Some structural patterns of the stand of Scotch pine (Pinussylvestris L.) in the conditions of Zavolzhsky - ObshchySyrt province

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Abstract. Under the structure of stands is understood the order of combination and the nature of the relationship of the trees that make them up according to the main taxation characteristics, both in statics and dynamics. Since the stand is an unified system where the growth and development of trees are closely interconnected, the study of the structure should be carried out for the entire set of trees without separating any of its constituent parts, as indicated by N.V. Tretyakov. A.A. Makarenko proposed a methodology for studying the structure of stands, based on the construction of distribution curves for 10 classes within the range of variation of taxation features. In the present work, it was found that the distribution of actual values within 9 or 11 steps does not significantly affect the statistics of the distribution series calculated on the same trial plots for 10 classes, and with an increase or decrease in the classes, the difference between these statistics will increase accordingly.

Keywords: stand structure, growth course, Scotch pine, model tree, pure culture

1. Introduction
The study of the patterns of formation, growth and development of tree plantations is based on the generally accepted laws of the unity and struggle of opposites, the transition of quantity to quality, the negation of negation. According to the principles of these laws, all phenomena in the forest are organically interconnected, causally determined, are in constant motion and change. The structure of stands is understood as the order of combination and the nature of the relationship of their constituent trees according to the main taxation characteristics, both in statics and in dynamics. Since the stand is a single system where the growth and development of trees are closely interconnected, the study of the structure should be carried out for the entire set of trees without separating any of its constituent parts.

The study of the structure of stands and plantations in general using mathematical and statistical methods allows us to solve a number of theoretical and practical issues not only in the quantitative and qualitative assessment of forest resources, but also in the development of silvicultural techniques for managing the formation of the most productive and sustainable forest cenoses.
Throughout the life of trees in the stands, there are continuous quantitative and qualitative changes due to their growth and development, which is manifested in the increase in wood supply, decay of trees, etc. Studying the laws of this complex process in quantitative and qualitative terms allows on this basis to control the ongoing processes in the right direction [1-3]. One form of displaying plantation characteristics by age is forest yield tables (FYT). Many methods have been developed for compiling FYT, among which the following methods are the main ones: stationary observations, index stands, CRIF, selective-statistical and selection of growth types [4-6].

Research on plant growth is of multifaceted importance in theory and practice of assessing plantations at different stages of their development and allows substantiating a number of measures that make up the main links in the system of rational use of forest resources and forest management in general [7–9].

Despite the long-standing start of research on plant growth (over 100 years), to date, methodological issues have not yet been unequivocally resolved. This is due not only to the biological characteristics of tree species and the variety of growing conditions, but also to a fundamentally different methodological approach to the collection, systematization and processing of experimental data. In connection with the foregoing, we set a goal: to study the laws of the structure of pure pine crops in the tract Kachkarsky mar of the Orenburg forestry. The object of research is pine culture in the tract Kachkarsky mar of the Orenburg forestry.

2. Materials and methods.
Studies of pine stands of the Kachkarsky mar were carried out on two trial plots. Trial areas were laid according to industry standard 56-69-83 (Forest inventory trial plots. Methods of laying trial plots.). The size of the trial plots is 0.22 - 0.26 ha.

The study of the stand structure was carried out on the basis of the analysis of statistics of the distribution series for continuous counting and for partial counting, when not all trees, but part of them were measured by indicators of selective taxation. This approach is due to the complexity of work on measuring the heights and parameters of tree crowns. The length of the crowns along the length of the trunk was determined by the difference in trunk height and height to the live part of the crown of trees. The main device was electronic and Makarov altimeters, tape measure and calliper. When counting, the trees were divided into categories of technical suitability (industrial wood, semi-industrial wood and low-grade wood) and deadwood was separately considered. At the accounting sites 2*4 m, undergrowth was taken into account for height groups [5-8].

Since the number of steps in the trial plots was different, the thickness structure was studied directly from the steps and 10 classes of thickness, which made it possible to exclude the influence of the number of steps on the values of the distribution statistics. In addition, in the analysis of the trial plots according to the structure and relationships of the trait, the presence of a carbonate horizon was taken into account - 60 cm on the trial plot 2, and no carbonate horizon on the trial plot 1. Thus, the stand structure was studied taking into account the depth factor of the carbonate horizon.

To assess the discrepancies in the studied trait, calculated for 10 classes, the chi-square test was used.

To identify the relationships of taxation-morphological characters, the correlation coefficient (r) was found. Interconnections were determined by a combination of signs - diameter at a height of 1.3 m, crown parameters, tree height. The equations are calculated using the standard programs "STATGRAPHICS" and "Microsoft Excel".

3. Results and Discussion
The structure of the trees was studied in two trial plots, on which growth course studies were conducted. The distribution of the number of trees in the trial plots according to the steps of thickness is shown in Table 1.
Table 1. The distribution of trees in the trial plots according to the steps of thickness during continuous enumeration

| Steps of thickness | TP № 1 | TP № 2 |
|-------------------|--------|--------|
| 4                 | –      | –      |
| 6                 | –      | –      |
| 8                 | –      | 2      |
| 10                | 3      | 2      |
| 12                | 5      | 6      |
| 14                | 4      | 6      |
| 16                | 6      | 11     |
| 18                | 31     | 13     |
| 20                | 19     | 11     |
| 22                | 33     | 19     |
| 24                | 17     | 15     |
| 26                | 15     | 6      |
| 28                | 3      | 7      |
| 30                | 1      | –      |
| 32                | –      | –      |
| 34                | –      | –      |
| Итого             | 137    | 98     |

The table shows that the number of steps in each trial is different, and also the samples are different in the initial and final stages of variation of the trait. For example, in trial plot № 1 - from 10 to 30 steps with the number of trees - 137 pieces, and in trial plot № 2 - from 8 to 28 steps, with the number of trees - 98 pieces.

Due to the different number of thickness steps within the trial plots and the unequal number of observations for calculating the statistics of the distribution series, it is necessary to bring the values for each sample into a single system, namely, to distribute the trees on the trial plots according to the so-called 10 thickness classes. Such a number of classes meets the requirements of mathematical statistics and ensures the finding of reliable parameters or statistics of distribution series. Table 2 presents the distribution of the number of trees in the trial plots for 10 thickness classes.

Table 2. The distribution of trees in the trial plots by thickness for 10 classes.

| № TP | Classes | Total |
|------|---------|-------|
|      | 1       | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    |       |
| 1    | 2       | 3     | 13    | 36    | 33    | 26    | 14    | 5     | 2     |       | 137   |
| 2    | 2       | 5     | 7     | 16    | 15    | 18    | 20    | 10    | 4     | 1     | 98    |

Based on the obtained values, the statistics of tree distribution series by actual thickness steps and by 10 classes are calculated. The calculation results are presented in table 3.
Table 3. Statistics of the distribution of trees in the trial plots by diameter (by actual steps / by 10 classes)

| Statistics | TP1   | TP2   |
|------------|-------|-------|
| $x_{avg}$  | 20,7  | 19,8  |
| $m_{avg}$  | 20,8  | 19,8  |
| $m_{avg}$  | 0,29  | 0,50  |
| $m_{avg}$  | 0,30  | 0,51  |
| N          | 11    | 12    |
| $N$        | 10    | 10    |
| $\sigma^2$ | 12,19 | 24,29 |
| $\sigma$   | 12,86 | 24,60 |
| $V, \%$    | 3,49  | 4,93  |
| $V, \%$    | 3,59  | 4,96  |
| $P, \%$    | 16,8  | 24,9  |
| $P, \%$    | 17,2  | 25,1  |
| $P, \%$    | 1,4   | 2,5   |
| $P, \%$    | 1,4   | 2,6   |
| As         | -0,347| -0,242|
| As         | -0,237| -0,223|
| Ex         | 0,487 | -0,567|
| Ex         | 0,493 | -0,613|

Analyzing the table, we can conclude that there are differences between the statistics calculated on the actual values of the diameter and the so-called 10 classes.

Minor changes in the average value of the attribute are associated only with rounding in the calculations.

Trial plot №1. On this trial plot, all indicators have changed, except for the accuracy indicator of experience. In the direction of increase, the standard deviation, coefficient of variation and kurtosis have changed. The asymmetry coefficient decreased.

Trial plot №2. On this trial plot, statistics have changed slightly. The standard deviation, the coefficient of variation, the accuracy of the experiment, and the excess coefficient increased. The coefficient of asymmetry has decreased.

If an analysis by comparing the number of classes, within which there is a distribution, it can be argued that the more classes covering variation in the actual diameters of the large differences are observed between the statistics calculated by the actual values of the diameter and 10 classes. For example, on the trial plot №1 - 11 classes. The greatest changes occurred in the trial plot №2, where the distribution of actual values covers the largest number of classes.

Based on this fact, we can conclude that the distribution of actual values within 9 or 11 steps does not significantly affect the statistics of the distribution series calculated on the same trial plots for 10 classes, and with an increase or decrease in the classes, the difference between these statistics will increase accordingly.

In a study of the stand structure, it is believed that the statistics of the distribution series by taxation characteristics depend on the average value of the distribution series or on the age of the stand. Since the average diameter depends on age, it can be argued that the value of statistics depends primarily on the average values of the distribution series, but in this case the influence of the average value of the attribute is excluded, since the differences between the diameters in all the trial plots are insignificant. Therefore, in this case, the difference in the stand structure between these trial plots is due to the soil and ground conditions of the location of the stands, namely, the occurrence of the carbonate horizon.
For the statistical evaluation of differences observed in the distribution of the number of trees of the actual values of diameter and 10 classes are widely used chi-square test or the so-called «consensus criterion» proposed by Pearson in 1901 year.

To assess the discrepancies in the studied trait (diameter) using this criterion, were compared the distribution of the trait in 10 classes between trial plots, which most significantly differ in soil and ground conditions and in main taxation indicators. A comparative assessment of the criteria calculated on test plots with a standard criterion value at a confidence level of 0.95 and 7 degrees of freedom shows that for all comparisons, the calculated criterion exceeds the standard for a given probability level, that is, the null hypothesis is rejected and the assumption that the discrepancy between values of the characteristic in the compared areas is random rather than systematic. This means that the differences in the distribution of the number of trunks over the thickness steps are significant. This regularity is justified by the occurrence and absence of a carbonate horizon in the trial plots - at sample № 2 - from 60 cm, and at sample № 1 no carbonate horizon was found at all.

When studying the stand structure, a series of thickness distribution of trees is recognized as the main taxation indicator of a forest element [5-7]. Determining the rank of the mean tree in practice simplifies the finding of a model tree with which the necessary calculations can be carried out.

The rank of the mean tree, as a rule, was determined graphically [8], using the Charlier distribution of type A, derived a formula for finding the rank of a mean tree:

\[ \text{Rd} = 50 + 6.65 \times \alpha \]

where \( \text{Rd} \) — rank arithmetic average of the diameter,

\( \alpha \) — the asymmetry coefficient.

The place of the mean tree in the arithmetic mean diameter is always located to the right of the median of the distribution series, and, with increasing age, the place of the arithmetic average diameter shifts to the left, approaching the median of the series. Thus, the diameter distribution of a tree with age becomes more symmetrical and approaches normal.

In this study, the average rank of the mean tree is defined in three ways. The results are presented in table 4.

| Trial plot No. | The rank of the mean tree in terms of arithmetic mean diameter, % | The rank of the mean tree in terms of rms diameter, % |
|---------------|-------------------------------------------------|--------------------------------------------------|
|               | by K.E. Nikitin by graph                         | by graph                                         |
| 1             | 48                                               | 47                                               |
| 2             | 52                                               | 46                                               |
| average       | 50                                               | 46.5                                             |

The rank of the mean tree in the arithmetic mean diameter is shifted to the left, especially due to significant differences in soil and ground conditions - there is a carbonate horizon at a depth of 40 cm in this area. The rank of the mean tree in terms of rms diameter, on the contrary, is shifted to the right, that is, its value is always more than in terms of rms diameter.

The average age of pine plantations in the trial plots is 58 years. Comparing this value with the values obtained in the study of these trial plots, we can conclude that it is less than the average rank compared to trial plot № 1 - 48%, trial plot № 2 - 52%, which confirms the significant dependence of the taxation parameters of the stands on the soil-ground conditions in these trial plots.}

Trial plot №1.On this trial plot, all indicators have changed, except for the accuracy indicator of experience. In the direction of increase, the standard deviation, coefficient of variation and kurtosis have changed. The asymmetry coefficient decreased.

Trial plot №2. On this trial plot, statistics have changed slightly. The standard deviation, the coefficient of variation, the accuracy of the experiment, and the excess coefficient increased. The coefficient of asymmetry has decreased.
If an analysis by comparing the number of classes, within which there is a distribution, it can be argued that the more classes covering variation in the actual diameters of the large differences are observed between the statistics calculated by the actual values of the diameter and 10 classes. For example, on the trial plot №1 there are 11 classes. The greatest changes occurred in the trial plot №2, where the distribution of actual values covers the largest number of classes.

4. Conclusion
In a study of the stand structure, it is believed that the statistics of the distribution series by taxation characteristics depend on the average value of the distribution series or on the age of the stand. Since the average diameter depends on age, it can be argued that the value of statistics depends primarily on the average values of the distribution series, but in this case the influence of the age of the stand is excluded, since the differences between the diameters in all the trial plots are insignificant. Therefore, in this case, the difference in the stand structure between these trial plots is due to the soil and ground conditions of the location of the stands, namely, the occurrence of the carbonate horizon.[9-12].

References
[1] Kalyakina R G, Ryabukhina MV and Maiski R A 2018 Influence of Orenburg gas condensate field development on ecological and biological condition of landscape-botanical complexes IOP Conference Series: Materials Science and Engineering 451(1) 012194
[2] Maiski R A, Ryabukhina M V and Kalyakina R G 2018 Ecological and technological aspects of increasing sustainability of vegetation cover of Caspian oil and gas provinces IOP Conference Series: Materials Science and Engineering 451(1) 012193
[3] Ryabinina Z N, Kalyakina R G, Ryabukhina M V, Khalikov B M and Bisaliev I N 2019 Studying the structure of pricopopulations and quality of seed seeds of bushes Ural river loan IOP Conference Series: Earth and Environmental Science 341012097
[4] Belchinskaya L I 2000 Bioindication of industrial toxicants with woody plants (Voronezh:VSPA) 93
[5] Bukharina I L, Povarnitsyna T M, Vedernikov K E 2007 Ecological and biological features of woody plants in an urbanized environment (Izhevsk:ISAA) 216
[6] Ryabukhina M V, Maiski R A and Salikhova R Kh 2017 Environmental risks of landscape botanical complexes and minimization of technogenic influence exerted by objects of oil & gas production in steppe zone of the Southern Urals IOP Conference Series: Materials Science and Engineering. International Conference on Construction, Architecture and Technosphere Safety (ICCATS 2017) 262(1) 012167
[7] Ryabuhina M V, Maiski R A and Kalyakina R G 2019 Transboundary air pollution and its effects on vegetation IOP Conference Series: Materials Science and Engineering 687066043
[8] Bezel V S, Pozolotina V N and Belsky E A 2001 Variability of population parameters: adaptation to toxic environmental factors Ecology 6 447–453
[9] Flora of the European part of the USSR 1974–1979 (Leningrad: Nauka)
[10] Sukachev V N and Lavrenko E M 1952 A brief guide for geobotanical research in connection with the forest shelter forest and the creation of a sustainable forage base in the southern European part of the USSR (Moscow: Academy of Sciences USSR)
[11] Dylis N V 1974 Program and methods of biogeocenological studies (Moscow: Nauka)
[12] Cherepanov S K 1995 Vascular plants of Russia and adjacent states (within the former USSR) (St. Petersburg: Peace and Family)