

On forest management in the forests of the Arctic zone of the European part of the Russian Federation: problems and solutions

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Abstract. This article discusses the problematic issues of timber harvesting in the Arctic zone of the European part of the Russian Federation, the implementation by entrepreneurs of legislation regulating relations in the field of forestry and other issues related to the topic. Taking into account the diversity of functions of forest ecosystems, it is necessary to differentiate forest management in the main directions: especially protective, protective forestry, climate-protective and exploitation. The whole system of forestry measures should be built on the optimization of forest reproduction, increasing their productivity. The studied forests are located in underdeveloped areas, which have high ripening age, low productivity, development of industries with unfavorable impact on the environment. In this regard, in order to improve forest management, it is necessary to take an integrated approach to the selection of harvesting methods, in addition to the intended purpose of plantations and forest type. Accordingly, adaptation scenarios should be built by selecting the necessary forest management measures and their combinations, taking into account the fundamental principles of forest management.

1 Introduction

Of particular concern is the unprecedented high rate of global warming occurring over the past decades [1]. Forests and soils have a huge potential to absorb and store annual anthropogenic CO₂ emissions [2]. In addition, the impact of a future, possibly more variable climate with increased frequency and intensity of precipitation events, more extreme temperatures and droughts on GHG budgets should be considered when implementing forest management policies and practices aiming at enhancing the mitigation potential of forests. Modern science finds more and more evidence that human economic activity, primarily associated with greenhouse gas emissions, is increasingly affecting the climate against the background of its natural variability [3-12]. Forests grow, age, burn, are cut down, regenerate, but it is difficult to account for everything. There are already proposals to create new protected areas in these regions, there are discussions about the importance of their organization, their area and status [2]. At the same time, it is necessary to increase the volume of logging to improve the economic situation in the regions. The

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Forest Code of the Russian Federation establishes that timber harvesting is an entrepreneurial activity associated with the cutting of forest plantations in operational and protective forests in the volume not exceeding the estimated cut (volume of timber removal), as well as with the removal of timber from the forest.

The Arkhangelsk region is the largest forestry region of the Russian Federation, where about one third of the country's pulp and paperboard volumes, up to 10 % of sawn timber and up to 11 % of the total Russian paper volume are produced [13]. The most important emphasis is the region's raw material reserves and developed seaport, which allow producing, trade forest products on foreign economic markets.

The forestry sector of the Arkhangelsk region follows the path of development in accordance with the main directions provided by the State Program of the Arkhangelsk region "Development of the forest complex of the Arkhangelsk region" for 2024-2026. The main tasks program such as: to create conditions for the rational use of forests; to ensure the balance of forest retirement and regeneration; to increase their productivity and quality; to reduce forestry losses from fires, pests and illegal logging; to achieve sustainable forest management, innovative and effective use, protection, conservation, reproduction of forests; to ensure the contribution of the forest complex of the region to the socio-economic growth and development of the region [14].

2 Materials and methods

Objects of research - forests of the Arkhangelsk region (NAO), Murmansk region, Republic of Karelia, Komi Republic. Purpose of the work - to improve the system of forest management measures in the forests of the Arctic zone of the European part of the Russian Federation, regulating the balance of deforestation and reproduction of forests with economically valuable coniferous species.

The research based on the analytical and statistical method. Open statistical and departmental data are used for the work: reports on the state and protection of the environment; forest plans; forest management regulations; brief reviews of sanitary and forest pathological condition of forests; federal target programs, state programs, including research materials of FBU "SevNIILHK".

3 Results and Discussion

Over the last 10 years, 27.7 million m³ of liquid timber has been harvested in forests on forest fund lands by all types of fellings (during the cutting of mature and overmature forest stands, during forest maintenance, during the cutting of damaged and dead forest stands, as well as during the cutting of forest stands on forest plots intended for the construction, reconstruction and operation of forest, timber processing infrastructure and facilities not related to the creation of forest infrastructure) including 26.6 million m³ in coniferous forestry (96 % of the total harvested volume) and 1.1 million m³ (4 %) in soft-leaved forestry. Of the total volume of harvested timber, 84 % was harvested in mature and overmature forest stands. At the same time, coniferous timber harvesting had a significant advantage. The forest using of the estimated harvesting area was less than 30 %. The low level of forest using of the estimated harvesting area in coniferous forests is due to the undeveloped road network to the mature forests.

Arkhangelsk region. The forests of the region referred to the area of tundra forests and sparse taiga of the European-Ural part of the Russian Federation and to the northern taiga area of the European part of the Russian Federation. The forest cover is 70.6 %. Protective forests occupy 46 % of the area. The share of the area of the forest fund lands transferred

for use to the total area of the forest fund lands is 74.9 %. The ratio of the actual volume of timber harvesting to the established permissible volume of timber is 31 %. The district characterized by poorly developed transport network. The road network ranges from 0.3 to 1.8 km per 1000 ha of total area. At the same time, for the development of the estimated timber cut it is necessary to have at least 7 km of all types of roads per thousand hectares, and in protective forests - 11-14 km. A significant part of forest areas not provided with roads, which causes difficulties in protecting forests from fires and forestry operations. In winter, snow and ice roads are used. The estimated annual cut (volume of liquid timber) for all types of felling is 6520.5 thousand m³, including coniferous - 5835.1 thousand m³. The territory is subject to clear-cutting, selective logging, forest maintenance logging, clear sanitary and selective logging. The actual volumes of harvested timber in all types of felling (clear-cutting, selective felling, thinning, sanitary felling) in the majority of forestry of the Arkhangelsk region are stable by felling years (the exception is Leshukonskoye forestry, from 129.4 thousand m³ in 2017 to 1388.4 thousand m³ in 2022). The average volume of timber removed per hectare ranges from 80-126 m³ in forestry district where clear-cutting in mature and overmature stands is allowed and 21-34 m³, where clear-cutting is prohibited (Arkhangelsk and Mezensky forestry). The volume of harvested timber in the Leshukonsky forestry has increased 11 times in the last 5 years, and in the last year during clear-cutting in mature and overmature spruce stands without timber harvesting. In the Arkhangelsk and Mezensky forestry clearcuts prohibited, the forest management system in the certified area based on voluntary selective harvesting with an intensity of up to 25 % of the reserve, with a frequency of 30 years.

NAO. The forests belong to the area of tundra forests and sparse taiga of the European-Ural part of the Russian Federation (Nenets Forestry). Forest cover is 43 %. Protective forests account for 100 % of the forest area. There is no transportation network. Estimated cut for 10 years - 279, 9 thousand m³ (272,7 coniferous, soft-leaved - 13,2 thousand m³, actually harvested for 10 years - 18 thousand m³). Cutting of mature and overmature stands (thinning) is carried out. The ratio of the actual volume of timber harvesting to the established permissible volume of timber removal is 3.3 %.

Murmansk Region The forests are classified as part of the area of tundra forests and sparse taiga of the European-Ural part of the Russian Federation and the northern taiga area of the European part of the Russian Federation. The forest cover is 58.5 %. Protective forests account for 64 % of the area. The share of the area of the forest fund lands transferred for use to the total area of the forest fund lands is 24.3 %. The ratio of the actual volume of timber harvesting to the established permissible volume of timber removal is 18 %. Poorly developed transportation network. The road network ranges from 0.15 to 3.1 km per 1000 ha of total area. While for the development of the estimated cutting, it is necessary to have at least 7 km of all types of roads per thousand hectares, and in protective forests - 11-14 km. The estimated annual cut (volume of liquid timber) for all types of felling is 644.1 thousand m³, including coniferous - 563.7 thousand m³. On the territory, there are clear-cutting, selective felling, and thinning, clear sanitary and selective felling. The forest industry complex of the Murmansk region is poorly developed; the forests growing in the region are of low quality and the timber is of low value; forest areas not provided with a network of forest roads. Under such conditions, timber harvesting in a significant part of the forest fund is unprofitable for potential tenants.

Komi Republic. The forests belong to the region of tundra forests and sparse taiga of the European-Ural part of the Russian Federation. The forest cover is 40 %. Protected forests account for 58.1 % of the area. The district characterized by a poorly developed transport network. The ratio of the actual volume of timber harvesting to the established permissible volume of timber removal is 16 %. The road network is 0.3 km per 1000 ha of total area. A significant part of forest areas not provided with roads, which causes difficulties in

protecting forests from fires and forestry operations. Snow and ice roads used in winter. The types of harvesting are selective and thinning cuts. The estimated annual cut (volume of liquid timber) for all types of felling is 1292.1 thousand m³, including coniferous - 1120.7 thousand m³. Selective felling, forest maintenance and sanitary felling carried out on the territory.

Republic of Karelia. Today, more than 75 % of the forest fund territory with the volume of harvesting 8.6 million m³. The existing timber processing industries in the republic are experiencing a shortage of raw materials, at the same time; the estimated cutting area underutilized by more than 2.5 million m³. The main part of the unused forest fund falls on the northern regions of the republic (Belomorsky, Kemsy and Louhsky), which are part of the Arctic zone of the Russian Federation. The volume of the estimated cut for these territories is 1.2 million m³. In the current year 53.3 thousand m³, i.e. the percentage of forest using is only 4.3 % (forest using was 12.4 %). The forests referred to the Karelian north taiga region. The forest cover is 54.7 %. Protective forests account for about 30% of the area. The share of the area of the forest fund lands transferred for use to the total area of the forest fund lands is 66.4 %. The ratio of the actual volume of timber harvesting to the established permissible volume of timber removal is 30 %. The district characterized by poorly developed transport network. The road network ranges from 1.6 to 4.1 km per 1000 ha of total area. A significant part of forest areas not provided with roads, which causes difficulties in protecting forests from fires and forestry operations. In winter period, snow and ice roads are used. The estimated annual cut (volume of liquid timber) for all types of felling is 2367.2 thousand m³, including coniferous - 2200.8 thousand m³. In the territory, there are clearcuts, selective logging, forest maintenance logging, clear sanitary and selective logging.

Forest using of the estimated harvesting area was less than 30 %. The level of utilization of the allowable volume of removal of liquid timber of mature and overmature stands at the beginning of 2023 over 80-90 % was observed in a number of forestry of the forest area under consideration. The low level of utilization of the estimated harvesting area for coniferous forestry is due to the undeveloped road network to mature forests.

There is a limited demand for soft-leaved timber, while there is a shortage of mature, high-yielding and thick-dimensioned birch stands with high sawlog yields. Thinning in the total volume of harvesting amounted to 10 %, of which 40 % was harvested in coniferous forestry. The maintenance cuttings fund included areas that need thinning cuttings, passing cuttings, a few reshaping cuttings and landscape cuttings according to forestry requirements. Most timber (73 %) is harvested during thinning and clearing, followed by clearcuts.

At the beginning of 2023, the volume of thinning was less than 10 % of the total timber harvest.

Among violations of timber harvesting rules and crimes related to illegal logging, the following are the most acute: non-compliance by lessees with the terms and conditions of forest lease agreements or contracts with the right of permanent use of forest land.

The actual development of forests of the Arctic zone of the European part of the Russian Federation for the last 10 years shown in Table 1.

Table 1. Actual development of forests of the Arctic zone of the European part of the Russian Federation for the last 10 years (numerator - estimated cut volume, thousand m³, denominator - actually harvested volume, thousand m³).

Region	Species	Cutting mature, overmature forests	Thinning	Cutting damaged and dead forest	Other harvesting	Total
Karelia Republic	coniferous	<u>18094.3</u> 6489.1	<u>2428.2</u> 55.7	<u>375.9</u> 48.5	<u>1441.8</u> 233.8	<u>22340.2</u> 6827.1
	soft-wooded broadleaf	<u>850.8</u> 195.4	<u>200.1</u> 0.10	<u>6.0</u> 0.0	<u>27.3</u> 1.3	<u>1084.2</u> 196.8
	total	<u>18945.1</u> 6684.5	<u>2628.3</u> 55.8	<u>381.9</u> 48.5	<u>1469.1</u> 235.1	<u>23424.4</u> 7023.9
Arkhangelsk	coniferous	<u>50242.0</u> 15154.0	<u>1244.0</u> 43.7	<u>3175.9</u> 2597.8	<u>1318.0</u> 553.1	<u>55979.9</u> 18348.6
	soft-wooded broadleaf	<u>5880.0</u> 760.4	<u>573.0</u> 0.0	<u>10.0</u> 1.3	<u>149.0</u> 42.6	<u>6612.0</u> 804.3
	total	<u>56122.0</u> 15914.4	<u>1817.0</u> 43.7	<u>3185.9</u> 2599.1	<u>1467.0</u> 595.7	<u>62591.9</u> 19152.9
Murmansk	coniferous	<u>3980.7</u> 669.8	<u>300.4</u> 68.3	<u>574.6</u> 127.2	<u>3.6</u> 70.5	<u>4859.3</u> 935.8
	soft-wooded broadleaf	<u>386.1</u> 6.9	<u>4.9</u> 0.0	<u>24.6</u> 1.3	<u>0.0</u> 5.3	<u>415.6</u> 13.5
	total	<u>4366.8</u> 676.7	<u>305.3</u> 68.3	<u>599.2</u> 128.5	<u>3.6</u> 75.8	<u>5274.9</u> 949.3
Komi Republic	coniferous	<u>7821.5</u> 62.0	<u>0.0</u> 0.0	<u>93.5</u> 0.0	<u>242.0</u> 406.6	<u>8157.0</u> 468.6
	soft-wooded broadleaf	<u>1246.3</u> 2.7	<u>5.5</u> 0.0	<u>2.2</u> 0.0	<u>24.2</u> 49.7	<u>1278.2</u> 52.4
	total	<u>9067.8</u> 64.7	<u>5.5</u> 0.0	<u>95.7</u> 0.0	<u>266.2</u> 456.3	<u>9435.2</u> 521.0
NAO	coniferous	<u>272.7</u> 13.2	<u>0.0</u> 0.0	<u>0.0</u> 0.0	<u>0.0</u> 0.0	<u>272.7</u> 13.2
	soft-wooded broadleaf	<u>6.3</u> 4.8	<u>0.0</u> 0.0	<u>0.0</u> 0.0	<u>0.0</u> 0.0	<u>6.3</u> 4.8
	total	<u>279.0</u> 18.0	<u>0.0</u> 0.0	<u>0.0</u> 0.0	<u>0.0</u> 0.0	<u>279.0</u> 18.0
Arctic zone	coniferous	<u>80411.2</u> 22388.1	<u>3972.6</u> 167.7	<u>4219.9</u> 2773.5	<u>3005.4</u> 1264.0	<u>91609.1</u> 26593.3
	soft-wooded broadleaf	<u>8369.5</u> 970.2	<u>783.5</u> 0.1	<u>42.8</u> 2.6	<u>200.5</u> 98.9	<u>9396.3</u> 1071.8
	total	<u>88780.7</u> 23358.3	<u>4756.1</u> 167.8	<u>4262.7</u> 2776.1	<u>3205.9</u> 1362.9	<u>101005.4</u> 27665.1

Frequent among such violations are considered to be:

- Exceeding the volume of timber removal outside the estimated cut.
- Violation of felling dates in the declared period (timber harvesting beyond the permit periods).
- Violation of skidding timeframes from the place of harvesting to the place of stacking.
- Non-compliance with the terms of storage and removal of blanks from the territory.
- Conducting economic activities in specially protected forest areas without the relevant authorization of the authority.
- Destruction or damage of boundary, quarter, harvesting and other posts and signs by lessees of forest areas.

- Leaving timber not removed in due time at the harvesting area.
- Improper implementation of forest reproduction measures.
- Damage to trees to the extent of plantation growth.
- Damage to vegetation and soils.
- Littering with industrial waste outside the harvesting area, etc.

We believe that the solution to the problems with illegal logging and other offenses related to forest use will be targeted state inventory and monitoring of forest use, improvement of forest control and supervision activities. It is necessary to create a clear system of control and accounting of timber movement, to develop interagency cooperation, as well as to improve Russian legislation and maintain a unified law enforcement practice.

4 Conclusion

The use of forests currently influenced by changes in the market conditions of forest use, the introduction of restrictions on the export of unprocessed timber to the Russian Federation, the lack of interest in the type of forest use as harvesting and collection of non-timber forest resources. There is a concentration of a fairly possible volume of harvested timber in the regions included in the Arctic zone, not counting the harvesting of non-timber forest resources. In some areas, there are quite large volumes of logging and now, investment projects so developed to significantly increase the volume of logging with the placement of wood processing facilities. The reasons for failure to develop the estimated harvesting area in a number of subjects are transportation inaccessibility of areas for harvesting (a significant part of forest areas is not provided with roads), which causes difficulties in protecting forests from fires and forestry operations.

Taking into account the geographical location and peculiarities of the nature of the forests of the Arctic zone of the European North of the Russian Federation, the low overall productivity of forests, the presence of even mountainous terrain and easily erodible soils (e.g. Murmansk region), the widely developed hydrographic network and the negative impact of industries on the environment, forest management should be developed mainly in a protective direction. In addition to Murmansk region, restrictions are particularly needed for the entire area of tundra forests and sparse taiga in the European-Ural part of the Russian Federation. Given the diversity of functions of forest ecosystems, forest management should be differentiated in the following main directions: especially protective, protective forestry, climate protection and exploitation. The whole system of forestry measures should be based on the optimization of forest reproduction, increasing their productivity. The main directions of forestry for the future should be considered fire protection, reforestation, thinning, regeneration sanitary and landscape cutting. In the forest and park zone it is advisable to reforest, including the use of reclamation and reclamation.

For their own needs of the local population, there is a need to harvest timber in the forests we are considering. Selective and gradual cuttings are the most appropriate as they permanently preserve the protective functions of the forest. However, clearcuts should not be neglected either, as they are dictated primarily by the need to replace conventionally single-aged, deeply overmature trees (primarily pine trees). Clearcuts are applicable in pine forests of lichen group and green-moss forests, which were destroyed by lowland fires 15-20 years before cutting and have under the canopy the amount of pine undergrowth, providing replacement of the mother stand. Preservation of the maximum amount of young growth of preliminary generations contributes to direct pine regeneration after harvesting. Pine and spruce forests damaged by fires, windthrow, etc. are designated for narrow clearcuts (as well as selective) sanitary cuttings. The width of clearcuts shall not exceed 70-80 meters. In all cases, pine seedlings and groups of spruce seedlings shall be left at a distance of 30-35 m from each other and forest walls. Cutting of adjacent areas is carried

out after 15-20 years. It is more expedient to cut stands in the year of satisfactory fruiting of pine or spruce. This will allow reducing the period of afforestation of areas and earlier removing the remaining areas of damaged stands that are losing or have almost lost their protective functions.

In multi-age pine forests, two-phase gradual cuttings are carried out with implementation of simple measures to promote natural regeneration of pine. In the first cut (intensity of 40-50 % of the reserve), pine trees older than 180-200 years and other undesirable trees are removed, regulating the composition of the undergrowth. The second treatment is carried out after 30-50 years. Afforestation is provided by the undergrowth of the preliminary generation and the youngest (III) generation of pine. In conditionally mixed-age pine forests, the oldest trees (35-40 % of the stock) are cut in the first cut. Final cutting is carried out after 40-60 years.

In sphagnum, long-moss and shrub types of pine forests, selective cutting is most acceptable. Along with removal of unpromising pines, a part of spruce and birch is selected from the stand. In the first cut, the number of trunks can reach 35-40 %, the stock - 20-30 %, later decreasing to 15-20 %. During harvesting, special attention is paid to the preservation of the young generation of pine, and its pre possession is ensured.

Taking into account the sharply pronounced different-age structure of spruce stands of the pre-tundra strip, selective harvesting should be carried out in them. At the same time, logging in spruce stands should be approached with particular caution due to slow natural regeneration of spruce, low completeness and low productivity of spruce stands formed in the Far North, which is caused by harsh forest conditions. Spruce should not be cut down earlier than 200-220 years, stocking in grass and green-moss spruce forests at one time should not exceed 10-20 % (10-20 m³), the number of trunks - no more than 10 % (20-50 pcs/ha). In other forest types, and especially in sparse forests, the selection of only individual spruce trees is allowed. Application of the above mentioned cuttings will contribute to the improvement, increase and preservation of protective properties of forests, will allow to prevent unproductive losses of timber as a result of its natural fall, improve the species composition and condition of forests and avoid costs for afforestation of cut areas by artificial methods.

The technology of thinning in the area of tundra forests and sparse taiga of the European-Ural part of the Russian Federation is similar to that in the northern taiga area of the European part of the Russian Federation, which is not always justified from the silvicultural and ecological points of view. Due to the low productivity of extremely northern stands, the average selection from 1 ha even with thinning is 6-7 m³, which is not economically justified. Selection during thinning cuts of more than 25-30 m³/ha leads to severe disturbance of the stand. The age at which different types of thinning should be carried out needs to be seriously adjusted towards its increase. When developing the methods of thinning in the area of primundra forests and sparse taiga of the European-Ural part of the Russian Federation, it is necessary to take into account the peculiarities of tree species growth at a young age and microclimatic parameters caused by heat deficit.

Thus, thinning is necessary in part of the areas of post-fire pine young growth where birch is actively settled (green-moss and long-moss group of forest types). A flexible system of thinning is required to preserve the protective properties of plantations and to avoid inefficiency of work. In general, the task of thinning in young forests can be defined as accelerating the replacement of derived forests by more sustainable native forests. Deciduous in coniferous plantations should be left in admixture. Special attention in thinning should be paid to post-fire young forests and, in particular, where the task is to restore native stands.

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