Digital platform for forest resources monitoring in the BAIKAL natural territory

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Abstract. Forest is the most important natural resource of the Baikal natural territory (BNT), which ensures sustainable development of the ecological system of the Lake Baikal, performing water protection, soil protection and water regulation functions. The article describes the issues of transition to a new technological order - the creation of a digital monitoring platform to support the rational use of forests. We formulate characteristics of the current state of forests and analyze the problems of forest resources monitoring in the BNT. We consider the types of digital platforms of different levels and propose basic requirements for forest digital monitoring.

1. Introduction
Forest resources monitoring is a system for observing the current state, assessing and predicting changes under the influence of natural and anthropogenic factors, and providing reliable information to minimize the adverse effects of environmental changes. Monitoring in the current format is accompanied by a number of difficulties that complicate the analysis of information. They can be overcome through modern digital technologies that allow integrating the information and analytical resources to support decision-making on forest resources in the BNT.

2. Federal forest monitoring
State environmental monitoring of forests at the federal level collects raw data in various formats. The information comes from the forest inventory data, forest plans of the Russian Federation regions, forestry regulations of forestry, acts of forest pathology surveys, remote sensing data. The Federal Forestry Agency, the Russian Forest Protection Center, and the Avialesokhrana Federal State Institution maintain different thematic databases on forest resources. Information on forests is collected by the departments of the Ministry of Emergency Situations and the Ministry of Internal Affairs of Russia, as well as the environmental prosecutor's office while monitoring fires at the regional level. The monitoring results are published for the RF regions and for Russia as a whole in the form of an annual report containing analytical information, tables, and thematic maps.

The executive authorities of the RF constituent entities post forest plans and forestry regulations on their websites, where one can find the data on forest areas of different species and age composition, permitted cut, burned-out areas etc. in text form. Acts of forest pathology surveys are also available there in the form of scanned paper documents. However, these data are not always relevant, the forms are regularly changed, and these changes can be unavailable or published only in the form of orders.
Scarcity of open data on forest resources does not provide an accurate picture of their condition, there is no transparency of activities in the forests. For the lands of the forest fund of the Russian Federation, there is no information on the network of compartments with numbering of and geographic references to the latter in a form suitable for use. At the same time, all economic activities carried out in forests are tied to forest compartments. For some regions, the schemes of the compartments network are posted on the websites of regional ministries in the form of annexes to forest plans and forestry regulations only in the format of raster maps. Information about the places of planned felling, forest pathology surveys and other forestry activities, about the boundaries of leased forest areas is often available only in text format, in the form of lists of block numbers.

3. Forest resources of the BNT

Under the provisions of the Federal Law "On the protection of the Lake Baikal", the Baikal natural territory is located on the territory of three regions of the Russian Federation: the Irkutsk region, the Republic of Buryatia, and the Trans-Baikal Territory, and includes the Lake Baikal, its water protection zone, catchment area, specially protected natural areas, areas adjacent to the lake with a width of up to 200 kilometers to the west and northwest of it.

The BNT's forest resources are one of its most significant natural wealth. Forests stabilize the unique ecological system of the Lake Baikal, perform water protection, soil protection and water regulation functions, help to prevent and weaken erosion processes. About 8350.7 thousand hectares of the area of BNT lands are covered with forest vegetation, 92% of the area is covered by coniferous and deciduous trees [1].

According to the State report "On the state and protection of the environment of the Irkutsk region in 2019", as of 01.01.2020, 80.4% of the region (62 million hectares) are covered with forests. The forest fund is represented by 72.6% of plantations with a predominance of conifers, 19.6% - soft-leaved trees, and 7.7% of the land is occupied by shrubs. Forest management in the Irkutsk Region is carried out by the Ministry of Forestry of the Irkutsk Region, the Ministry of Natural Resources and Environment of the Russian Federation (forests located on the lands of specially protected natural areas), and the Ministry of Defense of the Russian Federation. Also, in the region there are urban forests on an area of 50.1 thousand hectares, which are under the jurisdiction of local authorities. The total stock of timber in the stands of the Irkutsk region is 8567.9 million m³. In 2019, according to official data, 31.7 million m³ of wood were cut in the Irkutsk region, including 27.4 million m³ cut as ripe and over-mature plantations.

According to the State report "On the state and protection of the environment of the Republic of Buryatia in 2019", the forests occupy 84.8% of Buryatia’s territory, or 29.8 million hectares. The species composition of the stands is formed by coniferous trees on an area of 15.5 million hectares, 1.8 million hectares of deciduous trees, 0.3 thousand hectares of hardwood, and 3.2 million hectares of shrubs. The average age of forest plantations is 105 years. In 2019, 2765.9 thousand m³ of timber were harvested. The area of damaged and dead stands was 219.5 thousand hectares. Reforestation work was carried out on an area of 30 thousand hectares, with artificial methods applied only on 802.5 hectares.

According to the State report "On the ecological situation in the Trans-Baikal Territory in 2018", the total forest area in the region amounted to 34.1 million hectares. Most of the area is covered by forest dominated by light coniferous taiga; steppe vegetation prevails in the southeast. The distribution of forests over the region is uneven, which is associated with the difference in physical, geographical, climatic and soil conditions and the influence of human activities over a long period of the territory development. Forested land occupies 87% of the total area. Extremely unfavorable growing conditions affect the species composition of forests: 3.3 million hectares (11.8%) are occupied by shrubs (birch, dwarf pine, willows).

The BNT forests constantly experience negative impacts caused by forest fires, diseases, phytophagous insects, unfavorable weather conditions, soil-climatic and anthropogenic factors, which
lead to the loss of biological stability of the forest. To minimize the influence of unfavorable factors and restore the forests, it is necessary to continuously monitor and assess their condition [2-3].

Analysis of the existing forest monitoring systems of the BNT revealed the following characteristic features:

- territorial distribution and multiplicity of monitoring participants and their software and hardware observation systems;
- systems for obtaining and processing spatio-temporal forest monitoring data are sectoral and local, not coordinated with each other in parametric, chronological and other aspects;
- low relevance of the basic forest management information (the average age of materials on the BNT is over 10 years);
- lack of a unified system for storing forest monitoring data, various types of storage (in paper or digital form) and their different formats;
- use of various coordinate systems in project documentation and forest management plans;
- lack of an information system for integrated environmental monitoring, assessment and analysis of the state of forest resources;
- limited and poor promptness of access to forest monitoring data, which complicates management decisions and interdisciplinary scientific research.

This substantiates the relevance of digitalization of environmental monitoring in the BNT, which implies introduction of cyber-physical systems, transition to a digital method of data transmission, replacement of physical or analog resources with digital ones, and creation of digital platforms based on service-oriented, end-to-end technologies, cloud and distributed computing, Big Data.

4. Digital transformation of monitoring

Digital transformation is a leading trend in modern technological development. This is due to the improvement of digital technologies, creation of 5G networks, an increase in the capacity of computing clusters, development of the Internet of Things. The digital paradigm is based on the principle "everything as a service", focused on sharing the information resources, taking into account the requirements of interoperability and security [4-5].

The digitalization of forest monitoring in the BNT is carried out using digital platforms. Digital platform is a system for uniting forest monitoring participants in one information environment, where they use digital data processing technologies to improve the efficiency of services and reduce transaction costs [6-7].

The BNT forest digital monitoring platform is based on the following key principles:

- creation of digital platforms of basic types;
- creation of thematic WPS-services that solve applied forest-related problems (detection of cuttings, forecasting the spread of fires, determination of the species composition of forest stands, etc);
- integration of schemes and methods for forest monitoring;
- formation of a large volume of multi-format thematic spatio-temporal data;
- receiving data from sensors, IoT-devices, remote sensing, lidar surveys for registration of forest monitoring parameters in a quasi-continuous mode;
- use of mathematical modeling to obtain forecasts of the forest resources dynamics under the influence of natural and anthropogenic factors;
- storage of monitoring data in a cloud network of distributed data storage and processing centers;
- creation of an information and analytical environment for a comprehensive assessment, analysis and forecasting of significant environmental problems of forest resources, using information and mathematical methods, modern distributed service-oriented and end-to-end technologies for processing spatio-temporal data;
- creation of infrastructure for information exchange between the monitoring participants.
The digital monitoring platform for the BNT forest resources covers three types: instrumental, infrastructural and application platforms [8-9].

The instrumental digital platform contains instrumental software to support participants' access to the development and debugging of applied information and software and hardware monitoring by providing standard functions, universal services and their data processing interfaces.

The infrastructural digital monitoring platform includes:
- a catalog of services for the monitoring data processing, which ensures the exchange of information about the existing services between the participants of the digital platform;
• a catalog of data services, which ensures the exchange of information about the existing data provision services between the participants of the digital platform;
• basic spatial data providing unified reference books and classifiers;
• basic spatial services that support work with the basic spatial data;
• scalable computing resources dedicated to performing services;
• a system for scheduling and executing services on distributed computing resources;
• service for publishing data in the form of maps and diagrams.

The applied digital platform consists of digital environmental monitoring geoportal, services for providing the monitoring data, and thematic WPS services [10]. The data processing services must be an implementation of the OGC WPS standard.

The necessary conditions for digital environmental monitoring are formalization of requirements for digital spatial data and the services for their processing, development of tools for their creation, and provision of computing resources.

Conclusion
Formalization of requirements for digital spatio-temporal data and services for their processing, development of tools for their creation, provision of computing resources is a prerequisite for digital environmental monitoring. The proposed technology allows to integrate information and analytical resources to support decision-making on the environmental problems in the Baikal natural territory.

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