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GENERAL BIOLOGY

Ranking Similar Wood Areas by the Intensity of Competition through an Analysis of Their Contour Planes

V. V. Galitskii and A. V. Abaturov

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Construction of age ranks from data obtained from examination of woody test areas whose ages are clearly different from those of specimens of the main stock is a routine procedure in forestry. A similar approach is used by other sciences (for example, soil science), when the full cycle of development of the studied object is too long to be observed at present. The tables of growth dynamics, the main instrument for control over the forest, are compiled from such age ranks.

Practical forestry knows many examples of sample areas displaying wood stocks of similar species and age structure but differing in certain other respects. Ranking such areas in accordance with the stage of competition, which is the main process of development of woods, is obviously an important problem. This issue is considered below; we studied areas whose examination revealed differences in the growth density and the mean diameter of specimens.

More than 30 sample areas ranging from 0.25 to 2.25 hectares, containing a total of more than 10000 specimens were selected in mature, dense woods in Moscow suburbs. The areas contained all major wood species found in the region. Fir dominated most areas. Five sample areas of similar age (old wood) (Table 1) were analyzed. The estimated initial densities of these areas (except for H56) were higher than 5000 specimens per hectare, at H56 initial density of trees was 1250 trees per hectare.

The areas were examined by the common method: the trees having a trunk diameter at the height of human chest ($D_{1.3}$) of more than 6 cm were enumerated; the schemes describing the positions of trees, stumps, undergrowth, and the contours of crown projections of individual trees were drawn. The diameters of trunks ($D_{1.3}$) were measured, and model trees were examined in more detail (core samples were taken from certain specimens). The data were processed by means of the program CONTR, which was designed for this purpose. The program allowed: (1) entering data into a computer (including contours processed by a digitizer) and storing the data in a database for easy retrieval; and (2) processing the data. The data processing routines included: (1) calculation of geometric parameters of the crown projection (the area S_{cr}, perimeter, and shape index); (2) evaluation of the average projection of the crown; (3) calculation of descriptive statistics; (4) calculation of correlation and regression; (5) evaluation of the pattern of distribution of trees over the area (Grage–Smith's method [1]); (6) construction of Voronoi's mosaic for multiple points on the surface [2, 3] and calculation of the surface areas S_{pl} for the mosaic polygons; and (7) calculation of parameters of adjacent specimens.

Certain results are listed in Tables 2–4.

The analysis of competition in planted forests is simpler because the process had a distinct starting point. Our analysis was based on the following ideas: (1) the variability of individual characteristics increases during competition; and (2) the initial (before the crown merger and the beginning of thinning) distributions of $D_{1.3}$ and S_{cr} are normal.

The sample areas were ranked in accordance with the course of competition by comparing: (1) parameters of functions of distributions of trunk diameters $D_{1.3}$ and the areas of crown projections S_{cr} (normality and asymmetry) and (2) coefficients of variability for $D_{1.3}$ and S_{cr} (Table 1). The rank orders of increasing coefficients of variability for $D_{1.3}$ and S_{cr} were similar. The beginning of the sample area rank (the stage of strong competition) was characterized by a significant normality of distributions (Table 2) and a negative correlation between the trunk diameters of neighboring trees (Table 4). The normality then disappeared (more rapidly for crown projections), and the coefficients k_D of correlation between $D_{1.3}$ of neighboring trees were no longer negative. The latter effect was due to thinning, after which the earlier noninteracting trees became neighbors. Table 2 shows that the distribution of $D_{1.3}$ displayed only a slight positive asymmetry, which was 1.5–5 times smaller than in distributions of crown projection areas. These data showed that the distribution of S_{cr} is a more sensitive index of thinning.

Institute of Soil Science and Photosynthesis, Russian Academy of Sciences, Pushchino, Moscow oblast, 142292 Russia

Institute of Forestry, Russian Academy of Sciences, Uspenskoe, Moscow oblast, Russia

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Table 1. Sample area description

Parameter	Sample area				
	H56	D22	AL5	R22	AL7
Age, years	E-90 P-90	E-90	E-90	E-100	E-70 P-70
Density, specimens per hectare	E-264 P-139 O-15	E-612 P-51 B-126	E-528	E-504 A-46 P-27 B-17	E-716 P-80
Stock, m^3 per hectare	E-309 P-219 O-5	E-352 P-63 B-27	E-330	E-340 P-45 A-21 B-6	E-355 P-65
Density in the grove	0.7 (0.9)	0.8	0.5 (0.8)	0.7 (0.9)	0.8

Note: F, fir; P, pine; B, birch; A, aspen; O, oak.

The correlation coefficient k_{cr} for neighboring trees was positive and increased at the beginning and end of the sample area rank. The cross-correlation coefficients of crown projection areas and the areas of the corresponding Voronoi's polygons ($S_{cr} - S_{pl}$) at the ends of the rank were also significantly different from zero. This finding suggests that the wood stock of the end of the rank (AL7) is at the beginning of a new wave of competition, provided that the tree growth energy is conserved and the wood stock is sufficiently uniform [4].

Thinning resulting from competition destroys the relationship between parameters of individual trees and the geometrical structure of the community: (1) correlation coefficients ($S_{cr} - S_{pl}$) for D22, AL5, and R22, as well as coefficients of correlation ($D_{1.3} - S_{pl}$) for D22 were not significantly different from zero (Table 3); the difference between ($S_{cr} - S_{pl}$) and ($D_{1.3} - S_{pl}$) could be explained by the inability of fir trees to fill a narrow and long polygon with its crown; (2) the coefficient k_D for D22 and k_{cr} for D22 and AL5 also showed no significant difference from zero. The correlation was restored by the end of the rank (the area AL7), whereas the correlation coefficients for ($S_{pl} - D_{1.3}$) and ($S_{cr} - S_{pl}$) became higher (the coefficients were greater than that for H56), probably because of the rounding of sample areas.

The correlation coefficients k_D (Table 4) were calculated for all accessible trees (including stumps and dead specimens). There was a two- to threefold increase in the absolute values of correlation coefficients k_D between $D_{1.3}$ for neighboring trees. When the Voronoi's mosaic was constructed only for living trees, the general scheme of the rank of correlation coefficients underwent no change with the exception of the areas D22 and AL5, which stood next to each other in the rank.

These results did not confirm the conclusion made in [5] that ecological interactions between trees in biogeocenosiss are more strongly reflected by the horizontal structure of the wood stock of the same age than in the relative positions of trees of diverse sizes. These data indicate that correlation between parameters of neighboring trees is consistently found in such woods at certain stages of competition. At other stages, competition destroys the relationship between parameters of individual trees and the spatial structure of the whole wood. Unfortunately, we cannot compare the lengths of these stages; however, the stage with such a relationship is probably much shorter. The data reported here can be discussed in the context of the concept of biological age [6]. In sample areas containing woods of the same age, the role of biological age is performed by the linear structure of competition, which is the major process. In this context, the questions of a measure for the length of this process and the dependence of this measure on the structure of the cenosis and specific traits of individual specimens is of special interest.

The methodological role of the initial regular geometric features of woods studied in this work is of considerable importance. Natural wood stocks (see [5] for the explanation of this term] whose specimens are all of the same age display an initial local inhomogeneity;

Table 2. Distribution parameters for $D_{1.3}$ and S_{cr}

Parameter	Sample area									
	H56		D22		AL5		R22		AL7	
	$D_{1.3}$	S_{cr}	$D_{1.3}$	S_{cr}	$D_{1.3}$	S_{cr}	$D_{1.3}$	S_{cr}	$D_{1.3}$	S_{cr}
Mean, X	32.8	19.9	23.2	14.2	25.0	9.4	26.4	16.4	21.2	9.3
Variance, S^2	38.4	60.0	42.7	42.7	58.7	26.1	74.9	74.9	73.4	51.0
Asymmetry	0.28	1.0	0.18	0.88	–0.14	0.98	0.79	1.5	1.1	2.9
Normality	+	+	+	–	–	–	–	–	–	–
n	240		267		163		468		204	

Note: Minus sign indicates that the hypothesis of normality was rejected $p < 0.05$.

Table 3. Cross-correlation coefficients

Correlated pairs	Sample area				
	H56	D22	AL5	R22	AL7
$(D_{1.3} - S_{cr})$	0.72*	0.66*	0.82*	0.76*	0.78*
$(S_{cr} - S_{pl})$	0.34	−0.061	−0.009	0.008	0.59*
$(S_{pl} - D_{1.3})$	0.19*	0.037	0.35*	0.38*	0.40*

Note: Munus sign indicates that the hypothesis of linearity was rejected, $p < 0.05$; asterisk indicates significant difference, $p < 0.05$.

Table 4. Correlation coefficients for diameters $D_{1.3}$ (k_D) and crown projection surface areas S_{cr} (k_{cr}) for adjacent trees in the mosaic

Parameter	Sample area				
	H56	D22	AL5	R22	AL7
Total number of pairs, n	924	832	369	1419	572
k_D	−0.098*	0.009	0.146**	0.090*	0.089*
k_{cr}	0.080**	0.042	0.016	0.086**	0.147*

Note: Difference from zero is significant at: * $p < 0.01$; ** $p < 0.02$.

this increases the spatial variability of local stages of competition and results in indistinct relationships between characteristics that describe the process.

These results show that woods displaying similar mean characteristics can be ranked in accordance with the course of competition. The data showed a strong correlation between parameters of neighboring trees at certain stages of competition. This correlation disappears upon the wood thinning at subsequent stages of competition but can be then restored. The coefficients of correlation between the crown projection areas and the areas of the corresponding Voronoi's polygons can be regarded as markers of the peak of the competition. In natural woods whose specimens are all of the same age, the "competition age" is the variable that changes in space. This explains the failure of attempts at establishing a significant correlation between parameters of trees with local characteristics of the spatial structure.

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REFERENCES

1. Zahl, S., *Biometrics*, 1977, vol. 33, no. 4, pp. 681–692.
2. Voronoi, G.F., *Collection of Works*, Kiev: Akad. Nauk USSR, 1952, vol. 2, pp. 239–368.
3. Galitskii, V.V. and Mironenko, E.V., *Mozaika Voronogo na ploskosti. Algoritm postroeniya* (Voronoi Mosaic on the Plane: Construction Algorithm), Pushchino, 1981.
4. Galitskii, V.V., *Dokl. Akad. Nauk SSSR*, 1979, vol. 246, no. 4, pp. 1013–1015.
5. Buzykin, A.I., Gavrikov, V.L., Sekretenko, O.G., and Khlebopros, R.G., *Analiz struktury drevesnykh tsenozov* (Structural Analysis of Wood Cenosiss), Novosibirsk: Nauka, 1985.
6. Hari, P., *Ann. Bot. Fennici*, 1972, vol. 9, no. 2, pp. 107–115.