A platform approach to the organization of digital forest monitoring of the Baikal natural territory

I V Bychkov, G M Ruzhnikov, R K Fedorov and A K Popova
Matrosov Institute for System Dynamics and Control Theory SB RAS, 134 Lermontova Street, Irkutsk, 664033, Russia

E-mail: chudnenko@icc.ru

Abstract. This paper describes a platform approach to the organization of digital environmental monitoring of the forest resources of the Baikal natural territory (BNT), some characteristics of the current state of forests in the BNT and schemes of organization of state environmental monitoring in a traditional format. Some features and problems of forest resources monitoring of the BNT that complicate decision-making are formulated. Some basic requirements for digital forest monitoring and types of digital platforms of different levels are considered.

1. Introduction
Forests of the Baikal Natural Territory (BNT) are losing their integrity due to regular fires, illegal logging, and insect damage. Full-fledged monitoring of forest resources can be implemented using modern digital technologies that allow integrating information and analytical resources to support environmental decision-making for the BNT.

2. Study Area
The Baikal Natural Territory includes Lake Baikal, the water protection zone adjacent to Lake Baikal, its catchment area within the territory of the Russian Federation (RF), adjacent specially protected natural areas, and an area up to 200 kilometers wide to the west and northwest from Lake Baikal.

The unique landscapes of the BNT are protected by the «UNESCO Convention on the Protection of the World Cultural and Natural Heritage", which requires that the territory be preserved in its natural form. The BNT is located in the areas of three constituent entities of the Russian Federation: 28.5% in Irkutsk region, 57.1% in the Republic of Buryatia, and 14.4% in the Trans-Baikal Territory. The BNT area is 386 thousand km², which exceeds the total area of all reserves and national parks in Russia (317 thousand km²). There are 31 specially protected natural areas in the BNT, including 3 reservations, 2 national parks, 5 natural reserves, 6 recreational areas, and more than 120 natural monuments [1].

One of the most important natural resources of the Lake Baikal basin is the forest resources, which are a complex biosphere resource. The forests stabilize and optimize the natural environment of the unique ecological system of the lake, performing soil and water conservation, recreation and cultural values. The forests have a significant impact on preventing and weakening of erosion processes.

The area of land covered by forest vegetation within the BNT is 8517.73 thousand hectares, 95% of the area is covered by forests and 5% by shrubs. The forests are represented by two groups of forest-
forming species: coniferous and deciduous. Among the coniferous forests, pine (Pinus sylvestris) and larch (Larix) forests are equally represented: 25% each. Siberian pine forests (Pinus sibirica) are also widely represented: 17%. Among the deciduous forests, birch forests (Betula) prevail: 16%.

On 01.01.2020 on the territory of Irkutsk region, one of the main subjects of the BNT, wooded lands occupied 62 million hectares, which is 80.4% of the region's territory. The area of mature and overmature forests of the main forest-forming species is 24.2 million hectares, or 35.8% of the lands covered with the main forest-forming species. The share of woodlands with a predominance of conifers accounts for 84.1% of the area of mature and overmature stands. The total timber stock of the wood reserve of Irkutsk region is 8567.9 million m$^3$. The annual growth of all plantations in Irkutsk region is 111.7 million m$^3$, including 84.2 million m$^3$ of coniferous stands.

Thirty one and seven tenths of a million m$^3$ of marketable timber were harvested in the forests of Irkutsk region in 2019, including 27.4 million m$^3$ during the mature and overmature stands felling (clear and selective cuttings). 1.5 million m$^3$ were harvested during sanitary felling, including clear and selective sanitary cuttings.

The forests of the Republic of Buryatia, another main subject of the BNT, occupy an area of 29810.6 thousand hectares, which is 84.8% of its entire territory. The species composition of the forested area is mainly represented by conifers in an area of 15461.4 thousand hectares (75.3% of the forested area); deciduous in an area of 1834.2 thousand hectares (8.9% of the forested area); hardwood in an area of 0.3 thousand hectares (0.001% of the forested area), and shrubs in an area of 3242.1 thousand hectares (15.8% of the forested area). In 2019, there were 219.5 thousand hectares of damaged and dead plantations in the forest lands [2].

The environmental problems of the BNT forest resources include:
- reduction of the forest stocks due to illegal logging, fires, and tree diseases;
- increased insect damage of the conifers;
- lack of a consistent system of reforestation and forest care, which leads to forest depletion.

The BNT forests are constantly negatively affected, with the result that they gradually lose biological stability.

3. Forest resources monitoring

3.1. State level

Environmental monitoring in the Russian Federation is carried out by state environmental monitoring, an important part of which is monitoring of the forest resources. The system of state environmental monitoring includes two subsystems associated with regular monitoring of the forest state: forest pathological monitoring and forest reproduction monitoring. The state forest pathological monitoring covers the supervision of the sanitary and pathological condition of forests (tree diseases, insect damage, and weather conditions). The forest reproduction monitoring is focused on accounting for lands requiring reforestation, assessment of changes in forest areas, the characteristics of seed and planting material, as well as the effectiveness of the measures.

Information to the forest monitoring subsystems is obtained from the State Forest Register, statistical reports, forest inventory data, Forest Plans of the constituent entities of the Russian Federation, forestry regulations of forestries, forest pathological survey acts, and Earth remote sensing data. Monitoring results are published in the form of an annual report containing analytical information, data tables, diagrams, and thematic maps.

Information about the state of forests is fed into several federal databases:
- Automated information system "State Forest Register" (AIS SFR, aimed at automating document flow and reporting collection).
- Unified State Automated Information System for Wood Accounting and Transactions.
- Forest Fires Remote Monitoring Information System (ISDM-Rosleskhoz).

Access to the first two information systems is limited or closed for third parties: forest accounting data from the first one are not publicly available, the open data section in the second one is represented
by tables where information about leased forest areas, timber transactions, etc. is provided in text form.

3.2. BNT level
Currently, in Irkutsk region long-term planning for the development of the forestry industry is regulated by the following three documents: the regional "Forest Plan" developed for 2019-2028, the State Program of Irkutsk region "Development of Forestry" for 2019-2024, and a five-year forestry industry development plan commissioned by the Governor of the region in 2019-2020. The Republic of Buryatia and the Trans-Baikal territory also have their own forest plans and programs for the development of forestry.

The first two normative acts define the strategic and tactical tasks of the region's development, respectively. The Forest Plan specifies the parameters for forestry enterprises, the State Program is designed to achieve certain results and protect the forest resources of the region. The five-year forestry industry development plan includes investment projects aimed at improving the technical level of enterprises and creating new industries with a focus on deep processing wood. In fact, the documents overlap: for rational use of forest resources up-to-date forest inventory data are required, together with an increase in the reforestation and fire-fighting measures [3].

![Figure 1. Forest management scheme at the BNT level.](image-url)

On the Baikal natural territory, the state forest monitoring subsystems are assigned to the regional branches of the Federal Budgetary Institution "Roslesozashchita", the Forest Protection Center of
Irkutsk Region, the Forest Protection Center of the Trans-Baikal Territory, and the Forest Protection Center of the Republic of Buryatia, which perform regular and selective ground and remote monitoring of the sanitary and pathological state of forests, populations of pests, and assess the general condition of forests.

Scientific monitoring of the Siberian forests is carried out by the institutions of the Ministry of Education and Science. Research at the institutes of the Siberian Branch of the Russian Academy of Sciences and universities covers the problems of rapid detection of fires and cuttings from space images, predicting the direction of fire spread in the forest, detecting and mapping anthropogenic impacts on the forest, analyzing the dynamics of forest stand productivity, assessing the impact of climatic factors, calculating the volume of carbon sink, etc.

The analysis of the existing systems for monitoring the state of forest resources of the BNT made it possible to highlight their characteristic features:

- a large number of participants and users, localization of departmental observation schemes;
- low updating of official forest management information (the average age of materials on the BNT is more than 10 years);
- territorial distribution of software and hardware complexes of the monitoring systems and the generation of static, uncoordinated data;
- lack of a unified monitoring data storage system, as well as different types of storage (in paper and digital form) and different formats;
- lack of an information system for integrated environmental monitoring, assessment and analysis of the state of the forest resources in a continuous mode;
- use of various coordinate systems in the project documentation and forest management plans;
- poor promptness and limited access to the forest resources monitoring data, which complicates managerial decisions, as well as interdisciplinary research.

All this justifies the introduction of digital technologies into the monitoring of the BNT forest resources, which will allow integrating the information resources of monitoring participants, replacing the analog resources with digital data. The digital forest monitoring is organized according to an "everything as a service" principle, with the focus on sharing the digital information resources taking into account the requirements of interoperability and security [4-5].

4. Digital platform

The digital environmental monitoring of the BNT forests [6] should be based on (Figure 2):

- Creation of basic types of the digital platform (DP) for distributed environmental monitoring of the BNT forests, which allows one to automate the recording of forest data and their transferring to the centres for processing interdisciplinary spatial and temporal data (DPC) in a quasi-continuous mode (24/12/365).
- Interdisciplinary integration of schemes and methods of the forest monitoring participants.
- Creation of a cloud-based data centre network for the BNT forests.
- Increasing the reliability of forest monitoring data due to their multiplicity and complexity of the receiving sensors, measuring instruments, remote sensing data from a distributed network.
- Formation of an information and analytical system for assessing, analysing, and predicting of forest resources problems in the BNT using information and mathematical methods, modern distributed service-oriented and end-to-end information technologies for the processing of large spatial and temporal data on the environmental parameters of the BNT forests.
- Creation of thematic services to identify and assess the dynamics of the forest resources based on series of remote sensing data under the influence of destructive factors (including fires, felling, insect outbreaks, technogenic pollution, and abnormal meteorological phenomena).
- Extrapolation of the results of a comprehensive analysis of the environmental characteristics of BNT forests with similar landscape conditions.
- Information availability of scientific research results for forest resources management of the BNT.
Figure 2. Components of digital forest monitoring.

The digital forest resources monitoring of the BNT involves the use of a digital platform – a set of digital data, models and tools informationally, algorithmically, and technologically integrated into a single automated environment designed for forest management with stakeholder engagement in the BNT monitoring [7-10].

The platform approach to the organization of digital forest resources monitoring of the BNT is based on the following basic types: Instrumental Digital Platform (IDP), Infrastructure Digital Platform (InDP), and Applied Digital Platform (ADP).

Figure 3. Participant Interaction Scheme for the Digital Platform.
4.1. Instrumental digital platform

The Instrumental Digital Platform (IDP) for monitoring of the BNT forest resources consists of a software to support the development and debugging of applied information and software-based monitoring tools providing standard functions, data processing interfaces, and universal services. The IDP consists of tools for creating the main components: standard geoportals, data processing services based on open standards and their compositions [11], services for receiving and transferring data between the participants (Figure 4).

![Diagram of Instrumental Digital Platform](image)

**Figure 4.** Main components of the instrumental digital platform.

The use of the IDP reduces the time required to create applied DP by using ready-made tools. Such services can be created in various development environments and operating systems; their integration into a single system is made through virtualization mechanisms. The scaling function of the information and computing resources makes the IDP highly beneficial for collective use.

4.2. Infrastructure Digital Platform

The Infrastructure Digital Platform (InDP) for forest resources monitoring of the BNT is formed on the basis of the IDP. It is designed to develop thematic services for processing and storing data based on a geoportal that automate various aspects of digital forest monitoring. The thematic service solves the problems of one direction of digital monitoring (modelling the dynamics of tree growth, forecasting the fire spread, reforestation planning, etc.) by using spatio-temporal data. The functionality of such a service is determined by the type of information being processed (geospatial, navigation, biological, etc.).

The InDP should contain (Figure 5): catalogs of services for providing and processing data from monitoring participants; basic IDP spatial services; thematic data that form unified directories and classifiers; services for publishing data in the form of maps and diagrams; a system for scheduling and executing services on distributed computing resources; scalable computing resources of service execution. This allows one to construct application services and fill them with BNT forest monitoring data.
4.3. **Applied Digital Platform**

The Applied Digital Platform (ADP) for monitoring of the BNT forest resources operates with processed data at the level of a separate group or type of monitoring as a whole. The ADP supports the algorithmic exchange of the services between independent participants using a common information environment and information technology infrastructure. The ADP has its effect not due to the use of the processed data stream (as in the InDP), but due to a combination of many such flows within one information environment.

The applied digital platform for environmental forest monitoring includes:
1) geoportal for digital forest monitoring;
2) services for providing monitoring data;
3) tools to provide thematic WPS services.

**5. Conclusions**

The above-proposed platform approach can lead forest resources monitoring to a new level. Digital monitoring consists of end-to-end technologies, a service-oriented paradigm, big data and their content in the form of mathematical and computer models of natural processes, complemented by tools for collecting and analysing forest-related data, including remote sensing data and data from ground-based...
sensors. This can provide a basis for making management decisions that will help preserve the forest resources of the BNT.

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References
[1] Federal law of 01.05.1999 No. 94-FZ On Protection of Lake Baikal Income accessed online on 07th September 2020 via https://base.garant.ru/2157025/
[2] State report "On the state of Lake Baikal and measures for its protection in 2017" 2018 (Irkutsk: ANO "KC Expert") 340 p
[3] Alexeeva M Several forest planning documents are in force in the Irkutsk region 2019 LesPromInform 3 50-54
[4] Lindenmayer D B, Likens G E The science and application of ecological monitoring 2010 Biol. Conserv. 143 1317–28 https://doi.org/10.1016/j.biocon.2010.02.013
[5] Yousefpour R et al 2017 A framework for modeling adaptive forest management and decision making under climate change Ecol. Soc. 22 4 https://doi.org/10.5751/ES-09614-220440
[6] Bychkov I V et al 2019 Digital monitoring of Lake Baikal and its coastal area Information Technologies: Algorithms, Models, Systems (CEUR Workshop Proceedings) vol 2463 pp 13-23
[7] Hein A, Schreieck M, Riasanow T et al 2020 Digital platform ecosystems Electron Markets 30 87–98 https://doi.org/10.1007/s12525-019-00377-4
[8] Constantinides P, Henfridsson O, Parker G G 2018 Introduction—Platforms and infrastructures in the digital age Information Systems Research 29(2) 381–400
[9] De Reuver M, Sørensen C, Basole R C 2018 The digital platform: A research agenda J. Inf. Technol. 33 124-35 https://doi.org/10.1057/s41265-016-0033-3
[10] Andersson S J 2017 Platform Logic: An Interdisciplinary Approach to the Platform-Based Economy Policy and Internet 9 4 https://doi.org/10.1002/poi3.159
[11] Evangelidis K, Ntouros K, Makridis S, Papatheodorou C 2014 Geospatial services in the Cloud Computers & Geosciences 62 116-22