The structure of the regulatory framework for the assessment of forest resources in Yenisei Siberia and the ways to improve it

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Abstract. Yenisei Siberia lies within the administrative borders of the Krasnoyarsk Territory, and the republics of Khakassia and Tyva; this helps to link forest inventory standards to specific forest areas. Significant variation in environmental conditions across the Yenisei Siberia is caused by the zonal affiliation of its different parts; they fall into one of the following zones: the near-tundra, taiga, forest-steppe, northern and southern mountain ranges. The variety of environmental conditions has resulted in a variety of forest stands that not only supply timber, but also provide environmental services. Despite the almost century-long history of the existence of standards for the valuation of forest resources in Yenisei Siberia, they cannot be considered as complete and perfect.

1. Introduction
Yenisei Siberia stretches along the river Yenisei for more than 3000 km, from the north of the Taimyr Peninsula to the southern mountain ranges of the Tyva Republic. The area of this region is about 2.5 million ha. Yenisei Siberia lies within the administrative borders of the Krasnoyarsk Territory, and the republics of Khakassia and Tyva; this helps to link forest inventory standards to specific forest areas.

Significant variation in environmental conditions across Yenisei Siberia is caused by the zonal affiliation of its different parts; they fall into one of the following zones: the near-tundra, taiga, forest-steppe, northern and southern mountain ranges. The variety of conditions has resulted in a variety of forest stands that not only supply timber, but also provide environmental services.

The first regional tables for estimation of timber resources in this vast region were compiled in the 1920s. A start was made by B N Tikhomirov and B N Tischenkov [1] who compiled a growth table for normal stands of Larix sibirica Ledeb. in Khakassia. Further research was largely focused not only on patterns of growth and development of tree stands, but also on establishing their assortment and product structure.

2. Material and Methods
The object of the study was the plant resources of boreal forests of the Yenisei Siberia and normative tables for their evaluation.

The results has been obtained by analyzing a complex of standards developed on the basis of a method for laying out sample plots, adapted for each forest resource.
3. Results and Discussion

3.1. Standards for timber assortment estimates

The valuation of logging sites started in Yenisei Siberia in 1936, when the so-called temporary assortment tables for two species, *Pinus sylvestris* L and *Läríx sibírica*, were introduced; the tables were recommended for use by the enterprises of the Krasles trust.

However, the first sufficiently substantiated standards were compiled and published by M S Bogdashin [2]; those were tables for the main coniferous forest-forming species of the Eastern Sayan. The tables were based on a large amount of data, 2 727 model trees; however, the data were collected according to a simplified scheme for measuring trunks and recording defects.

The subsequent development of the regulatory framework for timber assortment estimates was shaped by the requirements of technical conditions and state standards for round wood of both softwood and hardwood species.

Regional standards for timber assortment estimates were developed primarily for the use in forest rich areas: Eastern Sayan, Lower Angara region, and several others. The data on the development of assortment tables for *Läríx sibírica* can be used as an example. The first group of tables developed in the period 1935–1966 includes five standards compiled by B N Tikhomirov, M S Bogdashin, M A Danilin, V M Vorobyova and others. Group two (1974–1976) includes four standards compiled by E N Falaleev, V S Polyakov, L V Donchenko, P I Machernis; group three (1980–1991), five standards compiled by E N Falaleev and S L Shevelev; and group four (1993-2018), four standards compiled by S L Shevelev.

Despite the fact that regional standards covered only those regions where there was intensive forest exploitation, the forest complex in general did not suffer from the lack of regional assortment and product tables, since for a long time general tables developed by N P Anuchin [3] were used throughout the country.

With the depletion of forest resources in accessible areas, the need to move to a regional regulatory base for timber assortment estimates became apparent; the move would have allowed to increase the accuracy of assessments as a result of taking into account the characteristics of tree stands formed in different growing conditions. The creation of such a set of standards should have been based on the selection of areas of uniform forest conditions ensuring a similar state of the stands.

In the development of assortment and product tables, A G Moshkalev [4] used the percentage of output of commercial wood by grade, size category and specific assortment as the main region-forming indicator. He suggested to classify forest fund territories as different forest inventory areas, if the average yields of certain categories of industrial wood differed by more than 6% in forest-rich areas, and by 5%, in forest-deficient areas. Area assignment would be carried out on the basis of a relationship between the output of industrial wood and the average timber metrics of the stands. Such timber metrics, in Moshkalev’s opinion, were: age, basal area, yield class (“bonitet”) and species composition. Those timber metrics are correlated with characteristics used in forest inventory and have an impact on the yield and grade of industrial wood: height/diameter ratio, the length of the knot-free part of the trunks, the presence of curvature, and the presence of stem rot.

Based on this methodology, A E Tetenkin and V E Popov [5] carried out forest inventory zoning of Yenisei Siberia. A set of regional assortment and product tables was developed by employees of the Siberian Technological Institute and the Institute of Forest and Timber of the SB RAS [5] under the supervision of E N Falaleev. Regulations were approved at the federal level in 1998.

However, the significantly delayed practical implementation of GOST 9462-88 [6] and 9463-88 [7] required a partial amendment of regional standards in terms of dividing commercial timber by grades. Such amendment was carried out by the Department of Forest Inventory, Forest Management and Geodesy of the Siberian State Technological University for the most economically important forest inventory area, the southern taiga forests of the Central Siberian Plateau including the Lower Angara region. The result of this work was a forest inventory reference book [8]. The reference book presents...
assortment and product tables, as well as mathematical models used in the development of the standards.

When compiling the reference book, the data were analysed and, if necessary, corrected. First of all, the content of volume tables, which is an important component of assortment tables, was analysed. It turned out that due to differences in the methods of calculating tables used by different authors and the imperfections of the mathematical apparatus used for processing the source data, the volume tables had a number of shortcomings. In order to further check the tables, a graphical and mathematical analysis of changes in the species' heights, species' diameters and species' areas of cross sections was carried out, which confirmed the shortcomings of the volume tables. To correct them, a mathematical adjustment of heights and trunk volumes was made with simultaneous use of data for all ranks of heights. The values of the old species number were calculated based on the adjusted values. The obtained data were analysed, and new mathematical models were selected, if appropriate. Thus, equations were obtained that do not violate the established relationships and provide the smallest residuals, i.e. the difference between the adjusted volumes and heights and the initial values. Based on those, the volume tables were adjusted.

Assortment and product tables were revised in accordance with the requirements of GOST 9462-88 and GOST 9463-88, taking into account the division of industrial wood into three grades. When modelling assortment and product tables, several methods of model selection were tested, applied and analysed. The modelling was carried out using polynomial equations; the choice of the optimal degree of the polynomial was based on the estimates of the coefficients of determination, standard errors and the series of residuals. Table 1 presents the availability of assortment and product tables that have been approved and currently have an official status on the territory of Yenisei Siberia. Over the past decade, the list of tables of this level has not changed [9]. This indicates a lack of interest in improving the accuracy of the assessment of forest resources both among tenants of forest plots (even very large ones) and representatives of state power.

In recent years, a number of tables and mathematical models have been developed in the course of a piloting exercise, but none of them have been officially approved and therefore cannot be considered as a standard.

In practice, due to the absence of specific tables, the same table is often used in different regions. Many tables have one or two versions; however, approved methodologies imply three versions of the same table. Depending on the nature of the information content, each version should have its own field of practical application.

An article by A Z Shvidenko [10] presents in sufficient detail the deficiencies of the currently available set of standards; those are: lack of consistency, different and often insufficient accuracy, outdated content and presentation. When improving the regulatory framework of forest inventory and resource assessment, these shortcomings should be eliminated. In addition, it is possible to expand the content of assortment and product tables, for example, by calculating the potential output of sawn timber from the growing stock [11]. Also, the expansion of the content means not only the improved presentation, but also the improved modelling; the latter will require a single methodology that ensures the consistency and unification of the regulatory framework. Consequences of mass outbreaks of forest pests and forest fires put on the agenda and make it important to create standards for estimation of the product structure of damaged tree stands.
Table 1. Availability of standards by forest inventory areas. The numbers in brackets indicate the types of assortment and product tables following the methodology developed by A G Moshkalev, N P Anuchin, and A F Gurov and approved by the USSR State Forestry Agency on 06.06.1980.

| Forest forming species | Types of tables for the enlarged forest inventory areas |
|------------------------|-------------------------------------------------------|
|                        | North taiga and near-tundra forests | Middle taiga forests | South taiga forests | Forest-steppe | Altai-Sayan mountain forests |

**Assortment tables**

*Pinus sibirica* Du Tour

- - 1; 2; 3 1; 2; 3 2; 3

*Pinus sylvestris*

- 2; 3 1; 2; 3 1; 2; 3 2; 3

*Lärix sibirica*

- 2; 3 1; 2; 3 2; 3 -

*Abies sibirica* Ledeb.

- - 1; 2; 3 - 2; 3

*Picea obováta* Ledeb.

- - 1; 2; 3 1; 2; 3 1; 2; 3

*Bétula pendula* Roth

- - 1 - -

*Pópulus trémula* L.

- - 1; 2; 3 - -

**Product tables**

*Pinus sibirica*

- - 1 - -

*Pinus sylvestris*

- - 1 1 -

*Lärix sibirica*

- 1 1 1 -

*Abies sibirica*

- - 1 - 1

*Picea obováta*

- - 1 - 1

*Bétula péndula*

- - 1 - -

*Pópulus trémula*

- - 1 - -

3.2. Growth tables

Since 1930s, regional tables have been constantly evolving. The tables exist in a variety of forms, and have been compiled for normal and modal stands, for pure and mixed stands, on yield class or forest type basis [12]. The results of an inventory of the regional growth tables are presented in Table 2.

The main disadvantage of this category of tables arises from differences in the methods of their construction. There is also no reliable information about the accuracy of the tables and their regional affiliation.

A team of authors led by A Z Shvidenko [13] carried out the selection, rejection and further modelling of some of the growth tables for the main forest-forming species of Yenisei Siberia. Forest inventory indicators were adjusted using the function of Drakin-Vuevsky or Richard-Chapman.

3.3. Tables for non-timber resource assessments

The lease of forest plots for the purpose of harvesting non-timber forest products, including food, medicinal, and technical products, should be based on the forecast of the change in resources. For certain species of wild, food and medicinal plants there are standards that allow such a forecast. For example, standards exist for the most demanded types of food resources, such as *Pinus sibirica* nuts, *Vaccinium vitisidaéa* L. and *Vaccinium myrtillus* L. Such standards are confined to regions with a low
anthropogenic pressure, but with regional roads, in addition to water transport routes. These regions include the mountainous areas in the south of the Krasnoyarsk Territory and the Republic of Khakassia, the Yenisei Ridge, the basins of the Sym and Kas rivers, and some other.

Table 2. Distribution of regional growth tables by species.

| Forest-forming species | Pinus sibirica | Pinus sylvestris | Lárix sibirica | Abies sibirica | Picea obováta | Bétula péndula | Pópulus trémula |
|------------------------|---------------|-----------------|---------------|---------------|----------------|----------------|----------------|
| Number of tables       | 4             | 10              | 10            | 11            | 4              | 10             | 5              |

Standards for predicting the yield of *Pinus sibirica* were developed for mountain pine forests of the eastern slope of the Kuznetsk Alatau [14]. The standards were built on a forest type basis, they also take into account the age and basal area of tree stands.

To estimate the potential yields of *Vaccinium vitis-idaea*, *Vaccinium myrtillus*, and *Vaccinium uliginósúm* L. [8], the yield category (high, medium and low) and the transition to the so-called “stabilized yield”, that is, the yield at 1% projective cover, were used. This made it possible to identify the relationship between the yield and basal area of a forest stand. As a mathematical model, equations of the exponential type were used. When developing standards for *Lonicera* L. and *Ribes nigrum* L., the yield was determined depending on the size of the bushes and their number within an area.

In addition to the tables estimating potential yield of food resources, tables for estimating the biomass of medicinal plants and the yield of raw materials in the air-dry state (*Bergenia crassifolia* (L.) Fritsch, *Leonurus cardiaca* L., *Lédum palústre* L., etc.) were also developed.

4. Conclusion

Despite the almost century-long history of the existence of standards for the valuation of forest resources in Yenisei Siberia, they cannot be considered as complete and perfect. Such a system does not tolerate static; it should respond dynamically to requests from users and be in line with government interests in improving the accuracy of forest resource assessments. Unfortunately, this important aspect of forest management does not receive adequate attention from both state authorities and tenants of forest areas.

5. References

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