

Dynamic of self-regeneration of vegetation cover of coal mine dumps of different ages on the steppe zone of Tuva (Russia)

Anna Sambuu^{1*}

¹Center for Biosphere Research of the Republic of Tyva, Kyzyl, 667003, Russia

Abstract. The article discusses the results of studying the natural vegetation restoration of different-age dumps of the Kaa-Khem coal deposit in the Republic of Tyva (Russia). Flora and vegetation, geographical and ecological spectra, ecological and cenotic groups, plant life forms of reclaimed dumps are analyzed. It was revealed that the basis of the vegetation cover of the dry steppes in the study area is the steppe type of vegetation. The flora of vascular plants is dominated by the Poaceae, Asteraceae and Chenopodiaceae families; The geographical spectrum consists of groups of species with Eurasian and Asian ranges; the ecological spectrum is dominated by xerophytes; weed species dominate at the initial stage of restoration, the number of zonal steppe plants gradually increases, but the proportion of weeds is high; herbaceous polycarpics predominate in the biomorphological structure. Vegetation restoration on coal mine dumps in the steppe zone of Tuva is characterized by a delay in the pioneer stage, significant adventization of communities on 20-50-year-old dumps. Communities of different age dumps are at one of the advanced stages of succession, quite far from the terminal level. The purpose of the study is to study the vegetation cover during self-healing of different-age dumps of the Kaa-Khemsy coal mine.

1 Introduction

Due to the intensification of human impact on the environment, research on flora and vegetation is becoming increasingly important – an important stage in understanding the patterns of the current state of vegetation cover, which are necessary for the development of scientific foundations for the protection and rational use of natural resources. Being a kind of indicator of the state of the natural environment, plants react sensitively both to natural changes and to the nature and intensity of economic activity. The main features of the vegetation cover, which form biological diversity and conditions for its conservation, are characterized by the geological history of the territory, the specifics of the relief, climatic and landscape mosaic, and the influence of economic activity. According to many authors, vegetation cover is formed on man-made dumps on deep rocks or other substrates that are completely or almost untouched by soil formation processes, as well as on soils extremely

* Corresponding author: sambuu@mail.ru

depleted of organic substances and mineral elements [1-6]. The duration of the initial stages may increase up to an indefinite period, depending on the degree of violation and the position of the violated territory [7-17].

2 Materials and Methods

The Kaa-Khem coal deposit is located in the Tuva basin in the northeastern part of the Ulug-Khem coal basin, 17 km from the capital of the Republic of Tyva – Kyzyl. Dumping on dumps has been taking place since 1970 to the present. The climate of the area is sharply continental with a negative average annual temperature (-2.6–4.6 °C). The absolute minimum temperature is observed in January (-52.6 °C), the absolute maximum is in July (37.5 °C). The height of the snow cover does not exceed 0.4 m. The average maximum depth of soil freezing is 3.0 m. The relief of the deposit area is shallow with absolute marks of 630–880 m. Jurassic coal-bearing deposits of Paleozoic rocks with a thickness of 1500 m on older Lower carboniferous formations take part in the geological structure of the deposit. The Quaternary system is represented by eluvial-deluvial deposits of large plate-like fragments of sandstones and siltstones. Deluvial deposits are widespread and are represented by sandy loams (60–65%), fragments of sandstones and siltstones with a thickness of 0.5–5 m. Sediments and rocks are non-toxic [18, 19].

The object of the study was the vegetation cover of the different-age dumps of the Kaa-Khemsky coal mine with an initial age of 1 year, communities at the beginning of observations that were 10, 20, 30, 40, 50 years old, as well as the vegetation cover of the control area of the initially dry steppe 2 km north of the coal mine (control). Geobotanical descriptions were carried out in July-August 2001–2023 [20]. Three positions were selected on each dump: at the top – eluvial (El), on the slope – transit (Trans), at the foot – accumulative (Ak), where 10 × 10 m trial areas were laid.

3 Results and Discussions

According to the botanical and geographical zoning, the northern macroscline and the highlands of the Tannu-Ola range floristically belong to the Altai-Sayan province of the Circumboreal region of the Boreal sub-kingdom of the Holarctic Kingdom [21-23]. According to the zoning of the territory of Tuva by K.A. Sobolevskaya [24], the Kaa-Khem coal deposit belongs to the Tuva steppe region; according to the scheme of natural districts and districts of the Tuva ASSR by V.A. Nosin [25] – to the South Altai-Tuva-Khangai basin-mountain province of the steppe zone, the Central Tuva basin steppe district, part of the dry steppe; according to the scheme of geobotanical zoning of Tuva, Yu.M. Maskaev, B.B. Namzalov, V.P. Sedelnikov [26] – to the Tuvan basin steppe province, the Central Tuvan meadow-steppe district.

In the adjacent territory of the Kaa-Khemsky coal deposit (control), the predominant type of vegetation is steppe. The terrain of the site is represented by undulating hilly plains alternating with massifs of small hills. Dry small-grain grass steppes prevail, occupying small-scale landforms, leveled habitats are occupied by grass-herbal, herb-grass, wormwood-fine-grained and shrubby-wormwood-grain communities on chestnut and light-brown low-power mainly sandy soils. In the steppe complex, significant territories are occupied by the fallow vegetation of former grain fields of different ages.

Characteristic features of dry-steppe vegetation are the constant presence in phytocenoses of *Stipa krylovii* Roshev., *S. orientalis* Trin., *Agropyron cristatum* (L.) Beauv., *Cleistogenes squarrosa* (Trin.), *Festuca valesiaca* Gaud., *Artemisia frigida* Willd. and *C. spinosa* DC are usually present and abundant. There are a series of petrophytic

groupings of desolate steppes: *Oxytropis aciphylla* Ledeb., *A. caespitosa* Ledeb., Artemisia-grass, *Stipa orientalis* Trin. Areas of fluttering sands that are not fixed by vegetation have also been identified, where the basis of sparse vegetation is *Leymus racemosus* (Lam.) Tzvel., *Orostachys spinosa* (L.) C.A. Mey.), *Astragalus laguroides* Pall., *Artemisia tomentella* Trautv., *Thesium tuvense* Krasnob., etc. Most of the territories adjacent to the coal mine are occupied by fallow vegetation of different ages.

Vegetation is represented by:

A class of formations – real (dry) steppes [27].

A group of formations – small-grain steppes.

Formations: Ckeistogenes, *Stipa krylovii*, Agropyron, Artemisia, Potentillia and Festuca.

A group of formations – large-grain steppes.

Formations: *Stipa krylovii*, Festuca, *Carex pediformis*.

A group of formations – shrubby real (dry) steppes.

Formations: small-grain Caragana, large-grain Caragana, Artemisia, *Potentillia acaulis* and *Koeleria cristata*.

Formation class – desert steppes.

A group of formations – grain steppes desert steppes.

A group of formations – semi-shrubby desert steppes.

Formations: Caragana Artemisia-grass with *Caragana pygmaea*.

The flora of the general composition of vascular plants on the different-age dumps of the Kaa-Khemsy coal mine includes 68 species, 38 genera and 21 families. The families with the predominant number of species include: Poaceae (22.0% of the species composition of the flora), Asteraceae (14.6%) and Chenopodiaceae (10.2%).

The predominance of the Poaceae and Asteraceae families indicates the steppe orientation of the development of plant communities (Table 1). During the succession, there is a decrease in the share of the Chenopodiaceae family. The number of species increases from 10 on a 5-year dump to 12 on a 50-year dump. The total number of species in the Ak position in the 50th year of overgrowth of the dump is greater than in the control area of the dry steppe.

Table 1. Shared participation of families in the plant communities of man-made dumps, %.

Family	5 years	10 years	20 years	30 years	40 years	50 years	control
Poaceae	36	36	47	36	35	27	17
Asteraceae	27	36	29	32	21	20	7
Chenopodiaceae	27	28	18	14	15	12	6
Total types:	10	14	17	28	33	59	54

The flora of the dumps of different ages is represented by various geographical elements, of which a significant group of species with Eurasian habitats (25%). The predominance of species with Asian (25%) and Central Asian (21%) habitats indicates the identity of the flora and the influence of Central Asia. 8.3% were assigned to the Holarctic group (Table 2).

The most common ecological groups are xerophytes – 30 species on a 50-year-old dump (*Stipa krylovii*, *Artemisia glauca* Pall., *A. sieversiana* Witld., *Festuca valesiaca* Tzvel. and others); mesophytes include 8 species (*Iris ruthenica* Ker Gawl., *Vicia cracca* L. etc.); xeromesophytes and mesoxerophytes – 7 species (*senescens* L., *Carum carvi* L., *Medicago falcata* L. and others. (Table 2). There is a gradual increase in the number of species in almost all groups.

Table 2. The number of types of ecological groups in the succession series.

Environmental groups	Years of recovery, years						Control (dry steppe)
	5	10	20	30	40	50	
Xerophytes	8	11	13	21	27	30	42
Xeromesophytes, mesoxerophytes	1	1	1	3	4	7	8
Mesophytes	-	-	5	5	7	8	1
Halophytes	1	1	1	2	1	2	2
Psammophytes	-	1	1	1	1	1	1
Total types:	10	14	21	32	40	48	54
Some of them are weeds:	6	7	6	8	6	7	8

8 ecological and cenotic groups were identified in the flora of the dumps: forest – 4 species, meadow – 3, meadow–steppe – 5, steppe – 23, mountain–steppe – 8, solontsovo–steppe – 3, desert–steppe – 2. Of these, weed – 13 species. Steppe species are dominant on dumps of different ages (58%). A significant number of mountain steppe species is associated with the relative proximity of the dump area to neighboring low mountains.

The biomorphological spectrum of flora is represented by six main types of life forms: trees (2%), shrubs (6%), shrubs (2%), semi-shrubs (4%), polycarpic grasses (67%), which is typical of the temperate zone of the Northern Hemisphere. Monocarpic grasses are represented by one- and two-year-olds (19% of the total flora), which give a large aboveground phytomass and play a significant role in the life of communities.

3.1 Rare and protected species

As a result of the conducted studies of vegetation from 68 species of higher vascular plants on dumps of different ages, plants from the Red Book of the Republic of Tyva were found [28] (*Oxytropis includes* N. Basil., *O. ammophila* Turcz., *Erythrichium tuvense* M. Pop.), from the Red Book of the Russian Federation [29] *Stipa pennata* L.

Endemics. *Oxytropis includens* is a Yenisei endemic; *O. amophila* is a Tuvan-South Yenisei endemic; *Erythrichium tuvense* M. Pop. is endemic to the Central Tuvan basin.

3.2 The similarity of phytocenoses in different positions of different age dumps and the indigenous steppe ecosystem (control)

To assess the similarity of dump communities of different ages and different positions, and to compare them with communities of the indigenous dry steppe (control), we used the Jacquard similarity coefficient. The species composition of phytocenoses of various positions of the 5-year-old dump was compared with the species composition of communities of 10-year-old positions, 10-year-old with 20-year-old, 20 with 30-year-old, 30 with 50-year-old, 50-year-old – with communities of various positions of the steppe ecosystem (control). The similarity analysis showed that on dumps of different ages, the species composition of phytocenoses for El-Ak positions differs sharply – the similarity measure does not exceed 0.2, on Trans-Ak positions the compositions of communities are close – the similarity measure reaches 0.58 for a 50-year-old dump and 0.63 for a steppe ecosystem (control).

4 Conclusion

The results of the study showed that the flora of vascular plants on different age dumps includes 68 species, 38 genera, 21 families, of which Poaceae (22%), Asteraceae (14.6%), Chenopodiaceae (10.2%) predominate.

The geographical spectrum consists of groups of species with Eurasian (25%), Asian (25%) and Central Asian (21%) ranges, etc. The ecological spectrum revealed the predominance of xerophytes (62%), xeromesophytes and mesoxerophytes – 24%. An analysis of the ecological groups of plants showed that, in general, some xerophytization is observed in the vegetation of the dumps. Of the ecological and cenotic groups, steppe (58% of the total flora), mountain-steppe (17%) and meadow-steppe species (10%) predominate. The biomorphological structure is dominated by herbaceous polycarpics (67%). The participation of one- and two-year-olds is significant – 19%.

The species composition of communities on dumps varies across the steppe ecosystem so that the measure of similarity between dumps of different ages decreases from the position of El to Ak, while at the same positions of the 50-year-old dump and the indigenous steppe ecosystem, the measure of similarity increases. The phytocenoses of the 50-year-old dump and the initial steppe ecosystem, which are in an accumulative position, are the closest.

Thus, the succession at the dumps of the Kaa-Khemsy coal mine in the steppe zone of Tuva is characterized by a lower rate of phytocenosis shifts, a significant delay in the pioneer stage, and a significant level of adventization of communities on 20-50-year-old dumps. Communities of different age dumps are at one of the advanced stages of succession, quite far from the terminal level.

Acknowledgement

The research was carried out as part of the most important innovative project of national importance “Development of a system for ground-based and remote monitoring of carbon pools and greenhouse gas fluxes in the territory of the Russian Federation, ensuring the creation of recording data systems on the fluxes of climate-active substances and the carbon budget in forests and other terrestrial ecological systems” (Registration number: 1022090600007-9).

References

1. L.V. Motorina, T.I. Izhevskaya, Vegetation and industrial environment (Ural Publishing House, 1980)
2. T.G. Lamanova, Structural and functional organization of agrophytocenoses on planned overburden dumps of Kuzbass (Abstract of the disser of the Doctor of Biolog Sciences, 2005)
3. A.N. Kupriyanov, Yu.A. Manakov, L.P. Barannik, Restoration of ecosystems on the dumps of the Kuzbass mining industry (Akadem. publishing house "Geo", 2010)
4. S.I. Mironova, Fundamental research **11** (2011)
5. V.I. Kurbatskai, A.A. Kuznetsov, Bulletin of Tomsk State University. Biology, **2** (2011)
6. S.A. Lednev, A.V. Sharapova, I.N. Semenov, T.V. Koroleva, Lime the WOUNDS. The series is geographical, **2** (2020)
7. F.A. Bazzaz. Ann. Rev. ecot. and systematic, **10** (1979)

8. B.M. Mirkin, The results of science and technology. Ser. Botany, **5** (1984)
9. V.A. Nedoluzhko, A.Yu. Gusachenko, Plants and industrial environment (Dnepropetrovsk, 1990)
10. S.P. Zhukov, Anthropogenic succession of vegetation in the dumps of Donbass coal mines (Abstract of the disser. of the candidate Biol. Sciences, 1999)
11. A.V. Karakulov, T.G. Lamanova, Bot. journal **86** (2001)
12. A.Ya. Grigorievskaya. Anthropogenic transformation of the vegetation cover of the Central Russian forest-steppe (Abstract of the disser of the Doctor of Geographical Sciences, 2003)
13. V.V. Rodaeva, A.N. Belov, Animal and plant world of the Far East **8** (2004)
14. D.Yu. Efimov, A.S. Shishikin. Izvestia of the Samara Scientific Center of the Russian Academy of Sciences **16** (2014)
15. M.A. Yakovchenko, V.A. Ermolaev, A.A. Kosolapova, D.N. Alankina, Bulletin of KrasGAU **4(127)** (2017)
16. A.N. Kupriyanov, O.A. Kupriyanov, Yu.A. Manakov, D.A. Shatilov, International Scientific Research Journal **9(123)** (2022)
17. A.I. Izmailov, Coal **12 (1175)** (2023)
18. N.I. Lebedev, Ugli Tuva: the state and prospects of development of the raw material base (TuvIKOPR SB RAS, 2007)
19. A.A. Titlyanova, A.D. Sambuu, Succession in grass ecosystems (Publishing House of the SB RAS, 2016)
20. Field geobotany **5** (1976)
21. V.I. Grubov, Determinant of vascular plants of Mongolia (Nauka. Leningr. edition, 1982)
22. A.L. Takhtajyan, Floristic regions of the Earth (Nauka. Leningr. publishing House, 1978)
23. A.S. Revushkin, The alpine flora of Altai (State University named after V.V. Kuibyshev, 1988)
24. K.A. Sobolevskaya, Vegetation of Tuva (Polygraphizdat, 1950)
25. V.A. Nosin, Soils of Tuva (Publishing House of the USSR Academy of Sciences, 1963)
26. Yu.M. Maskaev, B.B. Namzalov, V.P. Sedelnikov, Vegetation cover and natural forage lands of the Tuvan ASSR (Nauka. Siberian Branch, 1985)
27. A.Yu. Korolyuk, Steppes of Central Asia (Publishing House of the SB RAS, 2002)
28. Red Book of the Republic of Tyva (animals, plants, fungi) (Voronezh, 2018)
29. Red Book of the Russian Federation (Animals) (AST; Astrel, 2001)