Negative impact assessment on specially protected forest areas during placer gold mining operations

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Abstract. The work reviews the biological and ecological functions of forests in general and specially protected forest areas in particular, analyzed the impact of anthropogenic effect of placer gold mining on forest landscapes, and also present the results of studies of natural and artificial revegetation processes in disturbed areas of forest lands in the Republic of Buryatia and Khabarovsk Territory. Based on the data obtained, the study areas show low rates of overgrowing, especially in areas with steep slopes and hard bottoms formed by removing soil to rock. Reclamation activities, especially the technical stage, are of key importance in the issue of natural renewal and restoration of the protective functions of forests. Also, in order to preserve the main environment-forming functions of forests in the areas of alluvial gold mining, it is recommended to develop strict rules of nature management adapted to the processes occurring in various ecosystems, including minimizing the area of open territories intended for the operation of mines.

1 Introduction

The gold mining industry is one of the most important for the economy of the Russian Federation. Today Russia is one of the three largest countries producing precious metal [1, 2].

Alluvial gold mining is carried out by mining mines in vast areas of the Far Eastern Federal District (FEFD), mainly in remote and underdeveloped areas with difficult climatic conditions and widespread permafrost. Due to this specificity, the structure of mines, along with mining, washing and processing, operational and exploration units, includes transportation, energy, communications, repair and mechanical, administrative and social and welfare facilities, and these facilities can be dispersed at a considerable distance from each other and from the central base [3, 4]. The main gold-mining regions of the Far Eastern Federal District include: Republic of Sakha (Yakutia), Amur Region, Magadan Region and Khabarovsk Territory [5, 6]. The total area of forest lands of the Far Eastern Federal District transferred for use for geological exploration of subsurface resources and

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development of mineral deposits is 323.9 thousand hectares. Most of the gold placers are located in the mountain valley of rivers and streams, which are due to the principles of their origin and represented by oblique, channel, valley placers [3, 7-9].

Specially protected forest areas (SPFA) in the Far Eastern Federal District cover 39.2 million hectares, which is 46.3% of all SPFAs in the Russian Federation. They fulfill many functions, of which the following are of particular importance:

1. Focusing, this is significantly affected in mountainous areas. Here, mountain taiga and mountain tundra plant communities slow down the development of solifluctions, water and wind erosion, thermokarst, reduce the danger of mudflows, rockslides and debris flows, which is typical for regions located in the zone of permafrost and island frost;
2. Water protection - to maintain water reserves and fullness in the basins of small and large watercourses;
3. The anti-avalanche role is inherent in high-mountain landscapes, where exodynamic processes (kurum movements snow and block avalanches, landslides, and deflation) are not rare;
4. The anti-erosion function of plants is the main one in mountainous countries with altitudes over 1000 meters above sea level;
5. Biostationary role of vegetation, which is determined by the adherence of the main fauna species to certain biotopes that form plant communities [10-12].

The presence of SPFA on forest lands (forest fund lands) complicate the organization and conduct of geological study of subsurface resources, exploration and extraction of minerals, construction and operation of linear objects, since such activities on their territory are either restricted or prohibited [13]. Consequently, designers have to take into account their location and area, and then choose a compromise solution: either pay a fine or change the design area.

Any placer mining involves a large group of works, which imposes a huge anthropogenic load on river complexes. Extraction of placer gold leads to cardinal transformations of river valleys and adjacent territories. The turbidity and chemical composition of water changes due to oil products and huge amounts of suspended solids entering it [14-16]

In the process of gold mining, “lunar” landscapes, man-made lakes, channels and mountains are created and the soil cover is completely disappearing. Mechanical disturbance of the complexes forming the landscape causes significant changes in the vegetation cover.

Also, in the process of placer gold mining there is pollution of atmospheric air, groundwater, death or migration of living organisms, which leads to the loss of many important ecosystem functions of the territory [17-19].

Restoration of dead forests can take centuries. In this case there is not a complete return of the original plant communities, but new ecosystems and landscapes are formed [20, 21].

Thus, the purpose of this research was to assess the negative impact of placer gold mining operations on the functions of specially protected forest areas.

2 Objects and methods of research

The research was conducted in August-September 2023 on the territory of the Yeravninsky (Republic of Buryatia) and Mukhensky (Khabarovsk Territory) forestries (Fig. 1, 2). The objects of the study were the forest lands affected by placer gold mining.

The research of natural and artificial regeneration of forests in the areas after placer gold mining was conducted by counting the undergrowth on 2×2 meter plots located at 2 meter intervals. According to the generally accepted classification, the undergrowth was divided by height into three size categories. The condition of the undergrowth was taken into account and divided into healthy, weakened, dried and withered individuals. When assessing regeneration, the occurrence of undergrowth and the uniformity of its distribution over the area were taken into account [24-28]. The assessment of shrub and herbaceous cover was carried out by eye and simultaneously with taking into account the undergrowth. The characteristic of microrelief on the worked areas was determined according to the method of A.V. Pobedinsky [28].

Fig. 1. Map-scheme of Kamennoye mine location on the territory of Yeravninsky forestry (Republic of Buryatia).

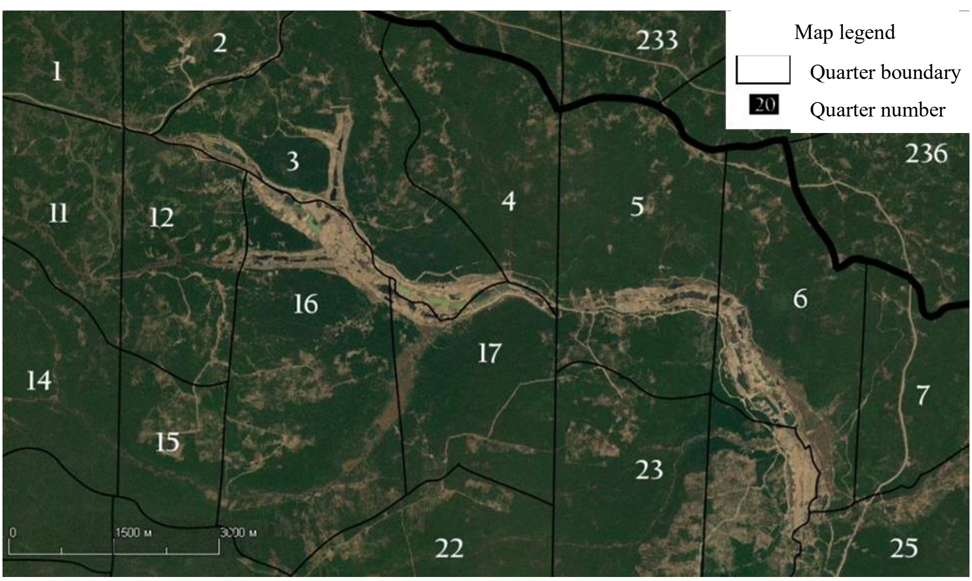

Fig. 2. Map-scheme of Bolotistoe mine location on the territory of Mukhenskoye forestry (Khabarovsk Territory).

3 Results and discussion

Yeravninskoye forestry is located in the eastern part of the Republic of Buryatia. The climate is sharply continental, characterized by dry air, abundance of sunlight, low annual precipitation and its uneven distribution by seasons, short growing season.

Climatic conditions of the territory form tree stands of low productivity. The main forest forming species are: *Larix sibirica*, *Pinus sylvestris*, *Betula platyphylla*, *Populus tremula*, *Salix caprea*. The relief is dominated by mountains of medium height, cut through by numerous river valleys and falls of tectonic and erosional origin. The altitude of the area above sea level varies from 800 to 1580 meters. Most of the territory of the forestry is included in the middle taiga subzone (900-1100 meters), smaller areas are occupied by the lower (up to 900 meters) and upper (1100 meters and above) taiga [29].

In 2005, pilot mining of the Kamenny brook placer was carried out here, and since 2006 - its exploitation. As a result of earlier studies on the anthropogenic impact of placer gold mining on the natural environment in the study area, it was noted that the most disturbed areas are river valleys, as they were subject to transformation as a result of stripping operations. It was also noted the impact on forest ecosystems due to deforestation for exploration, creation of access roads, construction of work camps, creation of infrastructure and other impacts [30].

In 2023, the staff of Far East Research University assessed the processes of natural reforestation (Fig. 3, Table 1).

Fig. 3. Natural regeneration of *Larix sibirica* in the placer gold mining area near brook Kamenny.

Table 1. Undergrowth characterization on the alluvial placers of the brook Kamenny.

Species	Distribution of viable undergrowth by size category, pcs/ha				Composition, %
	small, less than 0.5 meters	medium, 0.6-1.5 meters	large, over 1.5 meters	In total	
Pinus sylvestris	100	0	0	100	2
Larix sibirica	1600	300	1600	3500	76
Betula platyphylla	200	200	200	600	13
Salix caprea	300	100	0	400	9
In total	2200	600	1800	4600	100

According to the research, it was concluded that *Larix sibirica* and *Betula platyphylla* in the vicinity of the forest area of the brook Kamenny alluvial deposit dumps are satisfactorily overgrown. No regeneration is observed in the quarry part on slopes over 30°.

Mukhenskoye forestry is located in the southern part of Khabarovsk Territory. The area is located in the swampy Sredneamurskaya lowland. The climate is similar to the central regions of Khabarovsk Territory, with an average temperature of -24°C in January and +21.7°C in July, high air humidity and frequent winds.

According to forest zoning, the researched territory belongs to the taiga zone, the Far Eastern taiga forest area. The forests are dominated by coniferous tree species (about 85%), such as *Picea jezoensis*, *Abies nephrolepis*, *Larix gmelinii*, *Pinus koraiensis*. There are also deciduous species such as *Quercus mongolica*, *Betula platyphylla*, *Populus tremula*, *Fraxinus mandshurica*, *Tilia amurensis*, *Phellodendron amurense*, *Alnus hirsuta*[31].

Here, in the valley of the brook Bolotisty, from 2006 to 2011, hydromechanical development of a gold ore mine with bulldozer stripping and enrichment of sands on washing devices was carried out [32].

According to the forest inventory data, on the surface of the dumps selectively carried out measures to create forest crops on the area of 274.4 ha (Fig. 4a). Most of the cultures established from 2005 to 2020 are represented by *Pinus koraiensis* (Fig. 5). Cultures are in satisfactory condition and belong to the 3rd class of bonitet.

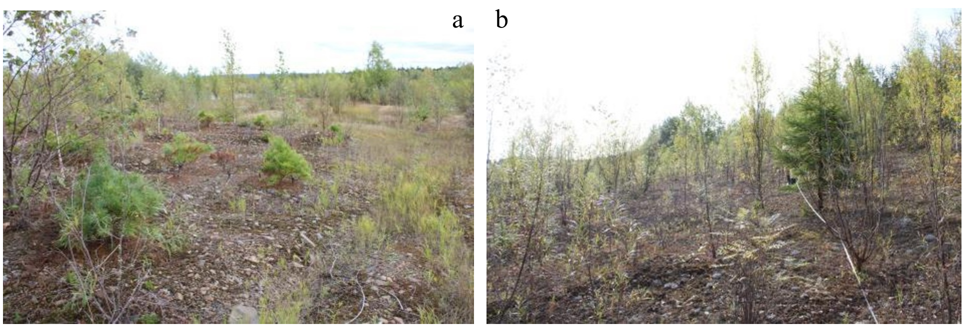

Fig. 4. Reforestation on the surface of the brook Bolotisty mine area: a) artificial; b) natural.

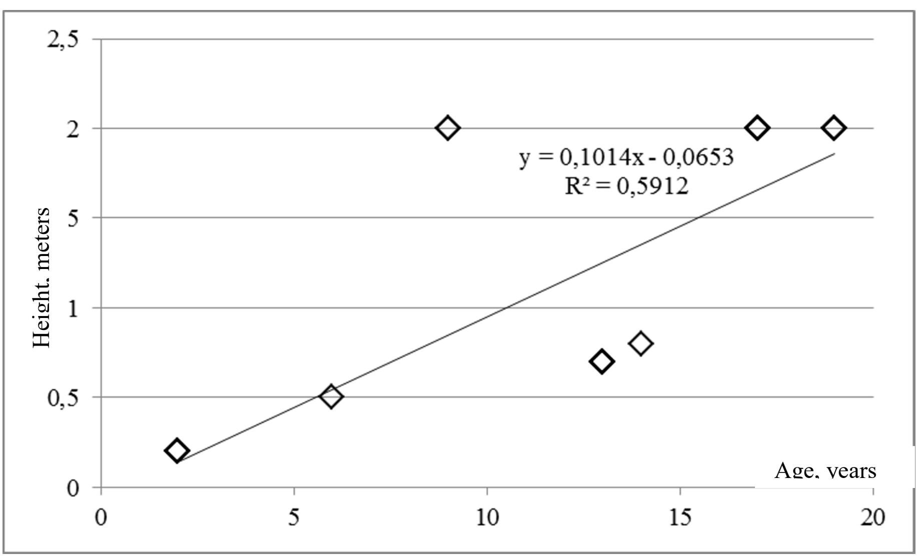

Fig. 5. Height growth rate of *Pinus koraiensis* crops.

The laying of sample plots in the research area allowed estimating the quantitative ratio of coniferous to deciduous species both in the reclaimed area and in the natural regeneration (Table 2).

Table 2. Undergrowth characterization on the alluvial placers of the brook Bolotisty.

Species	**Distribution of viable undergrowth by size category, pcs/ha**				**Composition, %**
	small, less than 0.5 meters	**medium, 0.6-1.5 meters**	**large, over 1.5 meters**	**In total**	
Area № 1. Recultivation has been carried out. Planting of forest crops.					
Pinus koraiensis	1700	0	0	1700	4
Picea jezoensis	2400	0	100	2500	6
Betula platyphylla	100	100	100	300	1
Salix caprea	38900	900	600	40400	89
In total	43100	1000	800	44900	100
Area № 2. Mechanical recultivation. Self-renewal.					
Picea jezoensis	4500	0	0	4500	23
Larix gmelinii	500	0	100	600	3
Abies nephrolepis	400	0	0	400	2
Betula platyphylla	8000	3300	2200	13500	67
Salix caprea	300	100	500	900	5
In total	13700	3400	2800	19900	100

According to the conducted research, it was concluded that the overgrowth of the dumps of the Bolotisty mine with deciduous species and *Picea jezoensis* is satisfactory. The condition of *Pinus koraiensis* crops should also be considered satisfactory.

4 Conclusions

As a result of the performed works it was revealed that in the places of alluvial gold mine development the processes of self-regeneration are very slow due to the complexity of the relief created. Steep slopes and hard bottoms formed as a result of soil extraction to rock formations prevent their settlement by woody and herbaceous plants.

It is noted that overgrowth in technogenically disturbed areas occurs more efficiently in places where recultivation measures, namely the technical phase, are carried out. Quantitatively natural regeneration in the form of *Salix caprea* and *Betula platyphylla* prevails over the established forest cultures.

Significant functions of specially protected forest areas in the study area are water protection and erosion control. This property of forests in the researched areas, after cutting and removal of potentially fertile soil layer as a result of exploration and mining, disappears and can be restored only through recultivation works.

Also, in order to preserve the main environment-forming functions of forests in the areas of alluvial gold mining, it is recommended to develop strict rules of nature management adapted to the processes occurring in various ecosystems. It is necessary to minimize the area of open territories intended for mine operations, administrative and production facilities should be integrated into the natural landscape to preserve vegetation, it is required to preserve the spatial diversity of communities.

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