

Vegetation recovery in open cast mines of Tver Region

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Abstract. In the study natural plant communities appearing at the first stages of vegetation recovery in open cuts are described. Sixty-three species of higher vascular plants were found, six of which are adventive (*Bunias orientalis* L., *Cichorium intybus* L., *Cirsium arvense* (L.) Scop., *Melilotus albus* Medik., *Sedum spurium* M.Bieb., *Solidago canadensis* L.). Species from the *Asteraceae* (15), *Gramineae* (8), *Fabaceae* (7) families prevail. The predominant life form according to I. Serebryakov are long-rhizome. According to G. Zozulin's classification, plants belonging to the meadow and birch formations are most common. The associations of *Calamagrostis epigejos* and *Bromus inermis* predominate. *Cirsium arvense* (L.) Scop., *Heracleum sibiricum* L., *Campanula glomerata* L. are single.

1 Introduction

Human-made changes in the environment at the present stage of economic development loom large. This process is especially significant in the open cuts that are formed because of human activity. When they appear, all components of the geosystem are violated. Unfortunately, it is impossible to completely avoid this type of mining. Therefore, the restoration of a disturbed open cut geosystem is a very important process, which can also be considered as a place for new biogeosystems [1].

There are a lot of studies from all over the world about vegetation recovery in open cast mines. The ecological features of plants in open cuts are considered [2,3,4]. Numerous scientific studies from different countries are about various issues of construction and other minerals mining impact [5,6,7,8]. The state and physical and mechanical properties of rocks disturbed during open cut mining, both left in place and moved to another place, undergo strong changes. They are very diverse and depend on the type and structure of massive material, the mining method, movement, laying and subsequent conditions of their existence. Excavation of rocks is almost always accompanied by disruption of natural structural bonds, disintegration, an increase in porosity, rock loosening, and a decrease in resistance to compression and shear [9, 10].

Reclamation issues are also of high priority [1,3]. At the same time, recovery is not always carried out. This happens because of various reasons, primarily because of illegal mining.

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There the recovery process occurs uncontrollably and spontaneously. The study of the vegetation recovery mechanisms in such open cuts is very urgent.

The aim of the study is to assess the natural vegetation recovery in open cast mines in Staritsky District of Tver region.

2 Methods and materials

Covering loess loam is widespread in Staritsky District. They are characterized by a homogeneous composition with a predominance of silt fractions. In terms of texture, these deposits are carbonate boulderless loams (less often sandy loams). These mantle loams and sandy loams overlap a thick (2-4 m) layer of water-glacial sands with lenses of gravel and cobble. Pre-Quaternary deposits are represented by Devonian sands [11].

Sand and gravel-cobble mixture open cut is located near the village Vasilievskoye of Staritsky district. It is illegal, so it is difficult to determine the age. We can suppose that it appeared because of the sand and gravel mixture excavation for road construction in the 1990s. The open cut has an asymmetric elongated shape and irregular relief due to illegal mining. Satellite images of the open cut from 2015 and 2018 are shown in Fig. 1 (a, b). The images were taken with Google Earth Pro.



Fig. 1. Space images of the cut in Staritsky District of Tver region: left – 2015, right – 2018.

The total area of open cut is 0.0175 m². The side of the open cut is a ledge, we could see decomposed rocks in the old excavations, there are no large boulders. The open cut sides are complicated by rain channels, erosional activity, and microslides. The main extraction of sand and gravel took place on side, which extends from northwest to southeast. The length of the worked-out side is 25 meters, the height is 2.5 m. Fluvioglacial Quaternary deposits were mined in the quarry from the Valdai glacier. Below, the fluvioglacial deposits are underlain by moraine. Currently, the open cut is used by residents as a landfill for household waste (Fig. 2). It also affects the plant communities of the open cut.



Fig. 2. Landfill at the site of a worked-out quarry open cut.

In the northwestern part of the open cut, there is a water reservoir, which was formed after the groundwater horizon was reached. The area of the water reservoir is 30 m². The water reservoir is a home for beavers (Fig. 3).



Fig.3. A pond formed at the bottom of a worked-out open cut with traces of beavers' vital activity

The climate is temperate continental. Its main features are: mild, snowy winter with a predominance of cyclonic weather; moderately warm summers with frequent rainstorms; pronounced transitional seasons; general excess moisture. The average annual temperature is + 3.3 ° - + 3.5 ° C. The coldest month is January, from -9.8 ° to -10.4 ° C. In summer, in July, average temperatures reach + 16.8 ° - + 17.2 ° C. The duration of the growing season is about 173 days. The amount of precipitation depends on cyclonic activity. The average long-term annual precipitation is 649 mm. The number of days with snow cover is on average 139 days,

the average height of snow cover is 36-47 cm. The amount of precipitation is greater than the amount of evaporation possible in terms of temperature conditions. Excess moisture contributes to the development of bog processes, feeds numerous rivers and streams. The winds of the western points prevail, especially the south-western directions (21%) [12].

The study of the open cut vegetation of the open cut was carried out in 2019 according to the standard method [19]. The sides, the bottom and slopes of the open cut were described, the sites were laid using the transect. The definition of the plant was carried out according to Gubanov et al., and Mayevsky, [13-15,16]. The projective cover of the species was assessed according to the Drude scale: "un" - the species is very rare, 1-4 individuals on the site; "sol", 1 point - the projective cover of species individuals is less than 1%; "sp", 2 points - from 1% to 5%; "cop₁", 3 points - from 6% to 25%; cop₂, 4 points - from 26% to 50%; "cop₃", 5 points - from 51% to 75%, "soc", 6 points - more than 75% [17]

The assessment of the phytocenotic confinedness of species was carried out according to G. Zozulin classification accompanying plants [18].

3 Results and discussion

During the study of the quarry, 63 species of higher vascular plants were found, 6 species of which are adventive (*Bunias orientalis*, *Cichorium intybus*, *Cirsium arvense*, *Melilotus albus*, *Sedum spurium*, *Solidago canadensis*) [17]. Species from the *Asteraceae* family prevail - 15, *Gramineae* - 8, *Fabaceae* - 7. These families are among the ten dominant families of the Holarctic region.

According to G. Zozulin classification of phytocenotic accompanying plants, the following groups are found: meadow, birch, anthropogenic, alluvial-herbaceous, pine forest, boreal-willow and alder (Fig. 4).

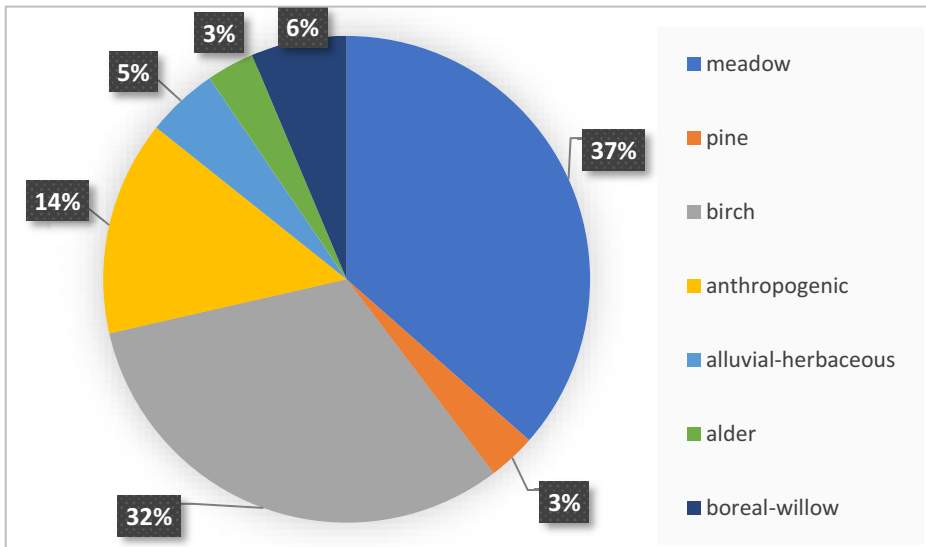


Fig. 3. The ratio of Zozulin's phytocenotic groups

The presence of meadow and birch forest species indicates that the processes vegetation recovery began relatively recently. The presence of anthropogenic species is primarily due to the landfill in the open cut [19]. The species belonging to the alder formations grow at the bottom of the open cut. Four species of the boreal-willow formation were also recorded.

Representatives of the pine forest and boreal-willow formations testify to the gradual vegetation that is specific for the southern subtaiga zone.

Thus, in accordance with the prevailing G. Zozulin's phytocenotic formations, the vegetation cover in the studied open cut is gradually recovering and it is at the initial stages of the succession process. The same results are observed in the study of other open cuts [20-22].

During the analysis in accordance with I. Serebryakov classification we identified 12 types of life forms (Fig. 4) [23].

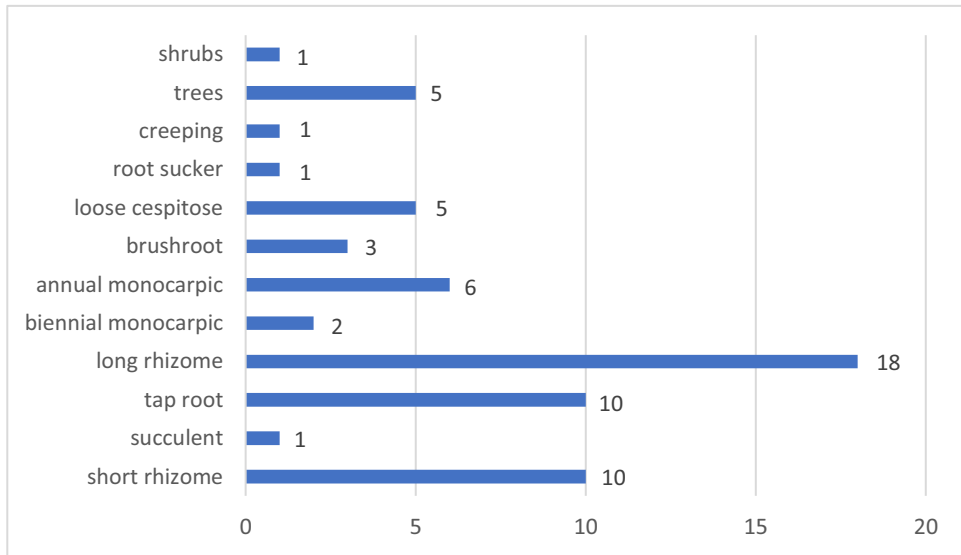


Fig. 4. Distribution of life forms according to Serebryakov

The most common are long-rhizome plants, as well as short-rhizome and taproot plants. This is primarily due to the peculiarities of the open cut substrate. Loose (mainly sandy loam and light loamy) and sufficiently moist soils are observed here, especially at the bottom. Trees and shrubs grow either along the open cut side or at the bottom. Their vitality is high. At the open cut bottom there are trees up to 15 m in height with a trunk diameter of up to 20 cm. Along the northern open cut side slope, there is abundant self-seeding of aspen and birch, up to 7 m in height.

The most abundant vegetation is on the sides of the open cut or in the upper part of the slope. The total projective cover (TPC) here was up to 90%. In the middle part of the slope, the TPC was from 20% to 80%, in the lower part - 20-50%, at the bottom - 50-70%. Motley grass-grasses communities prevail, in which grass with a projective cover of 50% or more prevails. The most common species are: *Tanacetum vulgare*, *Achillaea millefolium*, *Festuca pratensis*, *Calamagrostis epigejos*. They are noted in more than half of all geobotanical descriptions. At the same time, *Tanacetum vulgare* and *Achillaea millefolium* do not form a dense cover, their projective cover does not exceed 25%. Unlike *Calamagrostis epigejos*, *Brōmus inermis*, which form monodominant communities with a projective cover of 70-90%. *Cirsium arvense*, *Heraclēum sibīricum*, *Campanula glomerata* are found singularly.

On the southern and eastern slopes of the open cut, 25 and 20 species of vascular plants were found, and at the bottom 23 species were found. On the northern slope, 16 species of vascular plants were found, on the western slope 17 species were found. At the same time, different types of plants can be found on slopes with different exposures. Only on the northern slope of the open cut we found *Brōmus inermis*, which forms dense populations along the entire slope with an abundance of 3 to 5 points, as well as a single *Heraclēum sibīricum*. Only

on the southern slope are found singularly: *Cirsium arvense*, *Trifolium medium*, *Equisetum pratense*; with an abundance of 1 point, *Tussilágo fárfara*, with an abundance of 2 points: *Alchemilla vulgaris*, *Medicágo lupulina*. The most common *Gálium mollúgo* with an abundance of 1 to 3 points is found on the southern slope. Only at the bottom of the open cut there is a single *Cichóriúm íntybus*, with an abundance of 1 point - *Chelidónium május*, with an abundance of 2 points - *Veronica chamaedrys*, *Urtica dióica*, *Scrophularia umbrosa*, with an abundance of 3 points - *Chamaenérion angustifolium*.

4 Conclusions

With the spontaneous vegetation recovery in the open cut, succession processes occur, which are specific to the natural vegetation of the given natural zone. At the initial stages, species related to meadow and birch forests predominate. The least represented are the species belonging to the alluvial-herbaceous, alder and boreal-willow phytocoenological formations.

In the studied open cut, 63 species of higher plants were found. Because of the landfill in the open cut, adventive species belonging to anthropogenic formation (*Búnias orientális*, *Cichóriúm íntybus*, *Cirsium arvense*, *Melilótus álbus*, *Sedum spurium*, *Solidágo canadénsis*) were found.

The most common are long-rhizome plants, as well as short-rhizome and taproot plants according to I. Serebryakov's classification.

The largest number of species was recorded on the southern and western slopes of the quarry, as well as on the bottom, where more moisture-loving species were noted (*Urtica dióica*, *Álnus incána*, willows, etc.).

The most common are *Tanacétum vulgare*, *Achilléa millefólium*, *Festuca pratensis*, *Calamagróstis epigéjos*. *Festuca pratensis*, *Calamagróstis epigéjos* form monodominant communities. *Cirsium arvense*, *Heracléum sibíricum*, *Campanula glomerata* are found singularly.

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