (Włoczewski 1972, Muller 1982, Woods 1984), and only slightly higher than values ascertained by Peterken and Jones (1987) for hardwood stands developing below limestone cliffs. This indicates, that there must be a kind of mechanism which limits the tree stand density. Our hypothesis is, that the slope instability can be the main reason for that: Phyllitido-Aceretum community develops on steep, rocky slopes, usually below limestone cliffs or bigger rock outcrops. The occurrence of the hart's tongue fern, Phyllitis scolopendrium is positively correlated with the presence of gruss and boulders, while negatively correlated with the thick litter layers (Bodziarczyk 1992). Movement of gruss down the slope can prevent establishment of tree seedlings, while boulders moving down the slope can hurt or even break subcanopy trees. Also among the large trees in Phyllitido-Aceretum the probability of windthrows is bigger (Peterken and Jones 1987). The large amount of broken or windthrown trees in our permanent plots in Pieniny Mountains (Figs. 3–5) seems to support this hypothesis.

However, according to the results of comparisons made in Pieniński Potok and Ociemny plots, there is no simple linear relationship between gruss cover and tree density. Because gruss moves gradually down the slope, we expect the relationship between gruss cover and local tree density to be a complex one: number of trees, that grow in a given area, is a result of growth conditions during the whole period of stand development. Therefore, if the conditions vary with time, one shall not expect a close relationship between the number of trees – which integrates the influences of conditions prevailing during the whole period – and conditions determined in any given time period. Especially, if we consider the fact, that early stages of stand development – namely the phase of seedling establishment – are probably the crucial ones for the final stand density in harsh environments.

6. SUMMARY

The Phyllitido-Aceretum community in Poland is restricted to relatively small areas, but its forest stands are among the most diverse ones. Data concerning the species composition of those stands are quite numerous, but practically nothing is known about their size and spatial structures. In our work we wanted to answer, what is the density and size structure of tree stands in Phyllitido-Aceretum, and whether it is significantly different from density and size structure in other forest communities. By analyzing spatial structure in a quantitative way, we tried to determine, what are the spatial patterns and relationships between tree species in Phyllitido-Aceretum.

Materials for comparisons were taken from literature. Field studies were conducted in three nested rectangular plots, located in the eastern part of the Pieniny National Park. Each tree within the plot was mapped using a theodolite and measuring tape, and its diameter at breast height (DBH) measured. The size of each plot was: 16 x 32 m for shrubs and tree saplings, 32 x 52 m for trees over 7 cm DBH and 56 x 72 m for trees over 35 cm DBH. For ascertaining the statistical significance of differences between size distributions, the Kolmogorov-Smirnov test was employed. Spatial patterns of trees, as well as spatial relationships between tree species were determined using modified Ripley's K function.

Tree stands in Phyllitido-Aceretum are usually mixed, with sycamore maple as one of the main tree species, but very seldom the most abundant one. Regional differences are interesting, although in some areas the data are too scarce to permit reliable comparisons. The most striking feature is the very big share of silver fir in the Pieniny Mts.

Number of trees over 7 cm DBH in Phyllitido-Aceretum community ranged from 246 trees $\cdot$ ha^{-1} in Sokolica plot to 342 trees $\cdot$ ha^{-1} in Pieniński Potok plot, and the average was 290 individuals $\cdot$ ha^{-1}. Sum of DBH per 1 ha amounted to 9000 cm ha^{-1} in Pieniński Potok plot; in two other plots it was slightly lower, so the average was 8689 cm ha^{-1}. The lowest basal area was ascertained for Pieniński Potok plot (19.50 m^2 ha^{-1}), the medium one – 28.45 m^2 ha^{-1} in Ociemny Potok, and the largest one – 32.39 m^2 ha^{-1} in Sokolica plot. Results of comparisons made with K-S test indicated, that the size structure of tree stands in Ociemny Potok and Sokolica plots was almost identical; the size structure in Pieniński Potok plot differed significantly from them, and was practically a normal distribution. In all plots, distribution of trees did not differ significantly from a random pattern. This was ascertained both for all trees over 7 cm DBH and for large trees over 35 cm DBH. No significant difference between plots was found.

The very interesting feature of the tree stands in Phyllitido-Aceretum community turned out to be the negative spatial relationship between tree species at local spatial scales, probably reflecting habitat patchiness. The tree stand density in Phyllitido-Aceretum was two times lower

than in beech forests. Our hypothesis is, that the slope instability can be the main reason for that: Phyllitido-Aceretum develops on steep, rocky slopes, where establishment of tree seedlings is difficult, and probability of windthrows is bigger than in other forest communities.

7. POLISH SUMMARY

Występowanie zespołu jaworzyny górskiej Phyllitido-Aceretum w Polsce (rys. 1, tab. 1) jest ograniczone do stosunkowo małych powierzchni, ale zespoły te należą do najbardziej zróżnicowanych pod względem składu gatunkowego. Dane na ten temat są stosunkowo liczne, natomiast niewiele wiadomo o strukturze grubości i strukturze przestrzennej drzewostanów. Celem niniejszej pracy było określenie zagęszczenia i struktury wielkości drzewostanów Phyllitido-Aceretum na tle innych zbiorowisk leśnych. Na podstawie ilościowej analizy struktury przestrzennej chcieliśmy stwierdzić, jakie są wzorce rozmieszczenia drzew w zespole oraz relacje przestrzenne między gatunkami tworzącymi drzewostan.

Materiał do porównania składu gatunkowego został zaczerpnięty z literatury (Pancer-Kotejowa 1973, Staszkiewicz 1973, Wika 1978, Święs 1982, Michalik i Mazur 1991, Kozłowska i Matuszkiewicz 1993). Badania terenowe przeprowadzono na 3 współśrodkowych prostokątnych powierzchniach, rozmieszczonych we wschodniej części Pienińskiego Parku Narodowego. W obrębie powierzchni badawczych dokonano pomiaru pierśnic drzew oraz określono ich położenie przy użyciu teodolitu i taśmy mierniczej. Rozmiary każdej powierzchni badawczej były następujące: 16 x 32 m dla najmniejszego, środkowego prostokąta, w którym pomierzono wszystkie drzewa i krzewy powyżej 0,5 m wysokości, 32 x 52 m dla drzew powyżej 7 cm pierśnicy i 56 x 72 m dla drzew o pierśnicy powyżej 35 cm. Do stwierdzenia istotności różnic pomiędzy rozkładami wielkości zastosowano test Kołmogorowa-Smirnowa. Wzorce rozmieszczenia drzew oraz zależności pomiędzy gatunkami określono przy zastosowniu zmodyfikowanej funkcji Ripleya K(t).

Jawor jest jednym z głównych gatunków drzew w jaworzynie górskiej, ale bardzo rzadko jest gatunkiem najliczniejszym. Regionalne różnice w składzie gatunkowym są interesujące, ale niekiedy dane te są zbyt skąpe aby pozwolić na wiarygodną analizę. Najbardziej charakterystyczną z regionalnych odmienności w składzie gatunkowym jest duży udział jodły w Pieninach.

Liczba drzew o pierśnicy powyżej 7 cm przypadająca na 1 ha wynosi w jaworzynie górskiej od 246 (na powierzchni pod Sokolicą) do 342 (w Pienińskim Potoku), średnio 290. Suma pierśnic przeliczona na 1 ha dochodzi do 9000 cm w Pienińskim Potoku, podczas gdy w pozostałych wynosi nieco mniej, średnio 8689 cm. Najniższą sumę powierzchni przekroju pierśnicowego stwierdzono w Pienińskim Potoku (19,50 m^2 ha^{-1}), średnią – 28,45 m^2 ha^{-1} – w Ociemnym Potoku, a największą – 32,39 m^2 ha^{-1} – na Sokolicy. W porównaniach wykonanych przy użyciu testu Kołmogorowa-Smirnowa wykazano, że powierzchnie w Ociemnym i na Sokolicy mają prawie identyczne rozkłady grubości drzew, a powierzchnia w Pienińskim Potoku różni się od nich istotnie, wykazując rozkład zbliżony do normalnego. Na wszystkich powierzchniach rozmieszczenie drzew nie różni się istotnie od wzorca losowego, zarówno dla drzew o pierśnicy powyżej 7 cm, jak i dla drzew o pierśnicy większej niż 35 cm. Nie stwierdzono istotnych różnic w rozmieszczeniu drzew między powierzchniami.

Bardzo interesującą cechą drzewostanów jaworzyny górskiej okazały się negatywne relacje przestrzenne między gatunkami drzew w skali lokalnej, prawdopodobnie odzwierciedlające mozaikowość siedlisk. Zagęszczenie drzew w jaworzynie było średnio dwa razy mniejsze niż w buczynach. Prawdopodobnie jest to związane z niestabilnością stoków w jaworzynie górskiej; strome, kamieniste stoki są czynnikiem ograniczającym odnawianie się drzewostanu, a prawdopodobieństwo wywrotów przez wiatr jest większe niż w innych zbiorowiskach leśnych.

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