

BIOLOGICAL DIVERSITY OF PLANT COMMUNITIES OF TECHNOGENIC LANDSCAPES OF TYRNYAUZ TUNGSTEN-MOLYBDENUM COMBINE

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Abstract

*The results of studying the structure of flora and plant communities of the technogenic landscape of Tyrnyauz mining and processing combine (Kabardino-Balkarya Republic), the territory of which was previously a closed facility are presented in the article. The composition of the flora, including 229 species of vascular plants, was revealed. Ecosystem diversity includes both natural and landscapes, represented by high-altitude meadows, high-altitude forests of *Betula pendula*, *Betula litwinowii*, *Salix caprea*, shrubby, petrophytous groupings and steppe meadows. There is a significant disturbance of ecosystems, as evidenced by the high proportion of synanthropic plant species. Rare plant species are not registered, which also indicates a high unresolved community.*

Keywords: biological diversity, plant communities, technogenic landscapes, Tyrnyauz tungsten-molybdenum combine

I. Introduction

The study of the biological diversity of anthropogenic landscapes is one of the urgent problems of modern vegetation science [1]. Phytocenoses of technogenic landscapes differ from the original ones in the structure and composition of the flora. A specific synanthropic vegetation is formed here, characterized by a unified composition of its components and a significant change in the taxonomic structure [2]. The communities dominated by alien species are often found [3] in highly transformed geosystems, which are a source of biological invasions into natural ecosystems [4]. It is necessary to conduct scientific research of such territories to substantiate the proposed optimization solutions and to identify the real and expected geocological risks of man-made territories [5].

The purpose of the research was to study the flora and vegetation of technogenic landscapes as a basis for the development of scientific solutions to optimize the environmental management of Tyrnyauz mining and processing combine. Its tasks included inventory and analysis of the flora of natural and man-made ecotopes (road, areal man-made territories); identification of the diversity of plant communities with an assessment of the general patterns of changes in altitude zones; assessment of the level of synatropization of the identified communities.

Tyrnyauz urban settlement is the largest in the Elbrus district of the Kabardino-Balkarya Republic. It is located in the mountainous part of the Republic at an altitude of 1300 m above sea level and is rich in reserves of tungsten and molybdenum (Tyrnyauzskoye deposit). Tyrnyauz appeared in 1934 as a single-industry town, when the development of a tungsten-molybdenum deposit was started here. Over time, it became the leading production of non-ferrous metal

industry in the country, providing a third of the needs of the country's economy in this raw material. After the collapse of the Soviet Union, Tyrnauz began to lose its position like other single-industry towns of the country. A new stage in the development in the history of the city began after V. Putin came to power. Today, the goal is to restore the combine.

The closed territory of the mining and processing combine for visiting interested parties caused the absence of any floristic data of this territory. To date, there is no information not only about rare species and phytocenoses, but also about the general patterns of vegetation changes in high-altitude zones. The studied area is characterized by long-term intensive economic activity (grazing, logging, road works, intensive construction on slopes, etc.), which has a negative impact on the natural vegetation cover, causing degradation and an increase in the proportion of weeds in its composition.

II. Methods

The object of the study is flora and plant communities on linear (road) and areal (landfills, pumping station territory) objects of Tyrnauz tungsten-molybdenum deposit. The studies were carried out by traditional route and geobotanical methods in September 2020. Observations were made concerning the location of species by altitude zones, habitat types, phytocenotic role and ecological confinement of species. In total, about 200 herbarium samples were collected and 35 sample plots were made. The altitude range of studies is from 2494 m above sea level to a height of 1100 m above sea level. The names of plants are given in accordance with the latest floristic summary of S.H. Shkhagapsoev [6], Synopsis of the Flora of the Caucasus [7-9].

According to floral zoning, Tyrnauz urban settlement is located on the border of two subdistricts: Elbrus and the Jurassic Depression subdistrict. It occupies the area of the Jurassic (Northern) depression from Baksan to Cherek with altitudes from 1200 m up to 1800-2000 m above sea level. Within this subdistrict basins are isolated, having mainly upland xerophytic and steppe vegetation surrounded by mesophilic. A total of 896 species have been recorded here [6]. The originality of the flora lies in the predominance of upland xerophytic and petrophytic vegetation.

III. Results

219 plant species belonging to 51 families have been registered in the research area. The analysis of the flora showed that boreal elements predominate in the flora, but the presence of Mediterranean features is noted. The analysis of geographical elements characterizes the flora as Boreal-Caucasian (66.58%), where the species of the Caucasian element make up 33.4%. Boreal species prevail in the flora of individual belts and habitats, and the share of ancient Mediterranean species accounts for only 12.35% [7]. Ecological analysis of the flora shows that the number of species of open grassy spaces of highlands and forest birch communities predominate. According to Raunkiær [10], hemicryptophytes numerically predominate in the spectrum of life forms of the entire flora, with a small number of chamaephytes. It should be noted a significant number of therophytes (annuals-biennials), which is associated with a significant disturbance of vegetation cover along the roadsides of a linear object and especially areal territories. These are species belonging to a vagative life form that do not stay at the area of their growth but roam the area and germinate from seeds on new biotopes. One species of the parasites, *Monotropa hypopitys* L., was noted.

The following types of vegetation were observed in the research area, replacing each other when moving from top to bottom: rocky groupings of the upper mountain belt, fragments of subalpine meadows, high-altitude forests of *Betula pendula* Roth, *Betula litwinowii* Doluch., *Salix*

caprea L., shrub thickets of *Hippophae rhamnoides* L., steppe meadows, ruderal communities of anthropogenic ecotopes and rocky vegetation of the middle mountain belt.

The linear feature (road) is dominated by forests of *Betula pendula* and *Betula litwinowii*. The sodominants are *Salix caprea* and then *Hippophae rhamnoides* with decreasing of the height and lower is *Berberis vulgaris* L. Occasionally *Pinus sylvestris* L., *Ulmus glabra* Huds. are found. *Pinus sylvestris* does not form communities in the studied zone. *Myricaria bracteata* Royle grows along the banks of watercourses.

Betula litwinowii plant communities grow on rocky substrates and are characterized by low bonitet and form low-density stands on minor soils, largely bearing traces of anthropogenic disturbances associated with the road functioning during the operation of the combine. *Betula litwinowii* is about 50 years old. The most common type of ecosystems is *Betula litwinowii* communities with *Calamagrostis epigeios* (L.) Roth participating in the grass canopy, as well as with varying degrees of grass participation. They form ecotonic biotic communities. Their uniqueness consists in a combination of two types of plant communities: forest and treeless. Plant communities of *Betula litwinowii* are in contact with steppe meadow communities, meadow steppes and rocky ecotopes.

The uppermost sections of the research area are blocky-rocky-talus ecotopes with thinned rare vegetation. Abrupt and steep slopes are characterized by extremely weakly expressed soil cover. Significant areas are outcrops with a complete absence of soil. Communities are not genetically formed. The geobotanical description was made at an altitude of 2494 m above sea level (GK 381). Vegetation is rare, Alpine type. Here grow: *Betula pendula*, *Betula litwinowii*, *Salix apoda*, undergrowth of *Pinus sylvestris*. From herbaceous plants grow *Calamagrostis pseudophragmites* (Haller f.) Koeler, *Calamagrostis epigeios*, *Euphrasia caucasica* Juz., *Tussilago farfara* L., *Rumex acetosella* L., *Chamaenerion colchicum* (Albov) Steinb., *Erigeron orientalis* Boiss., *Gentianella biebersteinii* (Bunge) Holub.

The slopes of the linear feature (roads) are rocky barrows. Here rarely grow the shrub forms of *Betula pendula*, *Salix caprea*, *Hippophae rhamnoides*, *Juniperus communis* subsp. *oblonga* (M. Bieb.) Galushko and herbaceous plants: *Heracleum asperum* (Hoffm.) M. Bieb., *Festuca ovina* L., *Gentianella biebersteinii* (Bunge) Holub, *Crepis pulchra* L., *Achillea millefolium* L. rarely. *Hippophae rhamnoides* forms small clusters in the lower part of the slope near the road.

Here, there is a dry stacking landfill in the alpine zone at an altitude of 2500 m above sea level (GK 382). Plant communities are not formed, thinned, without layering. The vegetation cover is a set of species whose seeds quickly germinated on the secondary rocky ecotope. *Aster amelloides* Besser, thickets of *Calamagrostis epigeios*, *Rumex acetoselloides* Balansa and shrubby species of *Juniperus communis* subsp. *oblonga* grow here.

The vegetation on the areal territory "Conveyor tunnel and a section of a linear object" (GK-383) represents a range of different ecological types. There were recorded: woody species of *Pinus sylvestris* with a height of 2.5 m, thickets of *Hippophae rhamnoides*, *Betula pendula*, *Salix apoda*, *Salix cinerea*, herbaceous life forms: *Calamagrostis pseudophragmites*, *Calamagrostis epigeios*, *Veronica gentianoides* Vahl, *Sedum oppositifolium* Sims, petrophytic species of *Artemisia caucasica* Willd. and *Heracleum freynianum* Sommier & Levier, *Rhinanthus minor* L., *Scabiosa bipinnata* K. Koch, *Scrophularia ruprechtii* Boiss., characteristic of the mountain wastes of the Alpine belt.

The vegetation is more closed on the loose rock areas; the projective coverage is about 40%. Here grow: *Pyrethrum parthenifolium* Willd., *Calamagrostis epigeios*, *Artemisia absinthium* L., which grows in steppes, dry meadows and weeds, *Carlina vulgaris* L., characteristic of dry meadows from the lowlands to the middle mountain belt, *Aster amelloides* Besser, etc.

There are almost monodominant communities of *Calamagrostis epigeios* and *Chamaenerion angustifolium* (L.) Scop. that grow along the road.

The site of the surface stowing complex on the existing area of the Mukulansky quarry (GK-387). The territory is the remains of destroyed buildings, the vegetation of which is a random set of

species from different altitude zones. Here grow: *Artemisia austriaca* Jacq., *Crepis rhoeadifolia* M. Bieb., *Calamagrostis pseudophragmites*, *Calamagrostis arundinacea*, *Trifolium hybridum* L., *Tussilago farfara* L., *Plantago major*, *Euphrasia caucasica* Juz., *Chamaenerion angustifolium* (L.) Scop., *Scabiosa caucasica* M. Bieb., *Cichorium intybus* L., *Melilotus officinalis* (L.) Pall., *Senecio propinquus* Schischk., *Lapsana communis* L., *Anthemis sosnovskyana* Fed., *Tanacetum vulgare* L., *Picris hieracioides* L., *Anthemis rigescens* Willd., *Erigeron orientalis* Boiss.

The linear object from the site of the surface stowing complex has an average elevation of 2410 m above sea level. Coordinates N 43 23 286 E 42 52 806. Flora and vegetation change slightly. Here are registered: *Betula litwinowii*, *Salix caprea*, *Hippophae rhamnoides*, herbaceous: *Onobrychis petraea* (M. Bieb. ex Willd.) Fisch., *Epilobium angustifolium* L., *Trifolium medium* L., *Pyrethrum parthenifolium* Willd., *Lapsana communis* L., *Calamagrostis pseudophragmites* (Haller f.) Koeler, *Phleum montanum* K. Koch, *Veronica gentianoides* Vahl, *Medicago lupulina* L., *Artemisia austriaca* Jacq., *Achillea millefolium* L., *Artemisia caucasica* Willd., *Sedum album* L., *Diplotaxis muralis* (L.) DC., *Koeleria cristata* (L.) Pers., *Leucanthemum vulgare* Lam., *Leontodon autumnalis* L., *Carduus nutans* L., *Centaurea salicifolia* M. Bieb., *Plantago media* L., *Verbascum lychnitis* L., *Echium vulgare* L., *Lotus caasicus* Kuprian. ex Juz., *Melilotus officinalis*, *Dianthus caucaseus* Sm.. There are no formed communities. Scree groups alternate with thinned petrophytic communities.

The roadsides are covered with more closed plant groupings with a decrease in height above sea level. It is possible to distinguish a tree layer of *Betula litwinowii*, *Pinus sylvestris* pine, although they are short growing and have a shrubby form.

The heights at which the road is laid do not change much, because the road passes through a serpentine. There are often forks with secondary roads. Height is 2330 m. Coordinates: N 43 23 331 E 42 52 339. In this segment, communities from *Salix caprea* and *Betula litwinowii* begin to dominate in combination with herbaceous communities, which are difficult to attribute to a certain type of vegetation, because they are formed by species of different ecology and confined to high-altitude zones.

Forest communities are not yet grown at an altitude of 2300 m. The usual floral set of species is registered. In places rather closed shrub groups of *Betula pendula* and background species of the upper mountain belt are formed.

As closeness and projective coverage increase, the number of individuals of the same species increases, i.e. herbaceous plants form populations, *Salix caprea* and *Betula litwinowii* form shrubby thickets.

There is a tunnel platform at an altitude of 2300 m above sea level. The road to the tunnel is covered with rather disturbed communities, among which *Betula pendula* grow solitary. Ruderal communities are common at the tunnel. The projective coverage is 50%. Here are registered: *Tussilago farfara*, *Amoria repens* (L.) C. Presl, *Tanacetum vulgare* L., *Artemisia absinthium* L., *Heracleum asperum* (Hoffm.) M. Bieb., *Calamagrostis pseudophragmites*, *Cirsium pendulum* Fisch., *Leucanthemum vulgare* Lam., *Festuca ovina* L., *Alchemilla caucasica* Buser.

Further, the linear object goes to the zone of high-altitude forests of *Betula pendula* and *Betula litwinowii*. The crooked forests of *Betula pendula* and *Betula litwinowii* are not pronounced in this geographical point, which is explained by the arid climate of the Jurassic Basin. It is a stunted forest. The diameter of the trees is only 10 cm. *Salix caprea*, *Sorbus aucuparia* L. are mixed with *Betula pendula* and *Betula litwinowii*. The roadside before the beginning of the forest is covered with herbaceous vegetation, mainly vegetating grasses, *Trifolium repens* L., *Ajuga reptans* L., *Achillea millefolium* L., *Cirsium pendulum* Fisch. and bushes of *Pentaphylloides fruticosa* (L.) O. Schwarz. *Arum orientale* M. Bieb., *Alchemilla caucasica* Buser, Alpine meadow species *Rubus saxatilis* L., *Delphinium dasycarpum* Steven ex DC. are registered in the forest community.

Frequently, there are talus slopes along the sides of a linear object, where completely different species grow, ecologically more homogeneous petrophyte complexes.

A population of *Dryas caucasica* Juz. was noted on one talus (coordinates: N 43 23 523 E 42 52 181). The projective coverage is 40-50%. The community was registered once on the entire route of the study. Below the talus on the sides of the linear object grow closed herbaceous communities composed of *Cirsium obvallatum* (M. Bieb.) Fisch., *Cirsium pugnax* Sommier & Levier, *Calamagrostis pseudophragmites*, *Calamagrostis epigeios* including varying forbs.

Linear object (road). Herbaceous communities with decreasing altitude are replaced by thinned communities of *Salix caprea* and *Betula litwinowii* on both sides of the road. Height is from 2231 m above sea level to 1500 m above sea level.

An accumulation of construction debris is noted on the areal object – tunnel (9SHT-2165-M (07)). Communities are not expressed. The composition of the flora is random, the occurrence of weed elements is high (46%). Common elements are weed species *Tussilago farfara*, *Artemisia absinthium*, *Artemisia annua* L., *Pyrethrum parthenifolium*. In places, *Calamagrostis epigeios* and *Calamagrostis pseudophragmites* form dense groupings.

There is a linear object (road) below the tunnel (height is 2231 m above sea level). Birch forests grow on both sides, alternating with herbaceous communities of *Calamagrostis pseudophragmites* and communities of *Cirsium arvense* (L.) Scop. including diverse synatropic communities of roadsides.

The main industrial site (GK 400) was surveyed. It occupies a large area where there are ruins of buildings and trampled areas where vegetation is practically absent. Communities are sparse, the set of species is random, but floral richness is noted. There were registered here: *Echinops sphaerocephalus* L., *Polygala alpicola* Rupr., *Plantago major* L., *Verbascum thapsus* L., *Tussilago farfara*, *Artemisia austriaca*, *Calamagrostis arundinacea* (L.) Roth, *Rumex confertus* Willd., *Cirsium obvallatum*, *Cirsium arvense*, *Carlina vulgaris*, *Achillea millefolium*, *Securigera varia* (L.) Lassen, *Alchemilla caucasica*, *Dianthus caucaseus*, *Pinus sylvestris*, *Salix caprea*, *Dasiphora fruticosa*. Vegetation is closed on the outskirts of the site near the rainwater and meltwater wastewater facilities.

Forest communities of *Salix caprea* and *Betula litwinowii* dominate on both sides of the road up to the final point near the village. *Heracleum asperum*, *Calamagrostis epigeios*, *Urtica urens* L., *Alchemilla caucasica*, *Delphinium dasycarpum* Steven ex DC., vegetative grasses, etc. are noted in herbaceous layer.

The type of communities in the loop parts of the road turns changes somewhat. The height is 2000-1800 m above sea level. There are more disturbed forests of *Betula litwinowii* growing along the sloping roadsides. There is a random collection of weedy vegetation with elements of meadow vegetation on the treeless roadsides. Here are registered: *Euphrasia caucasica* Juz., *Mentha longifolia* (L.) Huds., *Amoria repens* (L.) C. Presl, *Plantago major*, *Leucanthemum vulgare* Lam., *Artemisia absinthium*, *Echium vulgare*, *Achillea millefolium*, *Securigera varia*, among which *Ononis arvensis* L. is first noted.

Steppe communities are spread along the gas pipeline line (on the way to the pumping station), where fringe, meadow, steppe and petrophytic species grow. There is subalpine species of *Scabiosa caucasica*, petrophytic species of *Sedum caasicum* (Grossh.) Boriss. and *Campanula alliariifolia* Willd., steppe species of *Stipa capillata* L., *Teucrium chamaedrys* L., *Salvia canescens* C.A. Mey. and meadow species of *Geranium sanguineum*, *Origanum vulgare*, *Briza elatior*. There are woody and shrubby species: *Juniperus hemisphaerica* C. Presl, *Juniperus communis* subsp. *oblonga* (M. Bieb.) Galushko, *Cotoneaster melanocarpus* Lodd., G. Lodd. & W. Lodd., *Pinus sylvestris*, *Betula litwinowii*, *Rosa canina* L., *Dasiphora fruticosa*. The projective coverage is 100%.

The linear object between the two loops is covered with birch-willow grass communities. *Betula litwinowii* dominates (diameter is 20 cm), combined with pine. The herbaceous layer is the usual set of species.

The communities change at 1650 m above sea level and there are birch-sea buckthorn shortear communities and birch-sea buckthorn with barberry with barely-passable monodominant communities of *Hippophae rhamnoides* and *Berberis vulgaris*. Both species are in a

state of abundant fruiting. *Berberis vulgaris* reaches a height of 2.5 m. *Salix caprea*, *Juniperus hemisphaerica* (height is 2 m), *Betula litwinowii*, *Betula pendula*, *Rosa canina* are registered in the communities. *Dryopteris filix-mas* (L.) Schott, *Eryngium planum* L., *Clinopodium vulgare* L., *Mentha longifolia* (L.) Huds., etc. were recorded from herbaceous plants.

The greatest disturbance was noted in the lower sections of the linear object near Tyrnyauz urban settlement. The height is 1500 m above sea level. Wormwood disturbed communities grow along the roadsides. The water supply line starts from the village (PP-14, the lower point of the water supply). Here the conditions are wetter and weed vegetation grows with elements of meadow (*Mentha longifolia*). There are no pronounced communities.

There is a rocky and rocky-talus outcropping with petrophytic vegetation at an altitude of 1363 m above sea level (coordinates N 43 23 687 E 42 54 721) on the steep slope of the eastern exposure. The point of the gas pipeline and the linear object in the lower part near the village of Tyrnyauza. The projective coverage is from 10 to 40%. Endemic species of *Salvia canescens* C.A. Mey., *Onosma caucasica* E.G. Levin ex Popov, *Astragalus* sp. are registered here, which are not found in the rest of the surveyed sites.

IV. Discussion

Phytocenotic cover of the territory of Tyrnyauz mining and processing combine is represented by several types of natural and synanthropic communities. Natural ecosystems are represented by high-altitude meadows, high-altitude forests of *Betula pendula*, *Betula litwinowii*, *Salix caprea*, shrubby thickets of *Hippophae rhamnoides* and *Berberis vulgris*, petrophytic groupings and steppe meadows.

Synanthropic communities have been developed on the roadsides, tunnels, in the security zone of the gas pipeline. The most transformed are areal objects characterized by significant disturbance of the geological environment, reduction of tree plantations, cluttering of the territory with construction debris. During the study of areal and linear objects, a floristic list consisting of 229 species of vascular plants was registered. The species differ in different phytocenotic confinement and are allocated to high-altitude zones.

Natural communities that are not disturbed by anthropogenic activity retain their structure unchanged, with the exception of communities that are directly adjacent to synanthropic communities of roadsides and man-made wastelands. Here it is noted the presence of weeds, which poses a threat of displacement to native species. Synanthropic communities of roadsides and areal technogenic sites are a random set of weeds with elements of meadow elements, poorly expressed horizontal and vertical structure. The high proportion of weed species is explained by the long-term functioning of the road and abandonment in recent decades. Especially weed species predominate at areal objects. There are no rare species in the vegetation cover of roadsides and areal objects, which is also an indicator of ecosystem disturbance.

The results of the study of vegetation formed on disturbed landscapes will help to define the degree of their suitability for biological reclamation; to identify areas that do not require biological reclamation; to develop methods of biological reclamation taking into account specific environmental conditions.

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