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HEIGHT STRUCTURE OF SCOTS PINE STANDS

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Abstract

The present study has been carried out to reveal the structure according to height of relatively even-aged - mature and middle-aged Scots pine dendrocoenoses in Rila and the Rhodopes Mountains and Sakar Mountain. A total of 111 sample plots have been established, 68 of these being in mature, natural Scots pine forests and 43 in young and middle-aged ones. Study has been aimed at analysing the structure according to height of natural Scots pine dendrocoenoses with a view to model their volume and their assortment structure. The height curves for both age groups of stands have been investigated. Yurdan Douhovnikov's method of natural indicators (MNIs) has been applied. Three groups of curves have been found out according to their levels of declivity, namely: slightly inclined curves, characteristic of the stands of zero natural indicator (ZNI) $SH_0 \geq 1.1$, semi-steep curves with $0.86 \leq SH_0 \leq 1.09$, and steep curves with $SH_0 \leq 0.85$. The distribution according to types of declivity has been investigated in two scenarios – separately and as a whole. This investigation has resulted in finding distributions of close values in both scenarios for the particular age groups, especially the general distribution. That gives reasons for investigating the stands as a whole in terms of their height structure through the method of natural indicators regardless of age. It was found that the average relative curves of the heights (or average curves of normal numbers) surveyed dendrocoenoses of Scots pine and United average curve of the relative heights of Turin are too close on his course. Since an average curve of Turin has been established for all species, this proximity proves the possibility of establishing common average diluted curves of the heights of Scots pine along with other tree species.

Key words: construction height, declivity of curves, natural indicators, Scots pine dendrocoenoses.

Introduction

It is important to permanently perfect the main standards and references pertaining to forests, as well as the models and tables of assessing the timber volume and the respective assortments. This is why increasing and improving the knowledge of the regularities in the growth and structures of forest dendrocoenoses (stands) remains an important scientific task.

Scots pine stands occupy a comparatively large area of the forests in Bulgaria. They comprise 51.7 % of the coniferous forests and are among the most highly productive lasting natural stands. These forests are important both for harvesting timber and for recreation, health care and amenity because they thrive under the conditions of mountains and hills. Scots pine laterally products, such as resin and lightwood, are valuable raw materials for colophony, turpentine and other products necessary for a number of industrial branches.

A number of authors have carried out studies of the structures of forest stands (Tyurin 1938; Tretyakov 1927, 1952; Sirakov 1947; Nedyalkov 1964, 1967; Dimitrov 1978, 2003; Mihov 1991; Mihov et al. 1993; Mihov 2005; Tonchev 2007). The most important inferences the above and other authors have made from their studies of stand structure according to height are as follows:

Tretyakov (1927) established that forest structure always has a constant nature, regardless of the relative stocking, age, tree species and growth conditions, even though these might pertain as to normal stands so to complex mixed ones. Thus he formulated the Law about the Unity of Stand Structure.

Tyurin (1938) found out that the height curves for homogenous, pure, even-aged growing stocks resembled one another in their forms and were not influenced by tree species and site conditions; only age and economic activity were found to have some influence. This gave him the reason for calculating an average general curve of relative heights for all tree species.

Dimitrov (2003) has pointed out that the relative heights, alias reduction numbers, in Tyurin's general curve of relative heights need to be specified.

Mihov (2005) shows the necessity of equalising the height curves by means of a parabola equation while using a polynomial function of some degree, or a logarithmic function. This equalisation has successfully been applied into the present study.

Tonchev (2007) comparing the average curve of relative heights for coppice Common beech growing stocks with Tyurin's average general curve has found differences indicative for a specificity proceeding from the tree species and the origin of dendrocoenoses.

We have carried out research concerning the structure in height of natural beech dendrocenosis (Petrin et al. 2014). With the usage of natural points method the steepness of the heights' curves was found out that the dendrocenosis built height does not depend on age and it is possible to create common curves of heights for more than one tree species.

The studies of the above and other authors have been used as a methodical background for our studies.

Aim of Study

The aim of study is to analyze the height structure of the natural Scots pine dendrocoenoses depending on their age. To carry out a comparison between the mean curves of the normal numbers concerning the height structure of Scots pine which occur, the mean curves of the normal numbers with the Unified Mean Curve were found for all tree species of Tyurin (1938).

Objects and Methods

Objects

The present investigation pertains to natural Scots pine stands in Rila Mountains (the regions of Samokov, Belovo and Yundola), the Rhodopes Mountains (the regions of Satovcha, Devin, Velingrad and Ardino) and Sakar Mountain (the region of Svilengrad). A total of 111 sample plots (SP) have been laid out, 68 of these being in mature and 43 in young or middle-aged natural Scots pine forests.

Methods

The main method assumed for this investigation is the one that uses natural indicators – Method of natural indicators (MNIs), invented by Yurdan Douhovnikov (1966). It enables to judge about the curve's form by only one number – the zero natural indicator (SH_0) of the structure according to height. For each sample plot, the natural levels of thickness (NLT) have been calculated after Tyurin (1938) by dividing the absolute levels of thickness by the average diameter and are received relatively not round degrees of thickness or relative diameters for example: 0.56; 0.67; 0.76; … 1.43. The curves of the heights are further equalised graphically and for round relative degrees of thickness, called Natural degrees of thickness, and are registered the absolute heights by choosing the real interval of research of the curve – in our research it is from 0.6 to 1.4.

The absolute values of the heights are converted into relative heights through the division by height of natural degree of thickness 1.4 which is adopted for final right. The curves of the relative heights in this type are called, in the method used, normal numbers or quality points. From the curves of the normal numbers is calculated the mean curve of the normal numbers (qx_{av}) for separate accumulations of curves depending on the age. Further each and every curve of the normal numbers (qx_i) is divided into the mean (qx_{av}) and the natural numbers straight lines are obtained $y = a \cdot x + b$. Their coefficients are calculated by the methods of the smallest squares through composition and solution of a system of two equations with two unknown values and those coefficients are namely Natural points the angle *a* and the zero *b*. Between both coefficients from their side there exists a direct connection which could be found out eventually. But for the aims of our study is used only the zero natural point – the coefficient *b* which is written as $SH_{0,n}$, where *S* is build (structure), *H* is height to point zero (0) and natural (n).

We have distributed the zero natural indicators (ZNIs) of the structure according to height (SH_0) on the basis of their values into three groups, namely: $SH_0 \leq 0.85$, $0.86 \leq SH_0 \leq 1.09$, and $SH_0 \geq 1.1$. Then, the influence of age upon the distribution according to types of declivity of the investigated height curves has been studied. The investigated Scots pine stands have been distributed according to types of declivity on the basis of the zero natural indicators values. This has been done separately for the mature, on the one hand, and the middle-aged or young dendrocoenoses, on the other, as well as totally, when they have all been considered as an aggregate. For this purpose, we obtained the average curves of the quality indicators (qx_{av}) separately – first, for the mature, and, second, for the young or middle-aged stands. In addition, an average general curve was calculated, regardless of age.

Results and Discussion

Types of structure according to height depending on the slope (declivity) of height curves

Height-curves' forms have been investigated by means of the characteristic called curve's declivity towards the abscissa. The less acute the angle of the slope is, the steeper the curve is, and here we have introduced the notion declivity of curve (curve's declivity).

Curves’ declivity reveals the difference in the heights for two or more levels of thickness, and the steeper these curves are, the bigger this difference is. The steeper curve suggests higher increment in height and vice versa – lower increments correspond with less inclined curves.

The steeper curve talks about a higher mean height increase on average height between two degrees of thickness in the frame of dendrocoenoses or height increase and the opposite the more slant curves less increase. Therefore, in equal conditions in the bigger supply of dendrocoenoses in this case moves towards the thicker and the taller trees and more good quality sorts. Such dendrocoenoses give better supplies and a better quality sorts.

Table 1. Values of zero natural indicators (SH_0) of the structure according to height for Scots pine stands according to sample plots, depending on the average curve (separate or general) of the quality indicators, and according to age groups.

No	Separate	Ge-neral	No	Separate	General	No	Separate	General	No	Separate	General	No	Separate	General	No	Separate	General
Mature stands																	
1	1.26	1.31	13	0.87	0.91	25	1.38	1.44	37	0.84	0.88	49	1.09	1.14	61	1.24	1.29
2	1.31	1.37	14	0.98	1.03	26	1.63	1.69	38	0.80	0.84	50	1.08	1.13	62	1.07	1.12
3	0.97	1.02	15	2.15	2.22	27	1.15	1.20	39	0.79	0.83	51	1.01	1.05	63	0.82	0.87
4	1.24	1.29	16	1.09	1.14	28	0.79	0.83	40	0.84	0.88	52	0.89	0.93	64	1.00	1.05
5	1.11	1.16	17	0.95	1.00	29	0.8	0.84	41	0.78	0.83	53	0.96	1.01	65	0.92	0.96
6	0.99	1.03	18	1.08	1.13	30	0.71	0.75	42	0.78	0.82	54	1.08	1.13	66	0.79	0.83
7	1.10	1.15	19	1.24	1.29	31	0.80	0.84	43	0.84	0.88	55	1.11	1.16	67	0.85	0.89
8	1.10	1.15	20	1.24	1.29	32	0.81	0.85	44	0.82	0.86	56	0.84	0.88	68	0.90	0.95
9	1.02	1.06	21	1.18	1.23	33	0.82	0.86	45	0.88	0.93	57	0.83	0.88			
10	1.31	1.36	22	0.95	0.99	34	0.86	0.90	46	0.78	0.82	58	0.86	0.90			
11	0.88	0.93	23	1.39	1.44	35	0.81	0.85	47	0.92	0.97	59	0.94	0.99			
12	1.14	1.19	24	0.88	0.92	36	0.82	0.86	48	1.03	1.07	60	0.88	0.92			
Middle-aged and young stands																	
1	1.01	0.96	9	0.72	0.68	17	0.75	0.71	25	1.21	1.15	33	0.9	0.85	41	0.93	0.88
2	2.05	1.98	10	1.02	0.97	18	0.41	0.37	26	0.89	0.84	34	0.86	0.81	42	1.12	1.07
3	0.97	0.92	11	0.72	0.68	19	0.48	0.45	27	0.74	0.7	35	0.93	0.88	43	0.7	0.66
4	1.52	1.46	12	1.07	1.02	20	0.56	0.52	28	1.12	1.07	36	0.97	0.93			
5	1.16	1.11	13	0.79	0.75	21	0.47	0.44	29	2.26	2.18	37	0.86	0.82			
6	1.13	1.08	14	1.18	1.12	22	0.51	0.47	30	1.11	1.06	38	0.81	0.77			
7	1.02	0.98	15	1.48	1.42	23	1.8	1.73	31	1.11	1.05	39	0.94	0.89			
8	0.95	90	16	0.87	0.83	24	1	0.96	32	0.95	0.91	40	0.96	0.91			

The above method has enabled us to find for the sample plots investigated the zero natural indicators used for characterising the height-structure curves (or height curves) of natural Scots pine dendrocoenoses, and these have been presented in Table 1.

As it is seen from Table 1, the values of zero natural indicators vary for the whole aggregate, regardless of age groups, within the range from 0.37 to 2.26. It was found the precise correspondence of the natural indicators' values with the declivities of height curves, namely: low natural indicators correspond with steep curves, and high indicators – with curves. According to the differentiated ranges, there are three types of height curves – steep, semi-steep and slightly inclined. These three types of curves and their corresponding values of zero natural indicators (SH_0) can be seen in Fig. 1.

Fig. 1 reveals that low values of SH_0 correspond with a steep curve, the high ones – with a slightly inclined one, and the natural indicators, whose values are about 1, with a semi-steep curve. The steeper the curve is, the higher the difference between two levels of thickness, or height increment between two degrees of thickness is. Therefore, stands of steeper height-structure curves are supposed to have higher volumes of timber and better assortment structures. This inference coincides with the better interpretation of the thickness-structure curves, as these curves correspond with the low values of zero natural indicators of thickness structure (SN_0), which have a right-hand-side asymmetry and are also supposed to have higher volumes (Petrin et al. 2013).

Based on the above-differentiated ranges for different types of height curves, according to their declivity, their distributions have been obtained with both scenarios of investigation – separately and generally, and these are presented in Table 1.

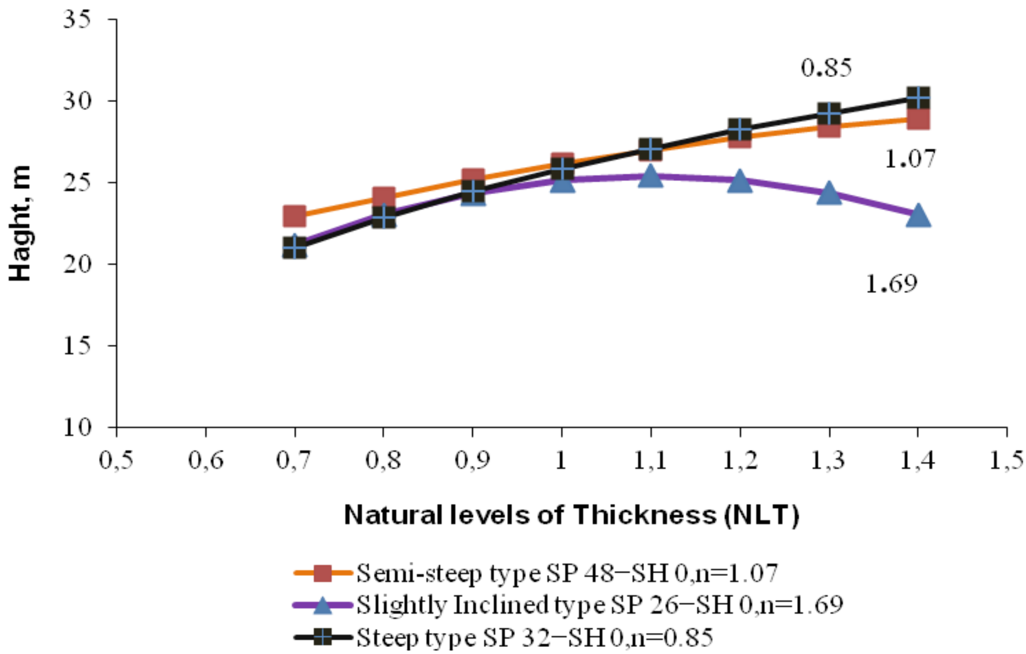

Fig. 1. Three types of height-structure curves depending on natural indicators SH_0.

Table 2. Distribution of sample plots according to height curves declivity for different aggregates with both scenarios of investigation.

Curves' declivity	Investigating separately		Total sample plots, number	Share of sample plots, %	Investigating generally		Total sample plots, number	Share of sample plots, %
	Mature, number	Middle-aged or young, number			Mature, number	Middle-aged or young, number		
Slightly inclined	19	13	32	28.8	23	8	31	27.9
Semi-steep	27	18	45	40.5	33	18	51	45.9
Steep	22	12	34	30.6	12	17	29	26.1
Total	68	43	111	100	68	43	111	100

In Table 2 one can see that for both age groups (mature, middle-aged or young), with the two kinds of investigation – in separate aggregates and in only one – almost one and the same distribution of the sample plots according to type of declivity is observed. In both scenarios semi-steep curves prevail. And after that, steep curves prevail with mature, separately investigated stands, and slightly inclined curves prevail with the stands considered as a whole. With young or middle-aged stands, when considered as a whole, steep curves prevail. The smaller number of sample plots under mature dendrocoenoses with steep curves, when they are investigated as a whole, together with the young or middle-aged ones, suggests a certain reduction of their timber volumes, which is explicable. It is just the opposite with the young or middle-aged ones – the prevalence of steep sample plots, when the stands are considered as a whole, reveals a certain increase in the volumes with a possible general model. These differences compensate one another with the distribution as a whole in both cases, and it is characterised by apparent prevalence of the semi-steep type and with the even distribution of steep and semi-steep curves. If we consider the general distribution of all plots, we see that 40.5 % of the stands are on semi-steep plots, when they are considered separately, and 45.9 % when they are considered as a whole. These results reveal that it is possible to model, generally and averagely, the structure according to height for all aggregates of height curves regardless of declivity type and age, which simplifies modelling, the simplification being an advantage.

Comparing the average relative-height curves (the curves of quality indicators) for natural Scots pine stands with Tyurin's general curve of heights

In Table 3, are presented the comparisons of our average relative-height curves (quality indicators' curves) and Tyurin's average general relative-height curve pertaining to all tree species.

Table 3. Average curves of quality indicators as compared with Tyurin's average general curve of quality indicators.

Curves's belonging	Natural levels of thickness									Indicators for accuracy			
	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	Correlation coefficient	Standard deviation	Variation coefficient	Error in aritmetic means, m
Mature stands	0.75	0.81	0.85	0.89	0.93	0.95	0.97	0.99	1	0.995	0.01	1.36	0.004
Middle-aged stands	0.7	0.76	0.82	0.86	0.9	0.94	0.96	0.98	1	0.998	0.03	3.69	0.010
Average general curve of quality indicators	0.73	0.79	0.84	0.88	0.92	0.95	0.97	0.99	1	0.996	0.02	1.96	0.005
Tyurin's average curve	0.77	0.81	0.85	0.88	0.91	0.94	0.96	0.98	1	-	-	-	-

As it is seen from Table 3, our average curves are very close to Tyurin's one (1938), designed for all species, which also show calculated statistical indicators suggesting a greater correlation between the curves. The magnitude of the correlation indicator is very close to 1 besides, apparent is the great closeness of the particular values of the quality indicators of the particular natural levels of thickness, as and in the Fig. 2.

This inference is very important for providing the possibility of assuming an average general curve of relative heights for more than one tree species. We have concluded this same about Common beech during an analogous study of natural beech and natural Scots pine stands (Petrin 2014, Petrin et al. 2014). Height-order curves are known to provide the basis of timber-volume measurement and assortment-volume distribution. Therefore, it is possible

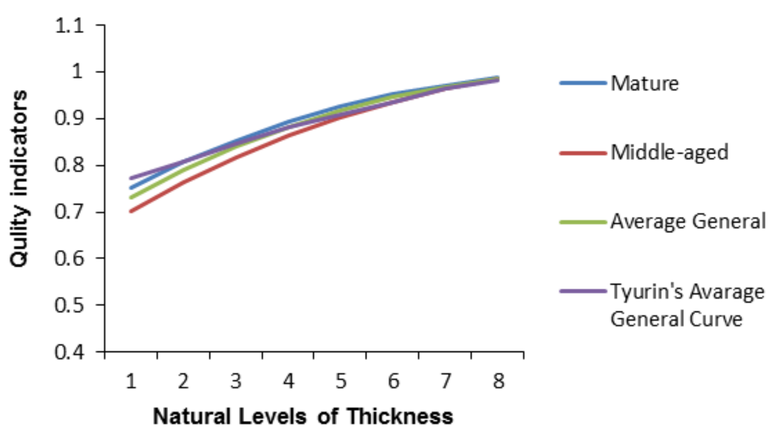

Fig. 2. Average curves of quality indicators.

to develop general models of the structure according to height (general height-order curves) for natural Scots pine and Common beech dendrocoenoses.

Conclusion

The main inferences from the investigation are the following:

Three types of height-structure curves have been found while investigating the young, middle-aged and mature natural Scots pine stands: steep curves, semi-steep curves and slightly inclined curves. Steep curves are related to low values of zero natural indicators – $SN_0 \leq 0.85$, semi-steep ones – to ZNIs' average values, within the range $0.86 \leq SH_0 \leq 1.09$, and the slightly inclined ones – to the high values of ZNIs – $SH_0 \geq 1.1$.

The apparently prevailing stands are those of the semi-steep height curves, and this gives the reason for considering the height curves of the investigated stands with a view to forming these curves' general and average models.

The similar distribution of the investigated stands according to their height-structure curves' declivity, when these are considered separately according to age groups and as one general aggregate, suggests the inference that stands' structure according to height does not depend significantly on age, so the stands can be studied together.

The average relative curves of heights (or the average curves of quality indicators) and Tyurin's average general curve of relative heights are very close in their development.

The results obtained prove the possibility of creating average general height-order curves for more than one tree species, as well as of developing general models of timber volumes and their assortment structure.

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