The role of anthropogenic factors in forest transformation in Southern Sakhalin

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Abstract. The article analyzes the forests changes in the south part of Sakhalin Island from the original, natural state as a result of its habitation and economic development. The most essential disturbances of forest cover occurred in the first half of the last century when 9 pulp-and-paper mills were built by Japanese in southern island. All acceptable and more productive dark coniferous forests for providing these mills were cut down. Moreover, significant share of the forests was destroyed because of repeated and large-scale fires, creating agricultural lands and habitable territories, construction of roads, power lines, oil-and-gas pipelines, etc. The most considerable forests transformation was on the territory of Yuzhno-Sakhalinsk, and also in Korsakovsky, Dolinsky, Anivsky, Kholmsky and Nevelsky districts.

1. Introduction
The result of settlement and development of any region, along with creating the habitable territories with related infrastructure objects, construction of the industrial establishments and roads, another anthropogenic changes lead to unavoidable disturbance of the local landscapes, significant fragmentation and transformation, or even total destruction of the natural vegetation. Undoubtedly, the forests as the most acceptable and needed natural resources from the time of appearing a human being on any plot of the Earth are exposed to the anthropogenic impact to a great extent.

The forests of Southern Sakhalin as well as all over the island are predominant type of vegetation attributed to taiga zone [1, 2], and have practically covered all its territory before the active colonization and scaled using forest resources. It was due to, first of all, favorable climate conditions for coniferous forests and particular geographical location. As a result, in the southern part of Sakhalin the most productive forests were formed mainly from the ayan spruce (Picea ajanensis) and Sakhalin fir (Abies sachalinensis) with a slight admixture in the southwestern regions of broadleaf species: Quercus mongolica, Phellodendron sachalinense, Acer mayrii, Kalopanax septemlobus, etc. However, now the structure of the forest cover in the southern part of the island is differ from its natural state. In this regard, the purpose of this work is to assess the role of various anthropogenic factors in the transformation of the original forests of the southern part of Sakhalin as a result of many years of economic development and habitation of its territory.

2. Materials and Methods
To establish a whole range of anthropogenic factors and the degree of their influence on the change in the structure of the forest cover in the southern part of Sakhalin, numerous archival, historical and
fund materials, forest management, statistical and other accounting data, plans of afforestations, topographic maps and atlases of various years were engaged in. In addition, changes in zonal vegetation were assessed based on the results of our own studies of the region forests, carried out over more than 30 years. At the same time, field research of forests was carried out according to standard methods in forestry and phytocenology [3–6 and others]. The available satellite images from the Landsat 8 spacecraft, taken in different periods, were also used to analyze the transformation of primary forests.

3. Results

The habitation and use of the natural resources of the southern part of Sakhalin took place most intensively in the first half of the last century, after the transfer in 1905 of its territory south of the 50th parallel to the jurisdiction of Japan. In a very short period of time, the Japanese built 9 pulp-and-paper mills in various regions, focused on the processing of valuable conifers, mainly spruce and fir. These mills were erected in the cities of Korsakov, Yuzhno-Sakhalinsk, Dolinsk, Kholmsk, Chekhov, Tomari, Uglegorsk, Makarov, Poronaysk, which led to almost complete coverage of the forest resource base. Place in operation all pulp-and-paper mills at full capacity led to a sharp increase in forest felling, the volume of which reached 5–7 million cubic meters by the mid-1930s of the last century. Moreover, most of the mills were erected in settlements with access to the sea, which ultimately ensured uninterrupted and very cheap export of finished products to Japan. These mills became one of the powerful city-forming factors and contributed to the active colonization of the south of Sakhalin. At the same time, other branches of the woodworking industry developed quite well: sawmilling, cooper, shipbuilding, plywood, where cut timber was processed on site, and then exported, along with cellulose and paper, in the form of finished products and other products of its processing.

Quite considerable volumes of forest resources, besides providing for the woodworking and pulp-and-paper industries, were also used for the manufacture of sleepers for the construction of railways. During the "Japanese" period, 120 stations, 24 tunnels, 618 bridges were built on Sakhalin, and the total length of railways was more than 700 km. Along with this, a significant amount of cut timber was used for the manufacture of mine racks and fastening beams in coal mines, the number of which reached 30. There 48 million tons of coal were mined [7, 8 and others].

In addition to being used at Sakhalin production facilities, timber was also prepared for export to Japan. In the first 15 years of colonization of the southern part of Sakhalin, the scale of export was not so significant and varied in the range of 4.2–84.4 thousand cubic meters per year. Then the volume of export of round timber to Japan began to increase sharply and in 1923 already amounted to 1.858 million cubic meters, in 1924 – 2.638, in 1926 – 3.002, in 1928 – 3.191 million cubic meters, etc. (figure 1). In 1921–1926, Japan exported 30 times more round timber from Sakhalin than from Korea and 80 times more than from Taiwan [8, 9, etc.]. With such volumes and intensive felling rates, by 1945 all available and most productive dark coniferous forests in the southern part of Sakhalin were under principal felling. Over the 40 years of the Japanese stay in the south of the island, more than 117 million cubic meters of timber were harvested [10].

Significant contribution to the transformation of the forests of the southern part of Sakhalin was made by agricultural development and creating the habitable territories. Until 1945, about a quarter of the local population was employed in agriculture, and it was almost completely self-sufficient in food. Sown areas in the south of Sakhalin at the apogee of agricultural development in 1935–1938 were 29.5 thousand hectares, the number of cattle – 8 thousand heads, pigs – up to 10 thousand heads, poultry – over 80 thousand heads, many indicators of which have not been achieved yet. During the "Japanese" period, in the valleys or at the mouth of almost every spawning river, settlements with corresponding infrastructure facilities were created and interconnected by a dense network of dirt roads. If in 1907 20.5 thousand people lived in the settlements of the south of the island, and in 1920 – 105.9, then by 1940 their number had already reached 415 thousand people [8, 11, 12, etc.], while at present there are slightly more than 470 thousand people all over the island.
Quite active deforestation in Sakhalin also lasted during the Soviet period of time. In 1946–1991 the forestry enterprises all over the island harvested in average from 2 till 3.5 million cubic meters of timber per year. Of course, at this time, special logging enterprises were created on Sakhalin – integrated timber industry enterprises with powerful technical equipment, as well as associated forest villages. In the Soviet period, about 20% of the population worked in the forestry sector of the Sakhalin Region economy. At the same time, the old Japanese-built pulp-and-paper mills, using only coniferous wood, practically did not stop their activities. To ensure their uninterrupted supply of raw materials, the forests of the southern part of the island were under repeated principal felling. In addition, forests were cut down for the rapidly developing construction industry of Sakhalin. At the same time, the population of the region did not stop harvesting wood for household needs. As a result of long-term and large-scale felling, the available dark coniferous forests of the southern part of the island were almost completely cut down.

Along with felling, the fires, mainly of anthropogenic origin, had a significant impact on the transformation of forests [13, 14]. During the "Japanese" period, 1107 cases of fires were registered in the south of Sakhalin. They destroyed a forest of 802 thousand hectares with a total reserve of over 8 million cubic meters [10]. In 1949, about 354 thousand hectares of forests burned out in the south of the island, in 1950–207, and in 1954–435 thousand hectares, which later, together with the felling, turned into wastelands overgrown with Kuril bamboo and reed grass, practically unusable for natural reforestation.

Certainly, the transformation or even elimination of forest vegetation in the southern part of the island during the entire past and at the beginning of the 21st century, in addition to large-scale felling and fires, also took place in the process of building roads, industrial enterprises and structures, expanding settlements, carrying out agricultural land reclamation, creating hayfields, and cultivated fodder lands for animal husbandry, laying of power lines and oil and gas pipelines, development of quarries, coal mines, open-pit mines, etc. [7, 8, 11, etc.].

A set of main anthropogenic factors and an assessment of their impact on forest vegetation in various regions of Southern Sakhalin are shown in Table 1. The degree of impact of the most significant anthropogenic factors on the structure of forest cover was assessed on a three-point scale: 1 – weak, 2 – moderate, 3 – strong. With a weak integral influence, disturbance of forest vegetation does not exceed 25% of the area of the analyzed territory, with an average – by 26–50% of the area, and with a strong one – forest transformation is observed on an area of more than 50%.

As you can see from the above materials, the greatest impact on the initial forest cover was made by industrial felling, fires, as well as the construction of roads and settlements. The frequency of occurrence of the latter in the south of the island is much higher than in the northern regions. Of course, during the construction of roads and settlements, the vegetation and soil cover was completely eliminated.

Zonal forests turned out to be most transformed on the territory of Yuzhno-Sakhalinsk, as well as in Korsakovskiy, Khomlsky, Nevelsky, Anivskiy and Dolinsky municipalities, where the main production facilities are located, agriculture is well-developed, large ports and cities of the region are with high population density. At the same time, the original forest vegetation on the territory of the regional capital, in Yuzhno-Sakhalinsk, was radically transformed (Table 1). Indigenous coniferous forests here were completely destroyed, and in their place forest cultures were created,
both from aboriginal and foreign forest-forming species (*Larix leptolepis*, *Pinus sylvestris*, *Picea abies*, etc.), which now represent suburban forest landscapes (figure 2). A similar situation developed on the territory of the Korsakovsky District, from where the Japanese began to develop the southern part of Sakhalin.

Table 1. Impact of anthropogenic factors on the forests of Southern Sakhalin.

| Administrative Districts (municipalities) | Types of anthropogenic impact | Cumulative anthropogenic impact |
|------------------------------------------|-------------------------------|--------------------------------|
|                                         | Forest felling | Forest fires | Plough lands for agriculture | Creation of pastures, forage lands | Construction of settlements, roads | Recreational loads | Construction of industrial enterprises etc. | Construction of oil and gas pipelines | Total effect of the factor |
| Smirnykhovsky                           | 10457.4         | 2            | 1                            | 1                               | 2                                | 1                        | 1                               | 1                           | 10                           |
| Poronaysky                              | 7284.3          | 3            | 3                            | 1                               | 1                                | 2                        | 1                               | 3                           | 15                           |
| Makarovsky                              | 2148.4          | 3            | 3                            | 1                               | 2                                | 1                        | 3                               | 1                           | 15                           |
| Dolinsky                                | 2441.6          | 3            | 2                            | 3                               | 3                                | 2                        | 3                               | 2                           | 21                           |
| Anivsky                                 | 2684.8          | 3            | 3                            | 3                               | 3                                | 2                        | 1                               | 3                           | 21                           |
| Korsakovsky                             | 2623.6          | 3            | 2                            | 3                               | 3                                | 2                        | 3                               | 3                           | 22                           |
| Tomarinsky                              | 3169.3          | 3            | 3                            | 3                               | 3                                | 1                        | 2                               | 0                           | 18                           |
| Uglegorsky                              | 3956.5          | 3            | 3                            | 3                               | 3                                | 1                        | 3                               | 0                           | 19                           |
| Kholmsky                                | 2279.0          | 3            | 3                            | 3                               | 3                                | 3                        | 2                               | 3                           | 20                           |
| Nevelsky                                | 1445.4          | 3            | 3                            | 3                               | 3                                | 3                        | 2                               | 3                           | 20                           |
| Yuzhno-Sakhalinsk                       | 905.0           | 3            | 3                            | 3                               | 3                                | 3                        | 3                               | 3                           | 24                           |
| **Total effect of the factor**          | **32**          | **29**       | **27**                       | **27**                          | **30**                           | **18**                   | **28**                          | **14** |                                        |

A very moderate transformation of the forest cover in the Smirnykhovsky District is due to the fact that the northern part of its territory was Soviet until 1945 and, therefore, was less developed. In addition, a pulp-and-paper mill and other large industrial enterprises were not built in the region, and agriculture was not developed. Throughout the last century, the district was engaged in logging, for the implementation of which the corresponding settlements were created, their inhabitants mainly worked in the forest sector of the economy. Moreover, a significant part of the coniferous forests is concentrated on the hard-to-reach steep slopes of the East Sakhalin Mountains contributing to their preservation to a certain extent. It was the Smirnykhovsky District that we managed to create the Vostochny Nature Reserve with a total area of over 68 thousand hectares in order to preserve intact forest areas [15].
Figure 2. The forests around Yuzhno-Sakhalinsk have been transformed to the greatest extent and are mainly represented by artificial plantations and secondary communities.

4. Conclusion

Consequently, the transformation of zonal forests in the southern part of Sakhalin actively started in the last century and was associated with the colonization and development of natural resources. The most significant anthropogenic disturbances of forest cover occurred in the first half of the past century, when the Japanese built 9 pulp-and-paper mills in the south of the island, for which all available and most productive dark coniferous forests were under principal felling. The volume of forest felling in the south of Sakhalin by the middle of the 30s of the last century reached 5–7 million cubic meters per year. In addition to cellulose and paper, a significant amount of round timber was exported from Sakhalin to Japan. Subsequently, during the Soviet period, even on the entire Sakhalin Island, annual logging did not exceed 2–3.5 million cubic meters. Undoubtedly, large-scale and repeated logging during the past century has significantly wrecked the forest resources of the region and radically affected the formational composition and structure of the forest cover.

Moreover, huge areas of forest land have been destroyed by fires because of human activities. Only in the “Japanese” period, more than one thousand forest fires occurred in the southern part of Sakhalin and led to the accumulation in 1945 of about 1.5 million hectares of unforested cutting areas, glades, wastelands and burnt areas. Along with felling and fires, the transformation or even complete destroy of zonal forests took place in the process of creating agricultural lands and habitable territories, building industrial enterprises, railways and highways, developing coal mines, quarries and open-pit mines, laying oil and gas pipelines and other related infrastructure facilities.

Maximum anthropogenic transformation of forest landscapes occurred on the territory of Yuzhno-Sakhalinsk. With forming the urban agglomeration, the natural forests were completely destroyed and on the related to the city plots were created the artificial afforestations from both the indigenous and non-regional conifers. Essential anthropogenic transformation of zonal forests or even their total elimination was also in Korsakovskiy, Kholmsky, Nevelsky, Anivsky and Dolinsky districts, where the main production facilities are located, agriculture is well-developed, ports and large cities of the region are with a very high population density.
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