Forest Husbandry in the Khabarovsk Territory: Environmental Risks and Ways of Addressing Them

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Abstract. The Khabarovsk Territory is characterized by considerable reserves of the forest resources. Their share is 18 % of the forested area of the Far Eastern Federal District and 25 % of the timber reserves. In the region, the forestry sector is the branch of national economic specialization which is associated with the export orientation of the forestry products. In this paper, the factors that determine environmental risks during logging are analyzed, including a low level of control of felling, violations of technologies, rules and standards for felling in the main-use forests, an increase in a fire hazard, violation of the hydrological regime of rivers, the development of erosion processes, pollution of aquatic ecosystems, expansion of road networks, increased poaching pressure on previously inaccessible forest areas, etc. Environmental problems caused by these factors are associated with a decrease in the resources, the ecological functions and the biological diversity of forests, the destruction of possibilities for traditional forest management, and the destruction and transformation of historically formed ecosystems. An unbiased inventory of the forest resources, their quantity and quality assessment, a governmental monitoring of the state of forest ecosystems, support for alternative types of forest use (recreational, tourist, etc.) are of paramount importance in solving these problems.

1. Introduction

The Khabarovsk Territory is characterized by significant reserves of the forest resources, which determines its leading role in the timber industry sector of the economy of the Russian Far East. They account for 18 % of the forested area of the Far Eastern Federal District and 25% of the timber reserves. The forest area of the Khabarovsk Territory is 75.6 mln ha with a total standing timber stock of 5.06 billion m³ [1]. The Khabarovsk Territory is characterized by an uneven distribution of forests, namely, in the southern areas of the Territory it is up to 80–85 %, whereas in the Okhotsk area it is 24–30 %. According to their intended purpose, the forests located on the lands of the forest fund are subdivided into protective (12.6 %), operational (47 %), and reserve (40.4 %). As large as up to 7.5 million m³ of timber is harvested in the region annually.

Forest management, being one of the main directions of the regional economy, is of great importance from the viewpoint of the regional development, including the infrastructure development. Forestry is also one of the key factors that determine the current state of terrestrial and aquatic ecosystems in the region. Its peculiarity is an unsustainable nature of forestry. New forest areas located in undeveloped or
underdeveloped areas are involved in the economic turnover, without investing in further advance of developed territories [2].

According to the estimates by various scholars, from 60 to 70 % of the forest ecosystems in the Territory are disturbed to varying degrees by felling and associated fires [3, 4]. The transformation of forest ecosystems is accompanied by a decrease in their ecological functions, biological diversity and increased environmental risks.

2. Objects, Data and Methods
The purpose of this research was to assess the state of forest ecosystems, their violation and stability in connection with forestry development. Research works on this topic cover more than 20 years.

An analysis of the available archives and satellite images has been carried out. To assess the dynamics of forest ecosystems, the Earth’s remote sensing data were used. The required characteristics of these data are high coverage, high frequency of repetition, and medium-to-high spatial resolution. This determined the use of publicly available data, primarily, the images of various generations of the Landsat Aster, Modis Terra and Aqua satellites. Their processing and classification were carried out in the ArcGIS 10.1 software environment with the integrated Image Analysis ENVI 5 module, followed by generalization and expert processing. The data obtained were verified in the field environment.

To organize monitoring, detailed route field studies were performed in the territories, involved in the economic turnover to varying degrees. The author used methodological developments in order to assess the indicator of plant objects at different levels and in different types of landscapes. The main quantitative and qualitative indicators of populations of indicator species and communities were used as criteria [5, 6].

3. Results and Discussion
The nature of the forest vegetation in the region is formed under the influence of zonal factors that determine the contact zones from south to north: the cedar-broad-leaved, broad-leaved – coniferous (dark coniferous and light coniferous) forests – tundra and forest tundra.

The exploitation of forests in the region is characterized by a long history and dates back to the 1850s with the foundation of the city of Nikolaevsk in the mouth of the Amur River. The main felling methods are forced-selective, as well as conditional clear since the 1930s. At the same time, the best part of the wood stock is extracted, amounting to 30–50 %. Less wood is cut during intermediate felling, but they make up a significant part of the harvest of valuable hardwood (Fraxinus mandshurica, Tilia amurensis, Tilia taquetii, and Quercus mongolica).

As large as up to 7.5 mln m$^3$ of timber is harvested annually in the region (Table 1). The stocks of the main forest-forming species are also decreasing due to illegal logging and fires, which in aggregate constituted in different years from 100 to 150 % of the volume of permitted logging. The result of the long history of forest husbandry is a significant transformation of forest ecosystems.

| Table1. Indicators of the state of forest resources. |
|----------------------------------------------------|
| **Years**                                          |
| 2016  | 2017  | 2018  | 2019  | 2020  |
|---|---|---|---|---|
| The forest area (thou ha) | 75624.0 | 75650.4 | 75630.5 | 75470.9 | 75632.7 |
| Controlled felling area, mln. m$^3$ | 25.1 | 28.3 | 28.3 | 27.9 | 27.9 |
| Use of the controlled felling area, % | 26.1 | 23.1 | 23.0 | 25.5 | 22.8 |
| Volume of timber harvested, mln. m$^3$ | 7.56 | 7.6 | 8.18 | 7.62 | 7.07 |
| Total area swept by fires, thou. ha | 186.0 | 137.8 | 451.2 | 314.9 | 238.7 |
| Number of fires | 286 | 379 | 447 | 479 | 418 |
| Volume of wood destroyed by fires, mln. m$^3$ | 0.134 | 1.2 | 1.3 | 0.448 | 0.569 |
| Forest restoration, ha | 60320.0 | 62061.0 | 65850.0 | 66617.3 | 63277.0 |
Factors that cause the main environmental risks during logging are as follows:
- low level of felling control;
- violations of technologies, rules and standards for felling in main-use forests,
- exacerbation of fire hazardous conditions,
- violation of the hydrological regime of rivers,
- development of erosion,
- pollution of aquatic ecosystems,
- expansion of the road network,
- an increase in the poaching impact on previously inaccessible forest areas, etc.

In recent decades, there has been a tendency towards a reduction in the mature and over-mature stands, an increase in the role of the deciduous and, first of all, small-leaved forests, a decrease in the average indicators of completeness and marketability of forest stands. Almost all enterprises work with violations of the forestry rules, the depletion of logging especially increased during the transition period of the 1990s. Timber drags, log spurs, cutting and loading areas, which occupy up to 20–35 % of logging areas, have a negative effect on the state of forest ecosystems [7, 8].

In these areas, the vegetation cover is completely destroyed, there is a danger of erosion processes, siltation of small rivers occurs, and the hydrological regime of mountain slopes is disrupted. In some cases, timber is skidded along river beds. It was noted that in the felling areas and after fires, the runoff of small rivers was doubled during the flood period. Cutting residues, liquid stock, and wood residues remain on the felling sites, which leads to a further exacerbation of fire hazardous conditions. Ultimately, these violations lead to the drying up and death of the vegetation cover in adjacent territories and the transformation of forest ecosystems.

The most productive and easily accessible cedar-broad-leaved and fir-spruce forests are severely violated and depleted as a result of prolonged and often irrational exploitation. So, for example, in 1968–1996, the area of cedar forests has been halved. In a number of indigenous habitats, *Pinus koraiensis* has lost its position, and, in some places, it has completely disappeared from the forest stands and undergrowth. With the destruction of edificators, the weakening of the upper layers of communities, the most sciophilous and mesohygrophilous representatives of the shrub and grass-dwarf shrub layers are falling out, the areas of plants that are phytocenotically associated with the cedar-broad-leaved formations of eastern Asia are decreasing, and the tendency of restructuring the main botanical and geographical boundaries in the southern part of the Russian Far East is increasing.

During the development and reduction of forest areas, the areas of the transformed landscapes are dozens (50–70) times larger than the areas of direct development. This is due to the “incidental” destruction of the vegetation cover and soils of the periphery of the developed zones, the radial spread of erosion along mountain roads and, most importantly, the most powerful pyrogenic degradation of vegetation and soils. At the same time, post-pyrogenic destruction in mountainous areas increases sharply due to the high impact and runoff force of monsoon precipitation. Artificial restoration, which accounts for less than 1 % of the forested area, is not older than 60 years and is unable to compensate for the loss of forest resources from felling and fires.

Periodically repeating extremely dry seasons, an abundance of flammable combustible materials in the form of logging residues, or commercial timber left on the plots, mountainous terrain and hard accessibility of the territory have ultimately led to high burning in the 1960–80s and predetermined a catastrophic fire hazardous situation in 1998–2002. During the fire hazardous periods of the last few decades, hundreds of forest fires were simultaneously active in the region, which merged, reached catastrophic proportions and acquired the character of a natural disaster. According to estimates by various authors, the total area covered by forest fires in the region is from 5 to 7 mln. ha.

By the average annual area, until the end of the 1980s, forest fires were comparable to industrial felling, and now they show a four- or fivefold excess [2]. The caused damage is by an order of magnitude higher in the case they overlap with various types of economic use.
Depending on the type of the fire spread, it is customary to divide forest fires into three types: creeping, crown and peat fires [9]. In the Amur region, creeping fires are most common, accounting for more than 90 % of the total fire area.

Crown fires account for 5–7 % of the fire area, while peat fires amount to 2–3 %. The most catastrophic fires of recent years have affected forest relict and endemic species of the cedar-broad-leaved, broad-leaved, and fir-spruce nemoral forests. In the territories covered by strong crown fires there is a sharp decline in species diversity (up to 70 %) in the first five years or the vegetation cover has been completely destroyed, depending on the fire nature and frequency [10]. Hygro- and mesophilic, sciophilic and thermophilic elements fall out of the composition of forest communities. In the cedar-broad-leaved and broad-leaved forests, they are represented by Lunathyrium pterorachis, Coniogramme intermedia, Achudemia japonica, and Urtica laetevirens, in the oak forests — Oreorchis patens, Cypripedium ventricosum, C. calceolus, Lilium buschianum, Platycodon grandiflorus, and Cotoneaster melanocarpus, whereas in the fir-spruce forests — Neottia asiatica, Epipogium aphyllum, Calypso bulbosa, Ilex rugosa, and Listera nipponica. Forest relict species, characterized by increased demands on moisture, shading, and soil conditions, replace species with a wider ecological range and an extensive range, namely, Rubus sachalinensis, Calamagrostis langsdorffii, Chamaenerion angustifolium, and Lagedium sibiricum. There is a decrease in the species diversity of forest cenoses; repeated fires lead to the formation of larch or small-leaved woodlands, the development of shrub and meadow groups and, in the future, to the complete destruction of vegetation and soil cover. In the basins of the largest tributaries of the Amur, forests damaged by fire have sharply reduced their ecological functions, which are expressed in water protection, water regulation, biostation, anti-erosion and permafrost-stabilizing properties.

Great damage was caused by fires in the cedar forests in 1976, 1988, and 1998, when a timber base located in the northern Sikhote-Alin in the Anyui, Gur, Yai, and Sukpai river basins, as well as in the mountain systems of the Amur left bank in the Gorin and Amgun river basins, burnt down.

According to the state of the phyto-genepool, even now in the territory of the Lower Amur region the zones with a catastrophic state can be distinguished, where 90 % of rare plants cannot recover due to the destruction of the indigenous vegetation cover over a large area.

Illegal felling, which started happening in the Amur region in the 1990s and, according to various estimates, is accounting for 50–100% in relation to legal felling, causes especially great damage to forest ecosystems [11]. At the same time, the cedar-deciduous forests suffer the most, losing most valuable species including Pinus koraiensis, Fraxinus mandshurica, Tilia amurensis, Tilia taquetii, Juglans mandshurica, and Quercus mongolica. As a result of noncompliance with the rules and norms of logging in places of illegal felling, the destruction of undergrowth is noted, and a higher, in comparison with legal felling areas, wastes and felling residues disposal level at sites, the wood residues that impede reforestation and sharply increase the fire hazard levels, the foci of soil erosion on mountain slopes, felling of water protection forests in floodplains, etc.

The expansion of the network of logging roads facilitates accessibility of the territory and increases the poaching pressure on hunting resources..

Environmental problems emerging during the development of the region’s forests include:

- reduction of mature and over-mature stands;
- enhancing the role of deciduous and, above all, small-leaved forests;
- decrease in the average indicators of completeness and marketability of forest stands;
- reduction of areas of primary forests, valuable forest species;
- transformation and destruction of historically formed ecosystems, habitats and food resources of valuable and rare species of plants and animals;
- destruction of opportunities for traditional forestry nature management;
- a change in the direction of evolution or a decrease in ecological functions, productivity, biological diversity of forest ecosystems and, accordingly, the degree of their resistance to external influences;
- increasing environmental risks, the threat of environmental degradation.
At the legislative level, in the Russian Federation and the Khabarovsk Territory, there are measures envisaged for the rational use and preservation of forests, regarding the norms and rules for felling, and restrictions on felling in various types of forests. It is only the state attention to the problems of forest management that is lacking for their implementation.

In this regard, a set of measures aimed at solving environmental problems of forest management in the current conditions includes:
- unbiased inventory of forest resources, their quantity and quality assessment, state monitoring of the state of forest ecosystems;
- strengthening of state authorities that control forestry activities (staff, funding);
- support for alternative types of forest use (recreational, tourist, etc.);
- formation of a system of rent payments and mechanisms of environmental insurance in the field of natural resource management, taking into account environmental services;
- development of the procedure for the implementation of state fire supervision in forests, increasing the efficiency of using data from satellite monitoring;
- development of a set of measures to preserve the main valuable non-timber forest resources, including environmentally friendly medicinal and food products;
- development of the Regulation on state monitoring of the natural environment in the field of biological diversity, regulation of the procedure for maintaining a cadaster of monitoring data for the biological state of Russian regions
- improving of the environmental education system;
- improvement and necessary adaptation of the ecological and environmental legislative and regulatory frameworks, mechanisms for their implementation under specific conditions, in parallel with the growth of responsibility for their implementation, etc.

4. Conclusions
The existing forest use in the Khabarovsk Territory is expressed in a reduction in the areas of indigenous forest plantations, valuable forest species, a change in the quality of forests, the transformation and destruction of historically formed ecosystems, a decrease in the ecological functions, productivity, biological diversity of forest ecosystems and, accordingly, the degree of their resistance to external influences, growing environmental risks, a threat of environmental degradation.

Factors that cause environmental risks during logging include a low level of felling control, violations of technology, rules and standards for felling in main-use forests, an increase in the fire hazardous situation, a violation of the hydrological regime of rivers, the development of erosion, pollution of aquatic ecosystems, the expansion of the road network, an increase in poaching previously inaccessible forest areas, etc.

The vulnerability of the forest vegetation of the region is caused by a number of factors which are as follows: the ecotonic position and, consequently, the instability of habitat conditions; relict plant taxa and communities of the southern half of the region, their inconsistency with modern natural and climatic conditions, a low degree of their adaptation; the “insular” position of a number of relict, and endemic taxa and communities.

To preserve and restore forest ecosystems and resources of the region, in the first place, it is necessary to strengthen government control and organize monitoring of forest ecosystems at the state level.

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