Quantitative and qualitative characteristics of forests in the Baikal Mountain Forest region

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Abstract. The article considers modern approaches to the study of the state of forests of the Baikal Mountain Forest region. All the obtained results of field studies are confirmed by a 13-year period of observations of the changes in the quantitative and qualitative indicators of growth and development of forests, the selected object. During the research, about 17 thousand ha of forest area were surveyed, 1570 permanent test areas were laid. According to the sanitary condition, the share of healthy plantings (class 1) accounts for 76.5%, the 2nd class of resistance (with the presence of small damage and signs of weakening) – 11.1%, the indicators of other classes of resistance of plantings vary from 0.5% to 2.6%. The main sign of damage and weakening of forests are grass-roots fires – 60.3%. The total stock of wood according to the GIL is 2568.9 million m³. Coniferous species have the largest share of the stock of business trees – 94.3%, a smaller share of the stock – soft-leaved – 5.6%. The obtained data allow us to develop measures for rational forest management for part of the forests of the Republic of Buryatia, the Trans-Baikal Territory and the Irkutsk Region.

1. Introduction
Due to the sharp reduction of forest vegetation on the globe, there is a need for regular monitoring, due to its continuous change, due to natural and anthropogenic reasons. The current stage of development of environmental monitoring of forests aims to develop a strategy for rational forest management and environmental protection. To achieve this goal, it is necessary to combine various types of monitoring and research methods.

The most important element of forest policy is the state inventory of forests, which is measures to check the condition of forests, their quantitative and qualitative characteristics, in order to timely identify and predict the development of processes that have a negative impact on forests and information support of management in the field of use, protection, protection, forest reproduction, as well as in the field of federal state forest supervision (forest protection).
The concept of "biological diversity" includes all the diversity of life forms, their ecological functions and genetic diversity [1-3]. In forests, biological diversity allows species to evolve and dynamically adapt to changing natural conditions (including climatic ones), preserve the ability to select trees and improve tree species (to meet human needs for goods and services and changing operational requirements for them), as well as maintain their functions in the ecosystem [4].

Monitoring of biological diversity (and changes caused by forestry and other types of activities) plays an important role in assessing the effectiveness of management and changes accumulated during forest use. However, such an assessment is associated with conceptual and practical difficulties. They are not specific to biological diversity as such, but are caused by general problems of accounting for characteristics with complex and extremely variable target parameters.

Biological diversity can be assessed at a variety of levels, each of which requires the use of different assessment methods. These levels include ecosystems, landscapes, breeds, populations, individuals, and genes. There are diverse and complex relationships between these levels. Since biological diversity encompasses the diversity of all forms of life, it is possible to assess and monitor only certain aspects of it or individual, specific indicators. There is no single, objective criterion for assessing biological diversity – there are only indirect signs that are suitable for specific and limited tasks due to circumstances. The species richness, for example, varies enormously from boreal to tropical forests. It is the change in biological diversity that is important for monitoring and developing forest policy, which involves identifying relevant criteria and tracking them over time [5, 6].

Baikal forests, being one of the most important components of a special and independent Baikal biogeographic region, perform water protection, water regulation, soil protection, climate control, sanitary and hygienic, recreational and other environmentally significant functions. Many of them do not have cost indicators and are often not less, but much more important than wood resources, which in everyday consciousness are associated with the possibility of obtaining high-quality wood. Therefore, economic activity here should be based on the principles of maximum complexity and rational use of all the useful qualities of forest ecosystems. With this in mind, the main goal of forestry practice in the region should be to achieve environmental sustainability of the natural complex in all its biological diversity. This means that the management of forest resources should ensure the permanent, close to natural, functioning of forest ecosystems, maintain

Biological diversity evaluation may be conducted at different levels using adapted and fundamentally different methods. The scale of the study may be as different as biosphere, continent, vegetation zones and sub-zones (geographical or climatic), region (sector), landscape, ecosystem, parcel, etc.

The existing shortcomings in the management system of the timber industry, control and supervision over the implementation of legislation in the field of forest relations, in the organization and conduct of protective and reforestation works, the lack of technologies for waste processing prevent the full-fledged renewal of forests (the areas of logging that exceed the areas where their restoration is carried out), which directly contradicts the principles of sustainable forest management, which is the basis for the development of a green economy [7].

Many scientists are engaged in this problem, and the works of Alekseev et al. [6, 8], Suslov AV and Mullagalieva R Z [9], G I Valieva [10], V V Pakhuchiy et al. [11], Kositsyn [12] are of particular interest [13]. All these works are aimed at considering the quantitative and qualitative characteristics of forests, with confirmation of the relationship between tax indicators, in the field of developing a system for monitoring the work of the state forest management.

In the Baikal Mountain Forest Region, such studies are being conducted for the first time as part of the state forest inventory. The features of the structure are revealed, and a quantitative and qualitative assessment of stands is given, depending on the types of forest and climatic conditions. The presented study of taxation indicators and information about the state of forests will allow us to conduct a comparative analysis of the forest development project and improve the efficiency of forest management in the Baikal Mountain region.

The purpose of our work is to establish and identify peculiarities of changes in the quantitative and qualitative potential of the forests of the Baikal Mountain Forest Region.
2. Methods and materials

Many scientists and specialists believe that there is currently no reliable data on the forests of Russia as a whole, and on the subjects of the Russian Federation. This is due to the lack of state forest management and a lack of forest accounting. It is possible to update information about the forests of the Russian Federation only at the expense of the state forest inventory. The work on the state forest inventory began in 2007, but due to the lack of a well-developed methodology, the data obtained for individual subjects of the Russian Federation cause many complaints.

Conditions and methods of research. The total area of the forest area is 20.24 million ha (in accordance with the state forest inventory (hereinafter - SFI)), including:

- Irkutsk region – 1.81 million ha;
- Republic of Buryatia – 13.64 million ha;
- Transbaikal Territory – 4.79 million ha.

The Baikal Mountain Forest region is part of a mountainous zone with altitudinal zonation, which occupies a significant part of the south of Eastern Siberia and the southwestern part of the Far Eastern Federal District. The relief is characterized by powerful mountain ranges and vast deep and, sometimes, almost closed intermontane basins. The Baikal Mountain region is characterized by significant elevation above sea level, and as a result, a very low average atmospheric pressure [14, 15].

The climate of the Baikal Mountain Forest region is sharply continental with large annual and daily fluctuations in air temperature and an uneven distribution of atmospheric precipitation over the seasons. The sharply continental climate inherent in this forested area in the central part of the Asian continent is characterized by cold winters and hot summers. Low winter temperatures can be easily tolerated because of the dry air. Summers are short, with hot days and cool nights, with heavy rainfall in July and August. Autumn is short and dry with sharp daily temperature fluctuations and often with early frosts [16, 17].

The Baikal Mountain Forest region includes the territory covered mainly with coniferous plantations. The main forest-forming species here are pine of the III-IV growth class, larch of the III-IV growth class, as well as birch and aspen of the II-III growth class with a predominance of such groups of forest types as lichen, cereal-forb, lingonberry and green moss-lingonberry. On the steep slopes of the ridges, in the river valleys and on individual hills, stony-skeletal soils, barely covered by the humus horizon, lie, in some places there are placers of rock-junk. The soil-forming process on these soils is in its infancy. Information on the areal characteristics of the forest area is given in table 1.

A brief description of the object of research allows us to draw the main conclusion about the growing conditions of such forest-forming species as Siberian larch (\textit{Larix sibirica} Ledeb), common pine (\textit{Pinus sylvestris} L.) and Siberian pine (\textit{Pinus sibirica} Du Tour) of low growth classes, as well as cedar elfin (\textit{Pinus pumila}) and various types of shrub birch [7, 9, 10]. Each of the tree species occupies its own ecological niche, due to the combination of soil, hydrographic, zonal, altitude and other characteristics.

| Name of the subject of the Russian Federation | Forest area, thousand hectares |
|---------------------------------------------|--------------------------------|
|                                             | Total | Including forest | Including lands on which forests are located |
| Irkutsk region                              | 1805.6 | 1656.6          | 1388.2          |
| Republic of Buryatia                        | 13644.7 | 11438.9        | 10356.0         |
| Zabaikalsky region                          | 4787.2 | 4602.4          | 4271.1          |
| Total for the forest region                 | 20237.5 | 17697.9        | 16015.3         |

3. Results and discussion
Materials for determining the quantitative and qualitative characteristics of forests were collected during field work on the network of permanent sample areas of the state forest inventory. The number of permanent sample plots of the state forest inventory is presented in table 2.

In the Transbaikal mining and permafrost area, the SFI works to determine the quantitative and qualitative characteristics of forests were carried out in 2007-2019. Over 13 years, 1,570 permanent plots were established. The calculation of the number of permanent sample plots for the forest area was carried out on the basis of the error in determining the total timber stock established by the Methodological Recommendations for the State Inventory of Forests, which is 5% (for a confidence level of 95%) [8].

Table 2. Information on the number of permanent test plots laid in the territory of the forest region.

| Name of the subject of the Russian Federation | Number of permanent test plots by year of establishment, pcs. |
|---------------------------------------------|------------------------------------------------------------|
|                                            | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Total |
| Irkutsk region                             | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 79   | 0    | 20   | 48   | 147  |
| Republic of Buryatia                       | 0    | 0    | 0    | 0    | 0    | 0    | 33   | 264  | 301  | 292  | 34   | 169  | 1093 |
| Zabaikalsky region                         | 0    | 94   | 145  | 0    | 86   | 0    | 0    | 0    | 5    | 0    | 0    | 330  |
| Total for the forest region                | 0    | 94   | 145  | 0    | 86   | 0    | 0    | 33   | 264  | 380  | 297  | 54   | 217  | 1570 |

For each forest region (forest land of the region), in our case for the Baikal Mountain Forest region, the calculation of the number of permanent sample plots was carried out on the basis of using the taxation indicators of forest inventory allotments established during forest inventory using mathematical relationships based on the planned accuracy of determining the total timber stock, variance of stocks and their joint variation in the corresponding forest stratum. The quantitative and qualitative characteristics of forests in the state forest inventory are determined on the basis of a sample method of observation in accordance with mathematical statistics and the use of regular relationships between the inventory indicators of forest plantations. On test plots, repeated observations of changes in taxation indicators will be repeated every 10-15 years.

Observation data on the state of quantitative and qualitative indicators of the Baikal Mountain Forest region are made for the first time. Based on the establishment of permanent test plots, the main indicators are: data on model trees; tree data - tree number, tree coordinates, species, age, diameter, height of the beginning of the living crown, crown projection, type of damage to the tree, area and degree of damage, vitality of Iufro; soil characteristics, the presence of erosion; characteristics of berries, mosses, undergrowth and undergrowth, as well as dead wood, deadwood and stumps.

According to SFI data, in the Baikal Mountain Forest region, the total forest area is 20237.5 thousand ha, including forest area – 17697.9 thousand ha, or 87.5%. The area of land on which forests are located is 16015.3 thousand ha, which is 90.5% of the forest area. Conifers are predominant both in terms of stock (79.2%) and occupied area (60.3%). The second most represented are soft-leaved species, their share in the reserve is 19.7%, in terms of area – 28.6%. The third in terms of representation are other tree species, their share in terms of stock is 1.1%, in terms of area – 3.2%. Hardwoods are the least represented, their share is, respectively, 0.1% in terms of stock and 0.1% in terms of the occupied area (table 3).

The average formula of the species composition of forest plantations in the Baikal Mountain Forest region, in fractions of composition units, has the form: 3.8%S-2.8%L-1.2%B-0.9%C-0.7%Os-0.3%P-0.2%E-0.1%Kst. In the forests on the territory of the plantations of the Baikal Mountain Forest region, ripe and overmature stands, as well as young stands, prevail. The first in terms of representation is the area of mature and over-mature stands – 32.3% and 58% of the stock. A large number of young growths
is a consequence of forest fires on the territory of the Baikal Mountain Forest region, and their share is
31.8% by area and 9.8% by reserve (table 4). The main reason for the accumulation of mature and over-
mature stands is the low level of use of the allowable cut.

| Tree species group | Stock of wood | Forest area, thousand ha |
|--------------------|---------------|--------------------------|
|                    | Total, thousand m³ | Average, m³/ha |
| Conifers           | 203301.1       | 191                      | 10669.8 |
| Hardwood           | 3243.1         | 225                      | 14.4    |
| Soft-leaved        | 503021.1       | 100                      | 5053.4  |
| Other tree species (Bird cherry, Rowan, etc.) | 29341.5 | 53 | 557.7 |
| trees with a diameter of 6 cm or more are absent | - | - | 1402.6 |
| Total              | 2568906.8      | 145                      | 17697.9 |

Favorable forest conditions of the Baikal Mountain Forest region are favorable for the formation of
medium-productive plantations (91.1%). The largest stock is concentrated in medium-productive
plantations (96.8%). The stock of low-productive plantations is much less (2.4%). The stock of highly
productive plantations is several times less and is only 0.8% of the total. In general, the tree species of
the Baikal Mountain Forest grow in favorable conditions. The distribution of forest area and stem wood
stocks by productivity is presented in table 5.

| Productivity         | Total timber stock, thousand m³ | Forest area, thousand ha |
|----------------------|---------------------------------|--------------------------|
| high- productivity (Ia-II bonitet classes) | 20434.4 | 79.8 |
| medium- productivity (III-V bonitet classes) | 2485787.3 | 16124.3 |
| low-productivity (Va-Vb bonitet classes) | 62685.1 | 1493.8 |
| Total                | 2568906.8 | 17697.9 |

The biodiversity of forest stands is an important indicator of their state; it significantly affects the
sustainability of stands and the performance of forest ecosystems functions that are not related to wood
production. Forest ecosystems of the Baikal Mountain Forest region are not distinguished by large
species formation of rocks.

On 51.8% of the forest area, species diversity is characterized by the presence of 2-3 tree species,
20.1% – 4-5 species, and on 19.7% of the forest stand is represented by one species. Almost the entire
spectrum of forest-forming species is found on an insignificant area of 125.4 thousand ha, which is 0.7%
of the area of forest land. Trees above the threshold value (12 cm) are absent in 7.7% of the forested
area (figure 1).
The state of the forests was determined by the following factors, such as the resistance class of the stand, damage to the stands, and the presence of dead wood.

Healthy plantations (class 1) are represented on the vast territory of the Baikal Mountain Forest region, the area of which is 13558.5 thousand ha (76.5%), the 2nd class of resistance was noted in plantations on the territory of 1961.4 thousand ha, which is 11.1% of the forest area. Indicators of other resistance classes of plantings vary from 0.5% to 2.6% (figure 2).

According to the GIL data, 60.3% of the total number of damaged trees in the Baikal Mountain Forest region were damaged by ground fires, and this is the maximum value of this indicator. The impact of frost damage is associated with damage – 14.4% of trees, with mechanical damage – 13.1% (this is due to large economic activities in the forest region). The influence of other factors is less significant.

The total timber stock according to the State Institute of Forestry is 2568.9 million m³. In the general stock of wood, coniferous wood predominates. According to the age structure, mature and over-mature stands have the largest stock. The timber stock of commercial trees growing in the Baikal Mountain Forest region is 1716.1 million m³, semi-timber – 464.3 million m³, wood – 388.5 million m³. The largest share of the stock of business trees is coniferous – 94.3%, the smaller share of the stock is soft-leaved – 5.6%. The largest share of the stock of business trunks in terms of constituent species falls on pine – 42.9%, larch – 32.9%, fir – 3.8%, birch – 3% and spruce – 2.6%. Among wood-burning trees, soft-
leaved species predominate – 64%. The technical suitability of the coniferous economy is much higher than that of deciduous ones.

4. Conclusion

During the conducted research, the following conclusions can be drawn:

1. Forest ecosystems of the Baikal Mountain Forest region do not differ in large speciation of rocks.
2. In the forests on the territory of the plantings, ripe and over-ripe plantings, as well as young plants, predominate.
3. Healthy plantings (class 1) are represented on the vast territory of the studied area, the area of which is 13,558.5 thousand ha (76.5 %), the 2nd class of stability is noted in plantings on the territory of 1961.4 thousand ha, which is 11.1% of the area of the forest area. Indicators of other classes of plant resistance vary from 0.5% to 2.6%. In this forest area, 60.3% of the total number of damaged trees were damaged by grass-roots fires.
4. The largest stock is concentrated in medium-productive plantings (96.8%). The total stock of wood according to the GIL is 2,568.9 million m³. Coniferous species have the largest share of the stock of business trees – 94.3 %, a smaller share of the stock - soft-leaved - 5.6%.
5. The main quantitative and qualitative characteristics of forests allow them to be used for the development of measures for the rational use and improvement of forestry culture for part of the forests of the Republic of Buryatia, the Trans-Baikal Territory and the Irkutsk region.

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