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THE AVERAGE TRUNK DIAMETER DISTRIBUTION ROWS IN THE NATURAL DIAMETER CLASSES WITH CONSIDERING OF THE TREE QUALITY CATEGORIES AND METHODS OF THEIR USE FOR THE RATED CUTTING AREA COMMODIFICATION

The article presents of the stem diameter distribution rows in the natural diameter classes with considering of the trees quality categories. These rows are formed of six main tree species in Belarus: pine, spruce, oak, birch, black alder and aspen. The use of such series together with the assortment tables allows you to commodification of the rated cutting without the use of timber quality tables. Method of calculation is described in detail. To perform this operation it is necessary for each element of forest in the stand to know the average diameter and height, absolute or relative density, and the proportion of merchantability trunks or class quality of wood. For the case where the proportion of the merchantability trunks don't known, but there is only class quality of wood, the article presents the average percentage of merchantability trunks depending on the species and class quality of wood. Present method of fitting the series averaged distribution of the natural thickness steps of the concrete forest element preserves all the relationships that occur between the total number of trees, the number of merchantability and fuel trunks on the diameter clsass and for the whole element of forest.

Key words: forest harvesting, principal harvesting, rated cutting area,volume of forest harvesting, commodification, natural diameter classes, assortment tables, timber quality tables.

Introduction. As it is known, the structure of forest stands by diameter is subject to certain laws, which has long attracted the attention of many scientists. In this regard, the rows of trees distribution by the natural diameter proposed by A. V. Tyurin appeared to be very useful [1]. The use of such series allows you to define the growing stock by eye-measuring inventory more accurately than when using standard tables or tables of species heights [2].

However, it is required to perform fairly laborious calculations that at the present level of development of computer technology should not be considered as a serious obstacle. For the forest characteristics onestock is not enough. It is well known that in the course of forest inventory design of the main use of forest the forest commodity structure, which will be harvested as a result of felling of main use of forest, is also determined along with the calculation of the size of forest management. Traditionally, commodity tables are used for this purpose. However, if you have rows of industrial and wood trunks distribution by natural diameter classes, the output of industrial wood and wood by size categories are also available by the assortment tables [3]. The accuracy obtained with this technique is not worse than that with the use of commodity tables.

In this case of the commoditization of the stock based on the average rows distribution of industrial and wood trunks by natural diameter classes an individual enumeration was being formed for each stand corresponding to the average diameter of the tree stand. In determining the amount of industrial and wood trunks the total number of wood trunks in the stand as well as the average share of industrial trunks for the corresponding class of merchantability was taken into account. However, as it turned out, after such a rows transformation of distribution of industrial and wood trunks their sum ceased to correspond to a number of distribution of the total number of trunks by the natural diameter classes. To avoid such situations, you need to develop a methodology for setting average rows of distribution of industrial and wood trunks on particular stands, providing the binding amount of industrial and wood trunks with a total number of trees by the natural diameter classes in any of merchantability class (the share of industrial trunks). In view of the foregoing, the aim of this work is the formation of average rows of distribution of industrial and wood trunks by the natural diameter classes for the main forest tree species, as well as the development of a methodology of the average rows for a particular timber element, which ensures the preservation of all the relationships between the total number of trunks and the number of industrial and wood trunks by the natural stages of thickness and on the whole for the entire row of distribution.

Main part. Rows diameter distribution of the natural diameter classes were obtained on the basis of the taxation data of forest stands in the test areas. Trial plots were laid in ripening, mature and overmature forest stands of the Republic of Belarus. The calculations were performed for the six components of wood: pine, spruce, oak, birch, black alder and aspen. The number of enumeration, by which the average rows of distribution by the natural diameter classes were formed, is given in Table 1. In this paper, the formation of rows of distribution the techniques used previously to create the rows diameter of distribution by the natural stages of the thickness was applied [4]. The rows of distribution were formed both for the total number of trunks by the natural diameter classes and for the number of industrial trunks. The rows of wood trunks distribution can be obtained as the difference between the row of distribution of the total number of trunks and the number of industrial trunks distribution. The distribution of trees by the natural diameter classes in the average number was expressed as a percentage of the total number of trunks. For all the species the average share of industrial trunks in the enumeration given in Table 1 was calculated.

Table 1

The number of enumeration used in the formation of average rows of distribution by the natural diameter classes

Species	Number of enumeration	Share of industrial trunks in the average rows, %
Pine	538	95.2
Spruce	210	96.2
Oak	61	91.2
Birch	182	71.6
Black alder	88	84.4
Aspen	63	70.1
Total	1,142	–

Besides, the average share of industrial trunks for each class of merchantability of the main tree species was also determined (Table 2). These values are necessary for adjusting the distribution of average specific rows on timber elements when only the class of merchantability is known, and the information on the share of industrial wood is not provided.

Table 2

Average share of industrial trunks, %

Species	Commodity class		
	1	2	3
Pine	98.5	80.6	43.5
Spruce	98.4	80.1	38.2
Oak	96.9	89.7	45.4
Birch	98.3	77.7	31.7
Black alder	98.7	86.3	41.4
Aspen	99.4	90.5	29.6

Formed distribution rows of the total, including industrial trunks by the natural diameter classes, are shown in Table 3. All the values in the Table are expressed in percentage of the total number of all trunks.

To perform the commoditization of allowable cut by using the average rows of distribution by the natural diameter classes and assortment Table 1 can offer the following method.

The first step is to adjust the distribution of average rows by the natural steps of thickness to a specific timber element. To do this, you need to know the share of industrial trees for each forest element. If such information is not provided, and only the class of merchantability is known, you can use the average values given in Table 2, depending on the species and grade of merchantability. In the case that the share of industrial trunks for wood element is less than the proportion of industrial trunks in the average number of distribution (Table 1), the absolute values of the natural frequencies of steps by thickness will be calculated as follows:

$$p_i^{\text{ind}} = \frac{\overline{p}_i^{\text{ind}}}{\overline{N}_{\text{ind}}} \cdot N_{\text{ind}};$$

$$p_i^{\text{w}} = \overline{p}_i - p_i^{\text{ind}};$$

$$g_{\text{avg}} = \frac{\pi d_{\text{avg}}^2}{40{,}000}; \tag{1}$$

$$G = FG_{\text{n}}; \tag{2}$$

$$N = \frac{G}{g_{\text{avg}}}; \tag{3}$$

$$n_i^{\text{ind}} = p_i^{\text{ind}} \cdot \frac{N}{100}; \tag{4}$$

$$n_i^{\text{w}} = p_i^{\text{w}} \cdot \frac{N}{100}, \tag{5}$$

where p_i^{ind} – number of industrial trunks at the i natural diameter class for aforewst element, %; $\overline{p}_i^{\text{ind}}$ – percentage of industrial trunks at the i stage of the natural thickness of the average number of distribution (Table 3), %; $\overline{N}_{\text{ind}}$ – share of industrial trunks in an average row (Table 1), %; N_{ind} – share of industrial trunks of a forest element (if it is not known, then it depends upon the commodity class in Table 2), %; p_i^{w} – a number of wood trunks at the i natural stage of thickness of a forest element, %; $\overline{p}_i$ – percentage of the total number of trunks at the i natural stage of thickness of an average row of distribution (Table 3), %; g_{avg} – cross section area of the average tree of a forest element, m^2; d_{avg} – diameter of the average tree of a forest element, cm; G – sum of the areas sections of a forest element, m^2/ha; F – relative fullnes; G_{n} – sum of the areas of the cross sections of the normal growing stand, m^2/ha; N – number of trunks of a forest element, pieces/ha; n_i^{ind} – number of industrial trunks at the i natural stage of thickness of a forest element, pieces/ha; n_i^{ind} – number of wood trunks at the i natural stage of thickness of a forest element, pieces/ha.

Table 3

Rows of distribution of the total number of wood trunks and industrial trunks by the natural diameter classes

The boundaries of the natural diameter classes	Frequency, %											
	Pine		Spruce		Oak		Birch		Black alder		Aspen	
	total	indus-trial	total	indus-trial	total	indus-trial	total	indus-trial	total	indus-trial	total	indus-trial
$0.15d_{avg}$	–	–	–	–	0.2	0.2	–	–	–	–	–	–
$0.25d_{avg}$	0.2	0.1	0.6	0.4	1.8	0.7	0.8	0.2	0.3	0.1	0.3	0.1
$0.35d_{avg}$	1.0	0.7	2.2	1.7	3.5	2.2	2.8	0.8	1.3	0.7	1.8	0.7
$0.45d_{avg}$	3.3	2.7	5.3	4.4	6.9	5.1	5.2	2	3.6	1.8	3.5	2.0
$0.55d_{avg}$	6.3	5.5	8.7	8.0	8.1	6.9	7.8	3.9	6.7	4.1	6.9	4.3
$0.65d_{avg}$	9.5	8.8	10.4	10.0	8.7	7.9	9.9	5.7	9.1	6.5	9.9	6.2
$0.75d_{avg}$	12.4	11.9	11.5	11.2	10.2	9.5	12.1	8.1	12.2	9.9	11.9	8.3
$0.85d_{avg}$	15.1	14.6	12.6	12.4	12.0	11.4	13.4	10.6	14.9	12.9	14.6	10.6
$0.95d_{avg}$	15.7	15.3	13.1	12.8	12.2	11.8	12.7	10.3	14.9	13.8	13.9	10.3
$1.05d_{avg}$	13.5	13.2	11.4	11.3	10.9	10.7	10.8	8.9	13.4	12.4	12.9	9.8
$1.15d_{avg}$	10.1	9.9	8.6	8.5	8.2	7.9	8.5	7.2	10.7	10.0	10.2	7.5
$1.25d_{avg}$	6.4	6.2	6.0	6.0	5.8	5.6	6.2	5.4	6.5	6.1	6.9	5.0
$1.35d_{avg}$	3.4	3.4	4.1	4.0	4.9	4.9	4	3.5	3.2	3.1	3.8	2.6
$1.45d_{avg}$	1.7	1.6	2.5	2.5	3.0	2.9	2.5	2.1	1.6	1.5	1.8	1.4
$1.55d_{avg}$	0.8	0.8	1.5	1.5	1.8	1.8	1.6	1.4	0.8	0.7	1.0	0.8
$1.65d_{avg}$	0.3	0.3	0.7	0.7	0.9	0.9	0.8	0.7	0.4	0.4	0.4	0.3
$1.75d_{avg}$	0.2	0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.2	0.2	0.2
$1.85d_{avg}$	0.1	0.1	0.2	0.2	0.4	0.3	0.2	0.2	0.1	0.1	–	–
$1.95d_{avg}$	–	–	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	–	–
$2.05d_{avg}$	–	–	0.1	0.1	–	–	0.1	0.1	–	–	–	–
$2.15d_{avg}$	–	–	–	–	–	–	0.1	–	–	–	–	–

In the case that the share of industrial trunks for a forest element was greater than the proportion of industrial trunks in the average row of distribution (Table 1), the relative frequency must be calculated by the following formula:

$$p_i^{\mathrm{w}} = \frac{\overline{p}_i - \overline{p}_i^{\mathrm{ind}}}{100 - \overline{N}_{\mathrm{ind}}} \cdot \left(100 - N_{\mathrm{ind}}\right);$$

$$p_i^{\mathrm{ind}} = \overline{p}_i - p_i^{\mathrm{w}}.$$

Further calculations of absolute values by the thickness stages should be performed in the same manner as in the previous case – by the formula: (1)–(5).

It is easy to notice that at this method of calculating the average after setting the average rows of distribution for a particular element of the forest all the relations between the total number of trees, the number of industrial and wood trunks by thickness as well as for the forest element are stored.

The absolute values of the natural thickness can be calculated by the formula

$$d_i = e_i d_{\mathrm{avg}},$$

where d_i – absolute value of the i stage of thickness, cm; e_i – value of the i natural stage of thickness.

After the enumeration for a particular element of the forest is formed, the total timber stock, the stock of firewood, as well as the stock of large, medium and small industrial timber aredetermined. To do this, use the following method of calculation.

Using the data presented in the assortment tables, the total amount of wood, the amount of large, medium and small-scale commercial timber for each natural stage of thickness were determined by interpolation using the following formula:

$$v_i^k = v_1^k + \frac{\left(v_2^k - v_1^k\right) \cdot \left(d_i^2 - d_1^2\right)}{\left(d_2^2 - d_1^2\right)}; \quad (6)$$

$$v_i^k = v_{\min}^k \frac{d_i^2}{d_{\min}^2}; \quad (7)$$

$$v_i^k = v_{\max}^k \frac{d_i^2}{d_{\max}^2}, \quad (8)$$

where v_i^k – amount of wood of the k category for 1 trunk in the i natural stage of thickness, m^3; v_1^k and v_2^k – amounts of wood of the k category for 1 trunk, taken from the assortment tables for the diameters d_1 and d_2, m^3; d_1 – maximum diameter from the assortment tables not exceeding d_i, cm; d_2 – minimum diameter from the assortment tables greater than d_i, cm; $v_{\min}^k$ – amount of wood of the

k category for 1 trunk taken from the assortment tables for the diameter d_{min}, m^3; d_{min} – minimum diameter from the assortment, cm; v^k_{max} – amount of wood of the k category for 1 trunk taken from the assortment tables for the diameter d_{max}, m^3; d_{max} – maximum diameter from ther assortment tables, cm.

Formula (7) is used for the natural thickness stages whose absolute value (d_i) is smaller than the minimum diameter (d_{min}), from the assortment tables.

For the natural stages of thickness, the absolute value of which (d_i) exceeds the maximum diameter (d_{max}) from the assortment tables, formula (8) is applied. For the rest of the natural stages of thickness calculating is performed using the formula (6).

The height class required to use the assortment tables can be determined by the ratio of the average diameter and the average height of forest elements.

Once the volume of wood of different categories for a single trunk will be defined for all stages of the natural thickness, it is necessary to calculate the total stock of wood per hectare corresponding to the categories for the whole stand:

$$M_1 = \sum_{i=1}^{m} v_i^1 \cdot n_i^{\text{ind}}; \quad (9)$$

$$M_{\text{avg}} = \sum_{i=1}^{m} v_i^{\text{avg}} \cdot n_i^{\text{ind}}; \quad (10)$$

$$M_{\text{sm}} = \sum_{i=1}^{m} v_i^{\text{sm}} \cdot n_i^{\text{ind}}; \quad (11)$$

$$M_{\text{f.ind}} = \sum_{i=1}^{m} v_i^{\text{f.ind}} \cdot n_i^{\text{ind}}; \quad (12)$$

$$M_{\text{f.f}} = \sum_{i=1}^{m} v_i^{\text{f.f}} \cdot n_i^{\text{f}}; \quad (13)$$

$$M_{\text{f}} = M_{\text{f.ind}} + M_{\text{f.f}}, \quad (14)$$

where M_l – stock of large industrial wood in the tree stand, m^3; m – number of natural thickness stages; v_i^1 – amount of large industrial wood for a single trunk in the i natural stage of thickness, m^3; M_{avg} – stock of average industrial wood in the tree stand, m^3; v_i^{avg} – amount of average industrial wood for a single trunk in the i natural stage of thickness, m^3; M_{sm} – stock of small industrial wood in the forest stand, m^3; v_i^{sm} – amount of small industrial wood for a single trunk in the i natural stage of thickness, m^3; $M_{f.ind}$ – stock of firewood from industrial wood, m^3; $v_i^{f.ind}$ – amount of forewood for a single industrial trunk in the i natural stage of thickness, m^3; $M_{f.f}$ – stock of firewood from firewood trunks, m^3; $v_i^{f.f}$ – amount of firewood for a single fierwood trunk in the i natural stage of thickness, m^3; M_f – stock of firewood in the forest stand, m^3.

Conclusion. Commoditization of the allowable cut is performed using the commodity tables. However, studies show that the same work can be done using the assortment tables and the proposed averaged rows of distribution of the trunk diameter by the natural stages of thickness. This will eliminate the compilation of trade tables, which is clearly beneficial in terms of cost for their development. The proposed method can be used not only for the commoditization of the allowable cut, but also for the material and monetary evaluation of cutting areas in the case of taxation by their sites. In addition, the combination of this algorithm of the commoditization of the stock of forest stands with new technologies of measuring deciphering of the materials of forest remote sensing [5] will significantly expand the list of information obtained.

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