A study of dimensional and quality characteristics of sawlogs of the Vologda region

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Abstract. Following the results of 2019, in the Vologda region harvested 16.9 million m³ of roundwood. Active forest utilization, combined with insufficient road construction, has led to the depletion of the forest resource base at an economically accessible distance from the timber enterprises. The purpose of the study is to assess the potential of wood resources and analyses the dimensional and quality characteristics of roundwood utilized as sawlogs at the sawmills of the Vologda region. As a result of the research, the following has been found out: the average diameter of harvested assortments, the parameters of curvature and taper depending on the apical diameter of pine roundwood. The following parameters have been evaluated: the diameter of the log, curvature, and taper of the roundwood. The studies were carried out by the photometric method. The established dimensional and quality characteristics of round timber allow us to conclude that sawmills in the Vologda region involve wood that has not reached the age of ripeness into industrial utilization, as a result of the depletion of the forest resource base near the infrastructure facilities. Termination of logging on leased areas occurs when the average diameter of the harvested raw material decreases to 13 cm.

1. Introduction

The productivity of modern sawmills in terms of processed raw materials reaches 1 million m³ of logs per year. In Russia, a model of intensive forest management is used, in which a substantial increase in the volume of timber harvested in the past 15 years, carried out in a concentrated manner, near the objects of transport infrastructure, has led to a change in the commodity structure of forest stands. Changing the parameters of roundwood has a great influence on the volume of output and requires justification of the type of equipment used to ensure the possibility of cost-effective processing of forest resources in regions with developed sawmill production.

The lack of reliable information on the dimensional and quality characteristics of roundwood and their distribution by diameter in the total volume of harvested wood does not allow sawmills to carry out effective planning of their activities.
Studies of the roundwood structure are actively carried out all over the world. The Forest Research Institute (Metla) is involved in assessing changes in forest structure in Finland and some regions of Russia [1, 2], and the European Forest Institute (EFI) is studying the dynamics of changes in the size and quality characteristics of round timber harvested in Europe [3, 4], in North America, a large number of studies are conducted at the Canadian Forest Service [5]. The subject of research is the structure of the species composition, the quality and efficiency of the processing of forest resources of European forests. Based on the data on the current structure and size and quality characteristics of sawing raw materials, recommendations are developed on the use of forest resources and the introduction of decision support tools for choosing an effective processing technology [6].

The lack of relevant information on the structure of harvested wood in Russia does not allow achieving a comparable level of economic efficiency, which is both a deterrent and a growth potential for the sawmill industry when such information is received and integrated into modern decision support systems. The analysis of received information will make it possible to reasonably choose equipment for wood processing, as well as determine the types of products whose production from available raw materials will be most effective.

The study of the age and species composition in the forests of the Vologda region as well as the analysis of the taxation characteristics of roundwood is an urgent task and has practical significance.

The purpose of the study is to assess the potential of wood resources and analyze the dimensional and quality characteristics of roundwood utilized as sawlogs at the sawmills of the Vologda region.

As a result of the research, the following has been found out: the average diameter of harvested assortments, the parameters of curvature and taper depending on the apical diameter of pine roundwood.

2. Methods and materials

The subject of research has been roundwood harvested using cut-to-length method at the leading enterprises of the Vologda region. The logs that went to the sawmills were subject to research.

The following parameters have been evaluated: the diameter of the assortment, curvature, and taper of the roundwood. Wood species – Pinus sylvestris.

Measurements were performed using a trusted and certified technique. The studies were carried out by the photometric method. The measurement accuracy was ±1 mm [7]. Measurements of the studied parameters along the length of the log were performed with a step of 10-15 cm.

The research has been carried out at the roundwood sorting site. Parameters of roundwood have been evaluated before debarking.

Measurements of the size and shape of roundwood have been made using a photometric scanner VECTOR 3D (Automatika Vector company, Russia, 2011) which allows three-dimensional scanning of the profiles of the studied assortment. Measurements have been made in compliance with the Russian standard 32594-2013 ‘Roundtimber. Methods of measurements’ [8]. Measurements have been made at the sites where sawlogs are sorted by diameter. The total number of sawlogs studied is 16,141 pieces. The length of assortments varies from 3 to 6 m. The range of roundwood diameters studied is 9 to 32 cm.

The research has been carried out from 2014 to 2018.

Round timber intended for sawing was harvested in the sawmills’ own forest lease base using harvesters and forwarders, as well as purchased from the logging companies of the region.

3. Results and discussion

Forests of the Vologda region cover an area of 11.7 million hectares, which is 81% of the region's territory. The forest yield exceeds 1.6 billion m³. With the total volume of allowable annual cut at the level of 30.1 million m³, including 10.7 million m³ of softwood, the region ranks first in terms of the intensity of wood harvesting with 1.7 m³/ha. The allowable annual cut is developed by 56%. Information on the forest resources of the region and the species composition of forest stands is given in tables 1-2. As of January 1, 2018, protective forests in the region cover 1,942.2 thousand hectares,
including 1,815 thousand hectares within the forest fund lands. Operational forests occupy 9,715.1 thousand hectares, including 9,658.2 thousand hectares within the forest fund lands. There are no forest reserves (unexploited forests) on the territory of the Vologda region.

**Table 1.** Forest resources of the region (based on the results of inventory as of January 1, 2018) [9].

| Thousand hectares | Total area | Including forest-covered area | Forest coverage ratio, % | Total yield of major forest-forming species, million m³ |
|-------------------|-----------|--------------------------------|--------------------------|-------------------------------------------------------|
|                   | 11,473.2  | 9,820.4                        | 68.9                     | 1,594.9                                               |

**Table 2.** Forest species composition in the Vologda region (as of 2018, thousand hectares) [9].

| Forest-covered area | Prevailing species | 2014  | 2015  | 2016  | 2017  | 2018  |
|---------------------|--------------------|-------|-------|-------|-------|-------|
|                     | Spruce             | 2,777.9 | 2,782.1 | 2,799.3 | 2,811.5 | 2,813.0 |
|                     | Pine               | 2,241.0 | 2,234.9 | 2,226.3 | 2,217.6 | 2,204.1 |
|                     | Birch              | 3,697.2 | 3,693.5 | 3,676.0 | 3,674.5 | 3,649.7 |
|                     | Aspen              | 957.2  | 960.6  | 961.1  | 977.8  | 983.0  |

Analysis of the data presented in table 2 allows us to conclude that provided that transport accessibility is ensured and the entire volume of available forest resources is involved into industrial production, there is a potential for production growth in the region. In addition, the observed distribution of forests by species provides an opportunity to diversify the operations of sawmills, who are able to involve the most popular pine and spruce timber in the production process, depending on the current market situation, following the example of leading European countries [1, 10, 11], and not experience a shortage of raw materials due to the depletion of one of the most valuable species in the region.

The data on the age composition of forests in the Vologda region, shown in figure 1, are of principal interest. The region is dominated by mature stands, as of 2018 occupying an area of 3,158 thousand m², which should ensure the raw material safety of enterprises and allow to involve wood of required diameters into the industrial production, as the equipment parameters were calculated based on such diameters. As a rule, this is roundwood with a diameter of 18 to 36 cm, which is cut from the stembase of the trunk and provides the maximum volume and quality of the output [12, 13]. However, as a result of the research, see figure 2, it is found that the average diameter of raw materials used in the lumber production is significantly lower.

Despite the growing forest utilization, the area of mature stands in 2016-2018 has practically not changed, and the area of overmature forests is increasing, but along with that, beginning in 2016 there is a systematic reduction of the middle-aged stands area, without a commensurate increase of the ripening forests area. For example, from 2015 to 2016, the area of middle-aged forests decreased by 711,000 hectares, while the area of ripening forests increased only by 276,200 hectares.
Figure 1. Age composition of the Vologda region forests (as of 2018) [9].

The growth in mature forest area by 296,200 hectares which happened in the same time period cannot be explained only by the transition of the share of ripening forests into mature ones, the area of which in the period from 2016 to 2018 decreased by only 30,000 hectares. The data obtained can serve as an indirect sign that ripening forests are actively used in the industrial wood harvesting, since a significant depletion of the forest resource base near the transport infrastructure facilities is found out [2, 9, 14]. The data available in the literature are confirmed by the results of our own research, figure 2, table 3.

Figure 2. The curve of round timber distribution by diameter, %.
Table 3. Distribution round timber by diameter, %.

| Log apical diameter, cm | Year of observation |          |          |          |          |
|------------------------|---------------------|----------|----------|----------|----------|
|                        | 2015                | 2016     | 2017     | 2018     |
| 9                      | 2.02                | 0.78     | 0.41     | 0        |
| 10                     | 4.00                | 6.23     | 2.12     | 0        |
| 11                     | 6.85                | 12.03    | 3.94     | 0        |
| 12                     | 13.24               | 16.44    | 5.67     | 0.13     |
| 13                     | **15.97**           | **17.20**| 9.52     | 0.98     |
| 14                     | 15.52               | 15.11    | **15.56**| 4.15     |
| 15                     | 13.92               | 10.07    | 12.41    | 9.23     |
| 16                     | 9.10                | 7.58     | 11.01    | 9.96     |
| 17                     | 6.10                | 4.77     | 4.76     | **10.88**|
| 18                     | 5.05                | 3.29     | 4.45     | 9.76     |
| 19                     | 2.87                | 2.01     | 4.40     | 9.01     |
| 20                     | 2.45                | 1.15     | 4.33     | 8.58     |
| 21                     | 1.47                | 0.85     | 4.28     | 7.06     |
| 22                     | 0.52                | 0.75     | 4.38     | 5.78     |
| 23                     | 0.27                | 0.43     | 3.90     | 4.80     |
| 24                     | 0.15                | 0.38     | 2.91     | 3.88     |
| 25                     | 0.05                | 0.33     | 1.76     | 3.33     |
| 26                     | 0.15                | 0.13     | 0.87     | 2.38     |
| 27                     | 0.12                | 0.08     | 0.46     | 1.45     |
| 28                     | 0.02                | 0.15     | 0.60     | 1.28     |
| 29                     | 0.02                | 0.10     | 0.43     | 0.90     |
| 30                     | 0.02                | 0.03     | 0.72     | 0.85     |
| 31                     | 0.02                | 0.03     | 0.46     | 0.70     |
| 32                     | 0.07                | 0.10     | 0.67     | 4.93     |

In the period under review, 2015-2018, the average diameter of round timber varied in the range of 12.5-17 cm, and the share of assortment with a diameter of more than 32 cm did not exceed 3.5%. However, according to [15], at the age of 100 years, the diameter of pine, determined at chest height, usually exceeds 30 cm, which also indicates that the assortments processed by sawmills in the Vologda region, figure 2, are obtained from wood that has not reached the age of ripeness [16].

Wood harvested in ripening and middle-aged forests differs from mature wood in its physical and mechanical characteristics [3, 17, 18], since it contains a larger volume of sapwood [13, 19], whose biological stability is lower, as well as a large proportion of juvenile wood, which makes it difficult to produce lumber of strength class C30 and higher and requires the use of methods for individual assessment of strength indicators of each assortment cut [20-22].

As a result of the research, it was found out that the value of taperness of roundwood coming to the sawmills of the Vologda region, figure 3, depends on the apical diameter. Average taper values can be determined using equation (1). The highest taperness is found in stembase and apical timber, which is consistent with the known data [23-24]. The amount of assortment taper varies in a wide range and depends on the age of cutting and the growing conditions of a particular tree. Such changes in the taper of round timber, harvested at different ages, in separate cutting areas, from trees growing in different natural and climatic conditions, complicate roundwood inventory at the industrial enterprises.

Equation (1) describes the general nature of the change in the taperness of assortments cut at the regional sawmills and cannot be used for a reliable assessment of individual assortments. To evaluate the taper parameters of each particular assortment and justify the plan of its cutting, it is necessary to use up-to-date photometric or x-ray scanners that allow to obtain a 3D model of the log shape and provide a continuous account of the features of the structure, volume and shape of each incoming assortment. These models should be the basis for classifying sawlogs into sorting groups, depending
on the shape of assortment and the requirements for lumber. General trends of the shape of sawlogs should be taken into account when justifying the type and model of sawmilling equipment, as well as in calculating cutting plans for sawlogs that are cut into lumber.

Averaged data on sawlog taperness in the Vologda region, mm/m, can be defined using the following equation

$$y = 0.0246x^2 - 0.9206x + 16.863 \quad R^2 = 0.8795$$

where x stands for apical diameter of roundwood, cm.

As a result of the research, the change in the curvature of sawlogs depending on the roundwood diameter has been found out. The figure 4 shows the results of research for sawlogs 3-meter long. The decrease in the quality of harvested wood forces sawmills to switch to sawing 3-m and 4-m long assortments, which reduces the productivity of equipment, but allows to increase the volume output of products. When using shorter-length assortments, the effect of its curvature on the output of products is reduced and the shape stability of lumber is ensured during its operation [25]. The dimensional stability of lumber is provided due to less cutting of wood fibers, which, accordingly, reduces the warping that occurs when the moisture level of lumber changes in operating conditions, as well as due to its subsequent gluing [26].
round timber. Technical conditions: 1st sort roundwood (curvature range: 0-0.5%) – 68.2%; 2nd sort roundwood (curvature range: 0.5-1.0%) – 27.3%; 3rd sort roundwood (curvature range: 1.0-1.5%) – 3.67%; 4th sort roundwood (curvature range: 1.5-3%) – 0.82%.

In general, the dependence of the sawlog curvature in the Vologda region, %, on the apical diameter of the assortment can be determined using the equation (2):

$$y = 0.0007x^2 - 0.0206x + 0.5981$$  \hspace{1cm} R^2 = 0.7933 \tag{2}$$

where x stands for apical diameter of roundwood, cm.

4. Conclusion

The established dimensional and qualitative characteristics of round wood allow us to conclude that, despite the fact that there are many mature and over mature forests of medium and large diameter in the region, sawmills use wood that has not yet reached maturity for industrial use. The estimated cutting area is only 56% used along roads. If road infrastructure facilities are created, large volumes of Mature and over-Mature wood will be involved in industrial use, which will create conditions for increasing the average diameter of round timber. As a result of the research has been determined, the average diameter of round timber received by sawmills is 13, 13, 14 and 17, respectively, in 2015, 2016, 2017 and 2018. The parameters of curvature and taper are determined, depending on the top diameter of the log.

The analysis of the obtained data suggests that the forest resource base in the region is developed unevenly by timber enterprises, and the harvesting of wood on leased areas continues even after cutting down the entire volume of mature wood, involving the ripening forests into industrial use that are located within the radius of economic accessibility of existing enterprises. Termination of logging on leased areas occurs when the average diameter of the harvested raw material decreases to 13 cm, at which there is a significant increase in the taper and curvature of round timber, the impact of which can be partially mitigated by reducing the length of the saw logs to 3 m.

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