The Transformation of Forest Resources in the South of Western Siberia: Data from the Altai Krai

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Abstract. The organization of sustainable forest management is of particular importance in low-forest areas, where forest ecosystems are the source of productive resources performing essential ecological functions. Therefore, the impact of economic activities on the natural vegetation cover can be direct (associated with the withdrawal of resources) or indirect (which occurs due to changes in the environmental conditions of plant growth). As a result of these processes, the productivity of ecosystems is reduced. We identified the main negative changes in the Altai Krai forest cover, which belongs to the West Siberian subtaiga forest-steppe and the Altai-Sayan subtaiga vegetation area. The decrease in forest productivity in the first district is associated with irrational felling, forest fires, and pests. The decrease in forest cover of the territory is particularly evident. The quality of foothill and mountain forests worsened due to the anthropogenic impact. Artificial restoration does not compensate for the damage to forest resources.

Keywords: Forest resources · Forest management · Forest productivity · Impact assessment

1. Introduction

Forest resources are affected by a combination of natural processes and human actions. The assessments of global forest resources conducted by the Food and Agriculture Organization of the United Nations [FAO] indicate that the total area of the world's forests decreased by 3% in 1990–2015 [3]. However, when the planet enters a phase of anthropogenic climate change with unprecedented speed and scale, natural ecosystems, previously adapted to local conditions, are threatened with extinction [1]. The rate of forest reduction may also dramatically increase. Forest ecosystems in the forest-steppe zone can become clear indicators of such changes. Such ecosystems are critical not only for their growing conditions due to the arid climate but also for a more significant anthropogenic load since they are located in resource-deficient regions.

Recently, more attention was paid to the conservation of forest vegetation due to the carbon-absorbing capacity of trees, which is considered a way to mitigate the increase in carbon dioxide in the atmosphere. During the 21st century, the planet's forests can "take over" up to a third of all efforts to reduce atmospheric carbon dioxide [7]. The calculation of the total carbon balance of Russian forests showed that forests absorbed 430 ± 70 Tg of carbon per year in the second half of the 20th century. Russian forests are considerable reservoirs of additional atmospheric carbon sequestration in the amount of approximately 200–600 Tg per year, which is possible when implementing sustainable forest management [8].

Located in the south of the West Siberian Plain, the Altai Krai has small reserves of forest resources compared to neighboring regions. Total wood reserves are about 540 million m^3. Forest ecosystems

cover 26% of the area, and the average forest cover in the region is only 22.9% [4]. Nevertheless, despite this relatively low figure, the region is home to valuable forest stands preserving the landscape and biological diversity and are among the most important natural components of the territory's ecological framework. More than 72% of the forest stands in the region belong to protective forests. Total wood reserves are about 540 million m^3. Forest ecosystems cover 26% of the area, and the average forest cover in the region is only 22.9% [4].

Simultaneously, the Altai Krai has historically developed the woodworking industry. Wood and timber products are an important export item of the region bordering the Kazakhstan steppe. In 2018, 2.8 million m^3 of wood was harvested in the Altai Krai, and almost 825 thousand m^3 of timber was exported [4]. Active exploitation of forest resources requires constant monitoring and assessment of woodlands to identify adverse trends in their quantitative and qualitative features.

2. Materials and Methods

The complex nature of interconnections in forest ecosystems has long been the subject of scientific research. Forest ecosystems are open systems since they exchange energy and materials with other systems, including adjacent forests, aquatic ecosystems, and the atmosphere [9]. When organizing forest management, management bodies need to understand and measure the quantitative and qualitative changes that are taking place. Additionally, it is necessary to assess the trade-offs that may arise when choosing different forest management strategies. There are several common methods for assessing the current and future state of the forest.

The information basis for the research and assessment was the performance indicators of enterprises and organizations of the forestry complex of the Altai Krai [4].

Since the main function of vegetation is the formation of organic matter (phytomass), we evaluate the state of forest stands based on the state of the phytoproduction process in this territory. Forest productivity refers to the number of various resources produced by the forest over a certain period per unit area and its effectiveness during the corresponding period [5]. A. A. Baburin offers a methodology for assessing the current state of forest vegetation. According to it, the author identifies background, shadow, and operational reserves [2].

The background stock includes all environmentally possible and available stocks. To a certain extent, it characterizes the potential of the territory under a given anthropogenic load and the species structure of forests.

The background stock is determined using the formula:

$$A=D/Sd \quad (1)$$

where: A – the background stock; D – the stock of mature and overgrown forests, m^3; Sd – the area of mature and overgrown forests, ha.

The shadow stock is the average stock of wood per 1 ha of wooded (tree-shaded) area. It reflects the deterioration of forest quality due to changes in the species, complete and age structure of the forest cover under the influence of various impacts (felling, fires, pollution, etc.).

The following formula determines the shadow reserve:

$$B=F/St \quad (2)$$

where: b – the shadow stock; F – the total wood stock, m^3; St – the forested area, ha.

The operational reserve reflects a complex total loss due to quality degradation and quantity reduction, i.e., in addition to changes in the completeness of breed composition, it also considers deforestation of the territory.

The following formula determines the operational reserve:

$$C=F/Sl \quad (3)$$

where: C – the operational reserve; F – the total wood stock, m^3; Sl – the forest area, ha.

Based on this, we can determine the allowed loss of background forest productivity, which is due to forest quality degradation and deforestation.

3. Results

On the territory of the Altai Krai, forest ecosystems belong to two forest regions: The West Siberian subtaiga (forest-steppe, combining the ribbon-like and the Ob forests) and the Altai-Sayan mountain taiga (including the foothill forests of the Altay mountains and Salair ridge). The forest resources of each district differ in reserves, species composition, structure, and conditions of forest use. The highest wood reserves are highly productive pine ecosystems of the West Siberian subtaiga forest-steppe region (table 1). Mountain forests, which were cut down in the past, are now mainly represented by secondary deciduous and mixed stands marked with lower indicators of wood reserves.

The impact of economic activities on the natural vegetation cover is deep and varied. It can be either direct, related to the withdrawal of resources, or indirect, which occurs due to changes in the environmental conditions of plant growth. Based on the methodology used, we evaluated the main negative changes in the forest cover of the Altai Krai.

Table 1. Transformation of the forest ecosystems of the Altai Krai.

Forest areas	Wood stock, m^3/ha			Loss of forest productivity, %		
	background	shadow	operational	loss of quality	changes in forest cover	complex
Altai-Sayan mountain taiga region						
Altai foothill forests	154.8	133.2	120.7	12.6	8.2	20.8
Salair Ridge forests	145.5	116.6	110.3	20.0	4.4	24.4
West Siberian subtaiga forest-steppe region						
Ribbon forests	169.3	161.0	132.4	2.4	18.5	20.9
Ob forests	164.0	148.4	138.4	10.3	6.2	16.5

Source: Compiled by the authors.

The indicators of change in forest quality in the region reach 30%. The average value is 6.8%.

In general, the loss of forest productivity due to deforestation is 12%. Simultaneously, this indicator exceeds 30% in some forest farms, which is observed in unique ribbon pine forests.

A comprehensive assessment consists of individual assessments. In our case, it is an assessment of forest degradation and deforestation of the territory. Complex losses of productivity of forest stands in the Altai Krai are observed almost throughout the territory, with an average of 19%.

4. Discussion

As a rule, the active exploitation of forest resources leads to a decrease in the territory's forest cover. The main cause of deforestation is the harvesting of wood and the death of forests caused by fires, pests, and diseases. Recently, the volume of wood harvesting in the region increased, and the use of the estimated cutting area exceeded 40%. As in many border regions of Russia, illegal logging is also actively carried out. The number of registered crimes in this sphere is 300–440 per year. The damage caused by these crimes has reached 54 million rubles [4]. The area of forest stands in more accessible flat areas is reduced the most actively. Currently, one of the most pressing problems in forestry is the low quality of forests. The deterioration of forest quality affects the change in the quality of wood and breed composition. It leads to a violation of environmental and ecosystem functions.

The most significant environmental damage to the quality of the forest ecosystems in the region is caused by forest fires, pests, and forest diseases. The stability of plantings is affected by the stem (*Ussuri*

polygraph) and coniferous pests (*Lymantria monacha*). Pathogens are mainly represented by various kinds of tinder and stem rot. A smaller area is marked with foci of necrotic-cancerous and bacterial diseases of birch. In the foothill forests of the Altai and Salair Ridges, the causes of changes in the quality of the forest include sunburn and windfalls. Due to these reasons, there is a mass drying of stands and clutter in the forest.

Based on the obtained data, it can be concluded that the most significant productivity losses due to forest quality degradation are observed in the territory of the Altai-Sayan forests. It is home to valuable conservation and economic black taiga-aspen and fir-aspen large-grass forests, including a complex of Pliocene relict species-remnants of broad-leaved forests that existed in Siberia in the preglacial era [6]. Low transport accessibility and difficult terrain of forests lead to the fact that wood harvesting in these areas is carried out mainly on the outskirts, which leads to a deterioration in the quality of forests.

5. Conclusion

The forests of the Altai Krai have been changed to some extent. They are subject to various negative impacts. There is a gradual degradation of forest ecosystems. The measures for protection and reproduction cannot compensate for the resulting losses.

In the forest stands of the Altai Krai, there is a decrease in forest cover in the belt forests (especially in the forest stands of the Barnaul and Kasmala ribbon-like forests), listed by the World Wildlife Fund (WWF) of Russia in the list of endangered ancient forests. In accordance with the Forest Code of the Russian Federation, the use of protective forests, which include belt forests, must be compatible with their intended purpose and useful functions. Nevertheless, belt forests continue to serve as a raw material base for logging companies, and they are used for selective felling for the harvesting of commercial wood. Despite its seemingly limited nature, selective felling leads to a significant reduction in forest productivity in this area.

However, a greater impact on the decrease in productivity of forest stands in the Altai Krai has a deterioration in the quality of forests, which occurs as a result of forest fires pronounced in the western regions of the Krai. Local forest fires can cause damage to foothill forest areas. Additionally, forest diseases, especially insect pests, have a substantial impact on the forest's quality. It is difficult to restore the disturbed stability of forest ecosystems because ribbon pine forests and black taiga are unique plant communities. Adverse changes in the exploited forests of the Charysh region violate the stability of the Tigirek Reserve, which is closely related to the spread of pests and diseases of the forest. These adverse processes lead to a decrease in the performance of important ecological functions of forest stands. These processes show the urgency of forestry problems and the necessity to detect them promptly and implement the rules of forest protection and restoration to preserve species diversity.

The component-by-component assessment of the state of forest resources allows us to identify the cores of various problems that occur in the forest fund. It serves as the basis for a comprehensive assessment that considers all potential resources and environmental benefits of forest vegetation in the region.

References

[1] Alfaro R, Fady B, Vendramin G, Dawson I, Fleming R, Sáenz-Romero C, … Loo J 2014 The role of forest genetic resources in responding to biotic and abiotic factors in the context of anthropogenic climate change *Forest Ecology and Management* **333** pp 76-87

[2] Baburin A A 1984 On the methodology for assessing the current state of forest vegetation cover *Geography and Natural Resources* **1** pp 134-137

[3] Keenan R, Frédéric A, Reams G, Freitas J, Granger A, and Lindquist T 2015 Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment *Forest Ecology and Management* **333** pp 9-20

[4] Ministry of Natural Resources and Ecology of the Altai Krai 2018 *State report "On the state and protection of the environment in the Altai Krai in 2017"* (Barnaul, Russia)

[5] Ostroshenko V V 2005 *A short dictionary of basic forestry and economic terms* (Ussuriisk, Russia: Primorskaya State Academy of Agriculture)
[6] Paramonov E G., Kudelya, V A, and Semenov M I 2013 Silvicultural features of the black forests of Western Siberia *Bulletin of the Altai State Agrarian University* **5**(103) pp 75-78
[7] Sohngen B, and Mendelsohn R 2003 An optimal control model of forest carbon sequestration *American Journal of Agricultural Economics* **85** pp 448-457
[8] Vaganov E A, Vedrova E F, Verkhovets S V, Efremov S P, Efremova T T, Kruglov V B … Shibistova O B 2005). Forests and swamps of Siberia in the global carbon cycle *Siberian Ecological Journal* **4** pp 631-649
[9] Waring R H, and Running S W 2007 *Forest ecosystems analysis at multiple scales* g (London, UK: Elsevier Academic Press)