The relationships between the gap structure, stand age, productivity, spatial distribution and competition of trees in pure Scots pine stands

JONAS SALADIS
Lithuanian Forest Research Institute,
Department of Forest Resources and Economics

Saladis J. 1999. The relationships between the gap structure, stand age, productivity, spatial distribution and competition of trees in pure Scots pine stands. *Baltic Forestry*. 1: 11-18.

In the article spatial structure and competition, its dynamics and investigated correlation between the stand age, productivity and gap structure are discussed. A total of 20 permanent sample plots of different age and productivity has been investigated. The pine stands were observed for 9-11 years. The stand volumes stop increasing at the age of 61-70 years. One of the causes of the current volume increment losses is an increase in the gap area. Trees in the investigated stands mostly are distributed regularly, in some stands the type close to random distribution prevails. It has been ascertained, that best related parameters are the current annual increment, the gaps area (in %), distance-dependent competition index and stand age. Models for approximation of the area of gaps and current annual increment have been constructed.

Keywords: Scots pine, gap structure, stand productivity, spatial distribution, competition

Introduction

Scots pine (*Pinus sylvestris L.*) is very important forest tree species in Lithuania. The stands of pine occupy the largest part of the forest area. The sensitivity of pine to environmental changes and management regime allows us to investigate important problems of forest productivity and stability. Pine stands in our conditions are quite stable but comparatively thin. Recent investigations have shown, that the loss of the current annual increment on fertile sites due to canopy gaps and their increase comprises from 5 to 25 % (Saladis 1996). Thus, estimation of canopy gap area allows us to solve the problems of productivity and stability, but the ascertainment of gaps area is quite complicated. It is necessary to create the methods of precise estimation and models allowing us to investigate gap structure more effectively. It requires further investigations to ascertain the causes and relationships of this phenomenon.

The purpose of this work is estimation of the relationships between different parameters of gap structure and stand age, productivity, spatial structure and productivity of trees.

Materials and methods

For investigation 20 mapped permanent sample plots in pure Scots pine were used. In 1983-1984 sixteen stands in the central, southern and south-eastern part of Lithuania were observed. The stands are located in typical Scots pine regions in the forest enterprises of Druskininkai, Dubrava, Jurbarkas, Kazlų Rūda, Valkininkai, Varėna, Veisiejai, Švenčionėliai. The stands before establishment of permanent sample plots were managed like all industrial forests. They were remeasured twice and the period of observation lasted for 9-11 years. Four pine stands belong to trials of formation experiment of productive and more stable coniferous stands. They were not thinned and the period of observation lasted for 3-5 years. The stands represent sites Nal and Nbl with height index H_{100} (predicted height at age of 100 years) from 20.1 to 30.9. The data of investigated stands represent most age classes.

During the first measurement the coordinates of the base (x, y), dbh, the condition of health for each tree with dbh>6.0 cm (live, damaged by wind, wild or dead), the height, the base of crown and radial increment over the last 5-10 years for model trees were measured. During the 2nd and 3rd measurement dbh, the condition of the health for each tree with dbh>6.0 cm, the height, base of crown for model trees were measured.

For all sample plots the mean dbh, the height, volumes of live and dead trees, site quality class, height index H_{100}, change in volume, the current annual increment and percent of its accumulated part have been calculated. Also the areas of gaps, their increment and the areas of small gaps („windows") have been ascertained. The parameters of spatial distribution of trees: the Hopkins aggregation index, the Morisita aggregation index, the percent of „zero plots" after Cox and competition indices, such as distance dependent indices *CI1, CI2* and distance independent BR have been calculated as well.

The data of the growing stock, current annual increment (Z_M), percent of accumulated increment ($100^* \Delta_M / Z_M$) and stocking level in observed stands are presented in Table 1. The growing stock of stands from the age of 50 years rises less intensively. It resulted from an intensive decrease in the current annual increment and accumulation of the volume increment. Stands younger than 60 years are stocked best. The stocking level of older stands as well as accumulation of the volume increment decrease. With increasing age from 51 to 80 years the stocking level decreases from 0.99 to 0.80. The accumulated volume increment diminishes from 73 % to 47 %.

Table 1. The dependence of stand parameters on the age in observed stands

Age, years	Height growing index H_{100}	Growing stock, m³/ha	Current annual increment m³/ha per year	Accumulated volume increment, %	Stocking level
1-10	26.6	6	1.3	88	0.14
11-20	26.0	40	6.2	100	0.71
31-40	28.0	217	11.8	63	0.99
41-50	25.0	223	9.4	65	0.95
51-60	24.1	265	9.1	73	0.99
61-70	25.0	295	7.1	67	0.88
71-80	25.6	303	6.6	47	0.80
81-90	27.1	328	6.2	68	0.74

Hopkins aggregation index I_H (Wenk G. et all, 1990) can be estimated by the following equation:

$$I_H = \frac{\overline{r^2}}{\overline{l^2}},$$

where r – the distance from the random point to the nearest tree i, l – the distance from tree i to the next nearest tree.

Morisita aggregation index I_δ (Василевич, 1969) well approximates the distribution processes by the following equation:

$$I_\delta = q\frac{\sum_{i=1}^{q} n_i(n_i-1)}{N(N-1)}$$

where q – number of plots; n_i – number of trees in a plot; N – number of trees in plots q.

The percent of „zero plots" can be established by dividing the area into squares, equal in area to the mean growing area of a tree. If a square contains no trees, it is called „zero plot". Under random distribution the percent of „zero plots" equals 36.8%. Under absolute regular distribution, the percent of „zero plots" equals 0, and under clump distribution constitutes about 100%. For practical use an index of aggregations is used. This index is estimated by the following equation

$$I_0 = 2.72 \times a,$$

where a – percent of „zero plots".

Under random distribution (Poisson process) of trees, I_H, I_δ and I_0 are equal to 1. Index less than 1 implies regular distribution of trees, while I_H, I_δ and I_0 more than 1 – clump distribution (cluster process).

Competition index of trees shows the use of potential possibilities of a tree (Pukkala, Kolström, 1987). We have chosen competition indices reflecting differences among neighbouring trees and distances between them to explore the relationships between the gap structure and competition of trees estimated by different methods.

$$CI1_j = \sum_{i=1}^{n} \alpha_i \quad \text{, when } i\#j$$

$$CI2 = \sum_{i=1}^{n} \frac{(d_i/d_j)}{D_{ij}} \quad \text{, when } i\#j$$

Competition indices *CI1* and *CI2* have been ascertained within distance *L*, which can be estimated by the following equation:

$$L=(5+10\ d_i)+(5+10\ d_j),$$

where L – the distance within which competition indices are ascertained, m; j – the central tree, for which competition index is estimated; i – neighbouring tree; α_i – angle, occupied by dbh of tree i in respect to tree j; d_i – dbh of tree i, dm; d_j – dbh of tree j, dm; D_{ij} – the distance between trees i and j, dm.

The coefficient of growth stress *BR* (Kuliešis, 1985) characterizes competition of trees according to the ratio of difference between the current radial increment of thickest and thinnest trees in the stand to the difference of the diameter of thickest and thinnest trees in the stand. To estimate this index, it is necessary to obtain data on stand diameters and the radial increment or diameter increment. *BR* can be estimated for permanent or temporary sample plots. In permanent sample plots the coefficient of growth stress *BR* is calculated according to the following equation:

$$BR = \frac{r_{ZD} \times \sigma_{ZD} \times \overline{D}}{\sigma_D \times \overline{Z}}$$

where BR – the coefficient of growth stress; r_{ZD} – the correlation coefficient between the diameter increment and diameter of trees in the stand; σ_D, σ_{ZD} – standard deviations of the diameter and diameter increment of trees in the stand; $\overline{D}$ – the geometrical mean of diameter of trees in the stand, $\overline{Z}$ – the diameter increment during the period between two measurements.

The coefficient of growth stress BR increases up to the phase of mid-aged stands, when it reaches its extreme values (up to 2.0-2.5). Later it decreases. Using of these competition indices allows us to ascertain the competition of trees and the relationships between the gap structure and competition of trees more exactly. The indices of spatial distribution and competition of trees has been calculated for the data of the last measurement in all permanent sample plots.

We used the original method (Saladis, 1998) for the establishment of gaps area. The scheme of the establishment of gaps is shown in Figure 1. In each sample plot we have calculated mean growing area F (Q/N). Then the area of the sample plot has been divided into small squares the area of which is equal to 1/4 F (side of square equals to $1/2\sqrt{F}$). For each square the coordinates of its center have been calculated. After calculating crown diameters (models constructed by Juodvalkis et al., 1985) it was found out which squares had been used by growing trees. These were the squares, the center of which was reached by one or more crown radius. As a result of joining the remaining squares compact plots with parameters of 2×2 squares or larger were set up. These areas were divided in 2 categories – gaps and small gaps („windows"). The area of „windows" was 4 – 7 squares (1-1.75 F), and that of the gaps – 8 or more squares (2 F or greater). This distribution was based on the results of our previous investigations (Saladis, 1996). An increase in gaps area was estimated using the data of the first and last measurements.

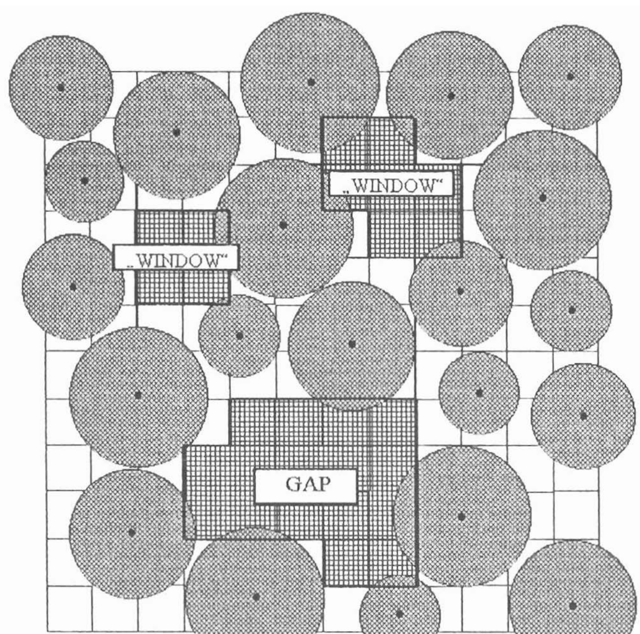

Figure 1. A scheme of ascertainment of gaps area

Results

Gap structure and its dynamics in pure pine stands. In studying gap structure, we have used such parameters of gap structure such as gap area (in %), an increase in gap area (in % per year), the mean area of a gap, the variation in gap area and the number of gaps per ha. The data are presented in Table 2, respectively. Gap area, the mean gap area, variation in gap area and the number of gaps were calculated at the start and finishing of observation period. An increase in gap area was estimated during the observation period.

Table 2. The dependence of gap parameters on the age in observed stands.

Age, years	Gaps area, %	Increase of gaps area, % per year	Mean area of gap	Variation in gap area	Number of gaps per ha
1-10	47.8	-10.0	17.1	108	224
11-20	31.6	-5.8	21.7	161	166
31-40	13.5	-0,2	34.9	51	43
41-50	18.4	0.5	54.2	79	42
51-60	18.7	0.5	42.6	62	52
61-70	25.8	0.1	74.9	67	35
71-80	30.8	0.1	90.0	62	35
81-90	36.3	0.0	115.4	61	31

A close correlation between the parameters of gap structure and stand age has been established. The gap area decreases up to the age of 31-40 years. In older stands the area of gaps increases. Extremely large gap area is in stands older than 80 years. The dynamics of gap area during the period of observation reflects it partly. The available data well reflect a significant decrease in gap area at the age of 20-30 years. A significant increase in gap area is at the age of 41-60 years. In the 60-80-year-old stands an increase in gap area comprises 0.1 % per year. The mean gap area increases with increasing age of stands. The most intensive decrease in the number of gaps is up to the age of 31-40 years. In older stands a decrease in the number of gaps is less intensive. The data on the variation in gap area has demonstrated, that in younger stands the variation of gap area is greater than in older stands (Table 2). The highest variation coefficient is in the youngest stands. At the age of 1-20 years the variation coefficient is 108 – 161 %. It decreases up to the age of 30 years (51 %). In older stands the variation in the mean gap area comprises 51-79 %. While analysing the variation in the stands with extremely large gap area it has been found that they have also very high variation in the mean gap area. The greatest number of gaps is in the 1-20-year-old stands. In these stands 166 – 224 gaps per hectare have been found. In the 31-60-year-old stands 42-52 gaps per hectare have been found and in the oldest stands – 31-35 gaps per hectare.

The indices of spatial distribution and competition of trees. To estimate spatial distribution we used 3 indices: Hopkins, Morisita and „zero plots" after Cox aggregation indices. The dependence of indices of spatial distribution on age and H_{100} and their variation coefficients are presented in Table 3. In accordance with the height index H_{100} the stands were distributed into 3 groups.

Table 3. Indices of spatial distribution and competition of trees in observed stands

Parameter		Distribution indices			Competition indices		
		Hopkins aggregation index I_H	Morisita aggregation index I_δ	Percent of „zero plots" I_O	*CI1*	*CI2*	*BR*
Age, years	1-10	0.65	1.10	1.12	4.3	4.12	1,46
	10-20	0.38	0.88	0.98	15.6	6.94	1.21
	31-40	0.66	0.83	0.93	27.4	4.10	2.01
	41-50	0.71	0.90	0.96	27.2	3.60	2.12
	51-60	0.63	0.83	0.92	27.5	3.19	2.00
	61-70	0.70	0.86	0.93	25.4	2.22	2.64
	71-80	0.66	0.84	0.95	24.0	1.83	2.34
	81-90	0.69	0.87	0.92	28.6	1.52	1.51
H_{100}, m	25.0 and less	0.69	0.89	0.95	27.1	2.91	2.28
	25.1-30.0	0.57	0.90	0.97	19.0	4.34	1.55
	30.1 and greater	0.68	0.84	0.90	27.0	1.78	2.17
TOTAL		0.64	0.88	0,95	23.8	3.26	1.96

In accordance with index I_H the trees in all stands are distributed regularly. Most regularly are distributed trees in the 11-20-year-old stands (I_H=0.38). Index I_δ and I_O contradict this. It indicates that aggregation index of Hopkins is insignificant. These indices in the 1-20-year-old stands show random and slightly clustered distribution of trees. The youngest stands are mostly inhomogenous according to all indices of spatial distribution. In older stands trees are distributed more regularly according to all indices and have more homogenous indices. In accordance with both aggregation indices of Morisita and "zero plots" trees in the 31-40-year-old stands are distributed most regularly. The differences of the aggregation indices in groups of stands having different H_{100} are negligible.

In accordance with competition indices *CI1* and *BR* the competition of trees increases up to the age of 31-50 years. In older stands its increase is insignificant. Competition index *CI2* is greatest in the youngest stands and in older stands decreases. It shows that competition index *CI2* is influenced by stand density and can not be used for comparison of competition in stands with different age.

In accordance with indices *CI1* and *BR* the lowest competition of trees was on sites of medium productivity (H_{100}=25.1-30.0 m). However, this difference can be the influence of different stand age. In more and less productive sites the difference of competition indices is insignificant.

The relation between the parameters of productivity of stands, spatial distribution and competition of trees. The coefficients of the correlation for all parameters of stand productivity, gap structure between themselves and with indices of spatial distribution and competition of trees were calculated and examined at three significance levels ($p<0.10$, $p<0.05$, $p<0.01$). The results of correlation analysis are given in Table 4.

The current annual increment is well related to the gaps area, an increase in gap area and the stocking level, moderately related to the aggregation index of Morisita. The area of gaps, apart from good relation with the current annual increment, is well related with the stocking level, aggregation index I_δ, moderately related with the aggregation index of „zero plots", competition index *CI1*. An increase in gaps area is well related with stand age, the current annual increment, competition index *CI1* and moderately related with the accumulation of the volume increment in stand, the aggregation indices of Morisita and „zero plots" and competition index *BR*. Thus, the best correlating parameters of stand productivity, gap structure, spatial distribution and competition of trees are the age of stand, the current volume increment, gap area and their increase, stocking level, aggregation index of Morisita, „zero plots" and competition indices *CI1* and *BR*.

On the basis of stand age and the parameters of stand productivity (the current annual increment and site index H_{100}) 2 simple models were created. The first model describes the dependence of gaps area on stand age and stocking level.

$$GA = -1274.81 + \exp(7.18135 + 0.0001825 \times A - 0.02576 \times S)$$

(R=0.9061)

Table 4. Correlations of parameters and indices of stand productivity, gap structure, spatial distribution and competition of trees

Parameter	Correlations					
	Gaps area	Increment of gaps area	Stand age	Height index H_{100}	Current annual increment	Accumulated volume increment
Gaps area	**1.00**					
Increment of gaps area	-0.21	**1.00**				
Age of the stand	0.12	-0.81***	**1.00**			
Height index H_{100}	0.12	-0.09	-0.14	**1.00**		
Current annual increment *CAI*	-0.77***	0.69***	-0.30	0.11	**1.00**	
Accumulated volume increment	-0.21	-0.68**	0.61***	-0.34	-0.09	**1.00**
Stocking level	-0.87***	-0.47**	-0.56**	-0.34	0.85***	0.75***
Morisita's aggregation index I_δ	0.58**	-0.47**	-0.40*	-0.17	-0.53**	0.31
Aggregation index of "zero plots" I_O	0.56**	-0.62**	0.46**	-0.19	-0.62**	0.42*
Competition index *CI1*	-0.45**	-0.86***	-0.68**	-0.13	0.82***	-0.37
Competition index *BR*	-0.22	0.55**	-0.44*	-0.04	0.32	-0.59**

* – correlations are significant at $p < 0.10$
** – correlations are significant at $p < 0.05$
*** – correlations are significant at $p < 0.01$

where *GA* – gap area, %; *A* – stand age, years; *S* – stocking level.

The equation demonstrates that gaps area increases with increasing age and stable stocking level of the stand (Figure 2). This phenomenon can be explained by increasing demand of pine for light with increasing age. An increase in gap area can be observed in stands with high stocking level as well as in less stocked stands. By using the data of observed stands gap area is approximated with the mean deviation ±9 %. In most stands the deviation does not exceed ±12 %. The greatest deviation of gap area approximated by the model was in mid-aged stands with an extremely large area of gaps.

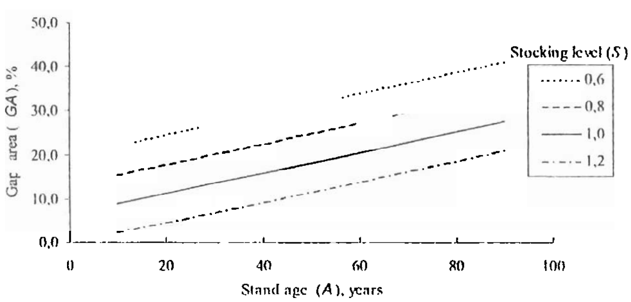

Figure 2. The dependence of gaps area on the stocking level in the stands of different age.

The second model allows us to estimate the current annual increment and has the following expression:

$$CAI = 4{,}451 - 0{,}1035 \times GA + \frac{52{,}246}{GA^2} + 5920{,}9 \times A^{-1{,}464} \times \exp\left(\frac{-51{,}02}{A}\right)$$

(R=0,9746)

where *CAI* – the current volume increment, m^3/ha per year.

This model according to the data of observed stands well approximates the current annual increment (Figure 3). In accordance with the model the current annual increment increases with decreasing gaps area. The current annual increment increases up to the age of 20-30 years. By using the data of observed stands the current annual increment is approximated with the mean deviation ±16 %. In most stands the deviations do not exceed ±20 %.

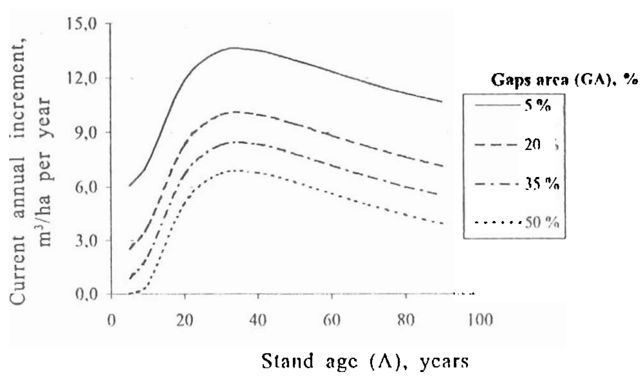

Figure 3. The depedence of current annual increment on stand age and gaps area

Discussion

The stands of Scots pine occupy in Lithuania the greatest part of the forest area – 37.2 % (Lietuvos miškų statistika, 1998). In the southeastern region of Lithuania the part of Scots pine stands is larger – in some forest enterprises it comprises up to 80 %. The stands of Scots pine in Lithuania are very different from the point of view of forest productivity (Kuliešis A., 1997). The index of height H_{100} is from 15 to 36 m. The current volume increment comprises from 3.4 to 6.7 m³/ha per year and more. Index H_{100} of pine stands tends to increase from west to east.

Scots pine is found to be the best investigated tree species in Lithuania, however, the problems in the management of pine stands still remain. In accordance with the data obtained by Lithuanian forest statistics (1998) 4,2 % of the area of Scots pine stands (29.1 thou. hectare) has the stocking level equal to 1.0, 9.2 % of the area has the stocking level equal to 0.9. Such stands are unstable and mostly sensitive to external factors. (Temos 2.3 ..., 1992). Thus, a large part of pine stands is in a hazardous state and can be damaged. Of sixteen pine stands studied the stocking level of 9 stands is 0.9 or more. They represent the most sensitive part of pine stands. However, it is possible to investigate and make conclusions about the correlation between the parameters of stand productivity and structure and their significance in pine stands with medium and higher stocking level.

In accordance with the data obtained by Kuliešis A. (1989) the volumes of Scots pine stands stop increasing in the VIII age class. One of the reasons for this phenomenon is too dense young pine stands. The ceasing increment of volume is observed in our stands at the age of 50-70 years (Table 1). It determines a fast decrease in the current annual increment and accumulation of the volume increment. The stocking level in stands older than 40 years decreases. In the 81-90 year-old stands the accumulation of the volume increment is 25 % less than in the 31-40 year-old stands. The stocking level in stands older than 40 years decreases. It can be explained partially by the data of gap structure.

The gap structure of stand has not been investigated in relation to stand age and productivity, spatial distribution and competition of trees. The results of our investigations have shown significant dependence of gap structure on stand age. The smallest gaps area is in the 1-20-year-old stands. In the 1-10-year-old stands a decrease in gaps area was 10 % per year, while in the 31-40-year-old stands 0,2 %. The gaps area starts increasing at the age of 41-50 years (Table 2). However, an increase in gaps area (in % per year) cannot explain the enlargement of gaps area in stands older than 40 years. This phenomenon can be determined by stand management before the establishment of sample plots.

In young stands many small gaps can be found. The area of these gaps varies on very large scale. After closing of stand canopy the differences in gap area diminish. At the age of 41-50 years the mean gap area starts increasing while the number of gaps and variation in gap area are quite stable. In the stands the area of gaps increases when trees die at the edge of the area. It determines a decrease in the accumulation of the volume increment and in the stocking level in the stands. The area of gaps and their increment allow us to explain some phenomenon of this kind. It has been found that the losses of the current annual increment caused by the area of gaps and their increase in pine stands comprise 12 % or 1.1 m³/ha per year. In some stands the losses of the current volume increment reach 23-33 % or 2.4-2.8 m³/ha (Saladis, 1996). However, estimation of the gap area by our method is complicated and influenced by the edge effect. Thus, it is possible only in large sample plots.

In forestry a great number of indices of spatial distribution (aggregation) and competition is used. Aggregation indices can be divided into 2 large groups. Some indices are based on distances between trees. Other indices are based on distribution of trees in small plots after dividing the whole area. The distance-indices are influenced by the edge effect and are not valid when in stands there are large gaps. The Hopkins aggregation index is least sensitive to these effects. The indices based on distribution of trees in small plots are easier estimated and less influenced by negative effects (Wenk G. et all, 1990). In accordance with the data obtained by Kavoliūnienė D. (1985) trees in young stands up to the age of 30 years have clustered distribution. The random distribution of trees was estimated in the 35-40-year-old stands. The oldest stands have a regular distribution of trees. The type of distribution is dependent on the site quality. In less productive stands during rotation trees are distributed in accordance with the cluster type. Our data reflect these relationships too. The Hopkins aggregation index in the stands with cluster distribution type was not valid. The other 2 indices are based on distribution of trees in small plots. They both showed the same distribution type in all stands observed.

To investigate the correlation between the parameters of productivity and gap structure of stands, we have chosen possibly large number of different indices of spatial distribution and competition. They demonstrate, that in most investigated stands trees are distributed regularly, in the youngest stands – close to random distribution (Table 3). The indices of competition have different trends. With increasing H_{100}, competition index *BR* augments and competition index *CI2* decrease. Our investigation has shown that index *CI2* is mostly sensitive to density of stands and can not be used for the comparison of competition in stands of different age.

The output of the correlation analysis of the parameters of stand productivity, gap structure, indices of spatial distribution and competition of trees has demonstrated, that the following parameters are related best: stand age, the current volume increment, the stocking level, the gap area and their increase. Both models based on these parameters allowed us to approximate the gap area and current annual increment rather accurately. The models have quite great deviation in younger stands with small or extremely large gaps area. The results obtained have demonstrated the possibility to create accurate models, allowing accurate approximation of gaps area. It permits us to apply these models in small mapped sample plots (for example sample plots of the Lithuanian National Forest Inventory) and investigate the dynamics of gap structure and the influence of gaps on the yield of stands.

Conclusions

1. The parameters of gap structure are largely dependent on stand age. The gap area decreases up to 31-40 years. Later it increases. With increasing age of the stands the mean gap area increases while the number of gaps and variation in the area of gaps decrease.

2. The trees in stands aged up to 10 years are distributed according to the clustered distribution type. In older stands trees are distributed regularly. The competition of trees increases up to the age of 31-50 years. The changes in the competition in older stands are insignificant.

3. Best related parameters of stand productivity, gap structure and indices of spatial distribution and competition of trees are stand age, the current volume increment, the stocking level, the gap area and their decrease, aggregation indices of Morisita, „zero plots", competition indices *CI1* and *BR*. This relation enables us to create quite accurate models for the estimation of gap area and the current volume increment.

References

Juknys R. 1974. Medžių išsidėstymo tyrimai pušynuose [Investigations of the distribution of trees in Scots pine stands]. LŽŪA mokslo darbai, T. XXIV. 5(74) P. 18-27.

Kuliešis A. 1989. Medynų našumas ir jo panaudojimas [Productivity of forest stands and their use]. Vilnius. 141 p. (in Lithuanian)

Kuliešis A. 1997. Lietuvos miškų rajonavimas pagal medynų našumą [The regionalization of forests on productivity of forest stands]. Lietuvos mokslas. Lietuvos miškininkystė /raida ir perspektyvos/. T. V. 13-14 knyga. P. 45-53. (in Lithuanian)

Lietuvos miškų stattistika. 1998 m. sausio 1 d. valstybinė apskaita [Lithuanian forest statistics 1998 01 01]. Spaudai paruošė A. Brukas, A. Kuliešis, A. Rutkauskas. Kaunas – 1998. 71 p.

Pukkala T. 1988. Competition indices and prediction of radial growth in Scots pine. Silva Fennica 21(1). P. 55-67

Saladis J. 1996. Miško aikščių formavimasis, jų dinamika bei poveikis pušynų našumui [Formation of the forest gaps, their dynamics and influence on yield in pine (*Pinus sylvestris* L.) stands]. Miškininkystė 2(38) 1996, p. 154-164. (in Lithuanian)

Temos 2.3 "Sukurti medyno formavimo ekologinius pagrindus, užtikrinančius aukšto produktyvumo ir atsparių miškų išauginimą". 1992 metų ataskaita [Report 1992. „Investigation of the ecological basics of the stand formation allowing to grow productive and stable forests"]. Temos vadovai akad., hab. dr. L. Kairiūkštis, prof., hab. dr. A. Juodvalkis. Kaunas-Girionys, 1992 (in Lithuanian).

Wenk G., Antanaitis V., Šmelko Š. 1990. Waldertragslehre („Science of forest yield"). Berlin : Dt. Landwirtschaftsverlag. 448 S. (in German)

Василевич В. И. 1969. Статистические методы в геоботанике [Statistical mothods in geobotanics]. Издательство "Наука". С. 232. (In Russian)

Каволюнене Д. 1985. Типы казмещения деревьев на свете закономерностей роста древостоев [Types of distribution of trees in relation to stands yield regularities]. В кн. "Закономерности роста и производительности древостоев". Доклады научной конференции, 16-17 апреля 1985 г. / Каунас, 1985. 283-286 с. (in Russian)

Received 27 October 1997

СВЯЗЬ ПАРАМЕТРОВ СТРУКТУРЫ ПРОСВЕТОВ С ПРОДУКТИВНОСТЬЮ ДРЕВОСТОЕВ, ПРОСТРАНСТВЕННОЙ СТРУКТУРОЙ И КОНКУРЕНЦИЕЙ ДЕРЕВЬЕВ В ЧИСТЫХ СОСНЯКАХ

Й. Саладис

Резюме

В статье рассмотрены параметры и динамика пространственной структуры и конкуренции деревьев, показана связь этих параметров с возрастом, продуктивностью и структурой просветов в чистых одновозрасных сосняках. Исследованы 20 древостоев разного возраста и продуктивности. Установлена стабилизация запаса исследуемых древостоев в возрасте 61-70 лет. Одной из причин этой стабилизации является просветы и их расширение в древостоях. В большинстве исследуемых древостоев деревья расположены регулярно, в некоторых - с уклоном к случайному и груповому распределению. Установлено наличие кореляционных связей между текущим годовым приростом, полнотой, площадью просветов (в %) и ее изменением, индексами агрегации Мориситы, "нулевых площадей", индексами конкуренции *CII* и возрастом древостоя. На основе этих параметров построены 2 регресионные уравнения, с помощью которых можно установить площадь просветов и текущий годовой прирост.

Ключевые слова: сосна обыкновенная, структура просветов, продуктивность древостоев, конкуренция деревьев, кореляция параметров.