

Restoration of florist diversity at dumps coal mining enterprises banks in southern Siberia

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Abstract

The results of a long-term experiment (2014-2020) on the creation of a natural meadow-steppe plant community and an assessment of the weed and meadow-steppe plant productivity dynamics in the long-term experiment taken place in the forest-steppe zone of Kuzbass are presented. The preparation of banks consisted in their levelling, and then applying 10 cm fertile soil layer (FSL) and potentially fertile rocks (PFR) represented by loess-like loams. A horizontal section of the bank without application of FSL and PFR was used as a reference. An herb-seed mixture (HSM) was harvested in meadow-steppe areas of hills covered with meadow-steppe vegetation. The highest productivity was obtained in areas with PFR application (555.2 g / m² in 2017); the share of ruderal plants was 6-25% of the total biomass. Application of FSL for four years leads to the intensive development of *Elytrigia repens*; by the sixth year, *Allium nutans* and *Artemisia frigida* become dominants of the nature-like plant community. In the reference areas, a pioneering group of legumes *Oxitropis pilosa* and *O. campanulata* is formed. Areas without the introduction of HSM are at the pioneer and group-overgrown stage of syngeneses.

Keywords: nature-like plant community, dumps of coal enterprises, fertile soil layer, potentially fertile rocks, herb-seed mixture, productivity

Introduction

The Kuz bass coal basin (Kuz bass) is located in the south of Western Siberia on the territory of the Kemerovo region (fig. 1). During the operation of the coal basin, there have been mined about 8 billion tons of coal. Banks and quarries occupy about 150 thousand hectares (fig. 2). The restoration of floristic diversity is extremely slow on these disturbed lands and is mainly due to ruderal plants.



Fig 1: The Kuzbass basin on the map of Russia



Fig 2: General view of dumps of coal enterprises

The formation of plant communities in territories subjected to catastrophic changes obeys the general laws of primary successions described in a large number of works [Clements, 1928; Ramenskiy, 1938; Grime, Hodgson, 1988; Mirkin, 1985] [15, 11, 7]. In time, the restoration of plant communities extends over tens, and sometimes hundreds of years. The dumps of Kuzbass are 30-70 years old, but their vegetation has not reached the state of natural phytocenoses characteristic of this climatic zone. On the dumps of Kuzbass, three stages of syngeneses were noted: the pioneer group, which is characterized by a low projective cover and an insignificant number of species of zonal flora; a simple phytocenosis characterized by the dominance of species with wide ecological amplitude; a complex phytocenosis dominated by species of zonal flora [Kupriyanov, Manakov, 2016] [2]. The successional development of plant communities is a strictly deterministic process [Razumovsky, 1981], and the climax stage is its final stage [Whittaker, 1970]. At the same time, the evolutionary development of vegetation [Mirkin, 1978] [6], as a rule, does not occur; zonal or introzonal communities are formed here [Kupriyanov, Manakov, 2008] [1, 18]. Historically, the restoration of the herbaceous vegetation cover on dumps refers to the agricultural direction of biological reclamation and is aimed at the formation of productive communities [Lamanova, Sheremet, 2012] [3]. Almost no attempts in order to restore the lost floristic diversity on dumps were made to create nature-like plant community. This raises the question of the interaction between ruderal plants (which are constantly brought to the bank) and species of artificially created communities.

Purpose of the research was to study the possibility of creating a nature-like plant community at the experimental site by adding herb-seed mixture (HSM) of meadow-steppe plants to the dumps and to trace the relationship of weed and

Meadow-Steppe species under the conditions of a long-term experiment.

Research Objects and Technique

The researches were carried out at a landfill located on the overburden dump of the Vinogradovsky surface coal mine (Kemerovo region) from 2014 to 2020. The bank is represented by clays and loams, sandstones, siltstones, and mudstones. The ratio of the main rocks in the surface mine is as follows: sandstones make up 72-78%, siltstones 28-20%, and mudstones up to 2%. The rockiness of soils increases from a depth of 20-30 cm, which indicates a slowdown in the process of in-depth weathering. There are pieces of rock mass that retain their shape and solidity under the upper layer of rock completely decomposed into fine earth.

At the time of setting up the landfill, the vegetation cover of the bank was at the pioneer stage and the stage of the formation of group-overgrown communities. 26 species of higher plants were found on the territory of the bank near the landfill under construction; they correspond to the initial stages of the formation of vegetation cover in the technogenic ecotopes of Kuzbass consisted of weed species characteristic for the first stages of dump overgrowing [Kupriyanov, Morsakova, 2008; Manakov, *et al.*, 2011] ^[1, 18, 5].

In applied botany, the term "ruderal plants" has several definitions in the agricultural practice section. V.V. Nikitin [1983] ^[8] believed that ruderal plants are plants not cultivated by humans, but historically adapted to the conditions of cultivation of cultivated plants, growing with them and harming them. T.N. Ulyanova [2005] ^[13] notes that a weed plant is made by the ecology of the secondary habitat and the human attitude to it for a certain period of time.

In our study, we consider those species as conditionally ruderal plants which do not belong to steppe, meadow-steppe, and meadow communities located near the bank, the flora of which is well studied [Lashchinsky *et al.*, 2011] ^[4]. The herb-seed mixture (HSM) was harvested in natural steppe communities in two periods (July and August). The amount of herb-seed mixture mowed from 225 m² was taken as the norm (for two cuts from 500 m²).

The steppe massif located 40 km from the bank became the donor of the HSM harvesting. Fragments of virgin associations of feather-grass-forb steppes with the dominance of *Stipa capillata*, *S. pennata*, *Festuca valesiaca*, *Koeleria cristata*, and also *Medicago falcata*, *Phlomis tuberosa*, *Onobrychis arenaria*, *Artemisia austriaca*, *Allium nutans*, *A. vodopjanovae*, *Hedysarum gmelinii* occur on flat upland sites. In the depressions, meadow steppes are formed with the participation of *Scabiosa ochroleuca*, *Filipendula vulgaris*, *Otites wolgensis*, *Phlomoidea tuberosa*, etc.

At the monitoring site, the following options for preparing a bank surface were studied: application of a fertile soil layer (FSL), application of a potentially fertile loam layer (PFR), reference sites (initial embryozem soil). Each site was of 225 m² area (15 x 15 m). A layer of fertile soil from piles (initially it was leached chernozem) with a layer of 6–10 cm was applied in 4 plots. On 4 plots, a similar layer of clay and loam of overburden dumps was applied. Four sites were left without improvement. When analysing the plant settlement, the following options were investigated: application of two HSM normal amounts on areas with application of FSL,

PFR, and reference soil. Three sections were free of HSM applied. The application of HSM to the plots was carried out in October 2014; observations of plants, and cutting were carried out annually in the second decade of July. Plants appearing on experimental plots were classified as ruderal plants (conventionally weed plants) [Ulyanova, 2005] ^[13] or meadow-steppe species inhabiting steppe or meadow-steppe communities. Accounting for productivity was carried out in 4-fold repetition on an area of 1 m² by mowing the aboveground plant parts at the soil level. Cameral treatment was carried out on the same day. The samples were divided into the following fractions: conventionally ruderal plants, meadow-steppe plants. Each fraction was wrapped in paper; the fractions were dried in a room with forced ventilation to a constant air-dry state and weighed on a balance with an accuracy of 0.1 g.

Results

For six years, 140 species have been registered at the experimental site, including 43 ruderal species: (**Acer negundo* L., *Agrostemma githago* L., **Amoria hybrida* (L.) C. Presl., *A. repens* (L.) C. Presl., *Artemisia sieversiana* Willd., *Atriplex sagittata* Borkh., *Berteroa incana* (L.) DC., *Bunias orientalis* L., *Camelina microcarpa* Andr., *Cannabis sativa* L., *Capsella bursa-pastoris* (L.) Medikus, *Carduus crispus* L., *C. nutans* L., *Chenopodium album* L., *Ch. hybridum* L., *Cirsium setosum* (Willd.) Besser, *C. vulgare* (Savi) Ten., **Conyza canadensis* (L.) Cronquist, *Crepis tectorum* L., *Descurainia sophia* (L.) Webb ex Prantl, *Echium vulgare* L., *Elytrigia repens* (L.) Nevski, *Euphorbia virgata* Waldst. & Kit., *Fallopia convolvulus* (L.) A.Love, *Galeopsis bifida* Boenn., *Jacobaea viscosa* (L.) Moench, *Lactuca serriola* L., *Lappula stricta* (Ledeb.) Guerke, *Linaria vulgaris* Mill., **Melilotus albus* Medikus, *M. officinalis* (L.) Pall., *Pastinaca sylvestris* Mill., *Polygonum aviculare* L., *Salsola collina* Pall., *Setaria pumila* (Poir.) Schult., *S. viridis* (L.) P. Beauv., *Sisymbrium loeselii* L., *Sonchus arvensis* L., *Stachys palustris* L., *Taraxacum officinale* F.H.Wigg., **Tripleurospermum inodorum* (L.) Sch.Bip., *Vicia cracca* L., *Viola arvensis* Murray), and 97 meadow-steppe species such as (*Achillea asiatica* Serg., *Agropyron kazachstanikum* (Tzvel.) Peschkova, *Agrostis gigantea* Roth, *Allium nutans* L., *A. strictum* Schrad., *A. vodopjanovae* N.V.Friesen, *Alyssum obovatum* (C.A.Mey.) Turcz., *Androsace septentrionalis* L., *Artemisia austriaca* Jacq., *A. commutata* Besser, *A. dracunculus* L., *A. glauca* Pall. ex Willd., *A. scoparia* Waldst. & Kit., *A. vulgaris* L., *Bromopsis inermis* (Leyss.) Holub, *Bupleurum multinerve* DC., *Campanula glomerata* L., *Centaurea scabiosa* L., *Cleistogenes squarrosa* (Trin.) Keng, *Dactylis glomerata* L., *Dianthus versicolor* Fisch. ex Link, *Dracocephalum nutans* L., *Elisanthe noctiflora* (L.) Rupr., *E. viscosa* (L.) Rupr., *Epilobium palustre* L., *Erigeron acris* L., *Erodium cicutarium* (L.) L'Her., *Eryngium planum* L., *Euphorbia esula* L., *Eu. subcordata* C.A.Mey., *Festuca pratensis* Huds., *F. pseudovina* Hack. ex Wiesb., *Filipendula ulmaria* (L.) Maxim., *F. vulgaris* Moench, *Galatella angustissima* (Tausch) Novopokr., *Galeopsis bifida* Boenn., *Galium mollugo* L., *G. uliginosum* L., *G. verum* L., *Geranium pratense* L., *Goniolimon speciosum* (L.) Boiss., *Gypsophila patrinii* Ser., *Hedysarum gmelinii* Ledeb., *Heteropappus altaicus* (Willd.) Novopokr., *Hieracium umbellatum* L., *Jacobaea vulgaris* Gaertn., *Koeleria cristata* (L.) Pers., *Lathyrus humilis* (Ser.) Spreng.,

L. pratensis L., *L. tuberosus* L., *Leucanthemum vulgare* Lam., *Lithospermum officinale* L., *Matricaria perforata* Merat., *Medicago falcata* L., *Melandrium album* (Mill.) Garcke, *Nonea rossica* Steven, *Oberna behen* (L.) Ikonn., *Onobrychis arenaria* (Kit.) DC., *Otites wolgensis* (Hornem.)Grossh., *Oxytropis campanulata* Vassilcz., *Oxytropis pilosa* (L.) DC., *Peucedanum morisonii* Besser ex Spreng., *Phleum phleoides* (L.) H.Karst., *Ph. pratense* L., *Phlomis tuberosa* L., *Picris hieracioides* L., *Pilosella echioides* (Lumn.) F.Schultz & Sch.Bip., *Plantago media* L., *P. urvillei* Opiz, *Poa angustifolia* L., *P. pratensis* L., *Potentilla anserina* L., *P. argentea* L., *P. bifurca* L., *P. canescens* Besser, *P. chrysantha* Trevir., *P. conferta* Bunge, *P. longifolia* Willd. ex Schldt., *P. sericea* L., *P. virgata* Lehm., *Pulmonaria mollis* Wulfen ex Hornem., *Scabiosa ochroleuca* L., *Senecio erucifolius* L., *Seseli ledebourii* G.Don, *Solanum kitagawae* Schonb.-Tem., *Stellaria graminea* L., *Stipa capillata* L., *S. pennata* L., *Tragopogon dubius* Scop., *Trifolium pratense* L., *Tussilago farfara* L., *Veronica incana* L., *V. spicata* L., *V. spuria* L., *Vicia nervata* Sipliv. *amoena* Fisch., *V. lilacina* Ledeb., *V.*

nervata Sipliv. * Transformer species included in the Black Book of Siberian Flora [Black Book, 2016] [14]. In the option with the application of fertile soil in the first year, the entire biomass consisted of ruderal plants, among which there were *Atriplex sagittata* *Chenopodium album* *Artemisia sieversiana*, *Elytrigia repens*, *Linaria vulgaris*. 95% of the total biomass was shoots of *Elytrigia repens* (fig. 3A). In the second year, seedlings of meadow-steppe plants appeared, such as: *Allium nutans*, *Artemisia austriaca*, *A. frigida*, *Dianthus versicolor*, *Goniolimon speciosum* and some others who had practically no share in productivity. For four years, there was an increase in biomass; the maximum was in 2017, when the productivity reached 365.6 g / m² (see table). On the fifth and sixth years of the experiment, the share of *Elytrigia repens* in the total biomass practically decreased to zero (fig. 3B). In 2020, the biomass decreased almost five times compared to 2017 and consisted mainly of meadow-steppe plants: *Artemisia frigida*, *Allium nutans*, *Dactylis glomerata*, *Galium verum*, *Seseli ledebouri*, *Stipa capillata* (see table). The share of weed species in the total biomass was high for four years and dropped sharply by the sixth year (fig. 4).

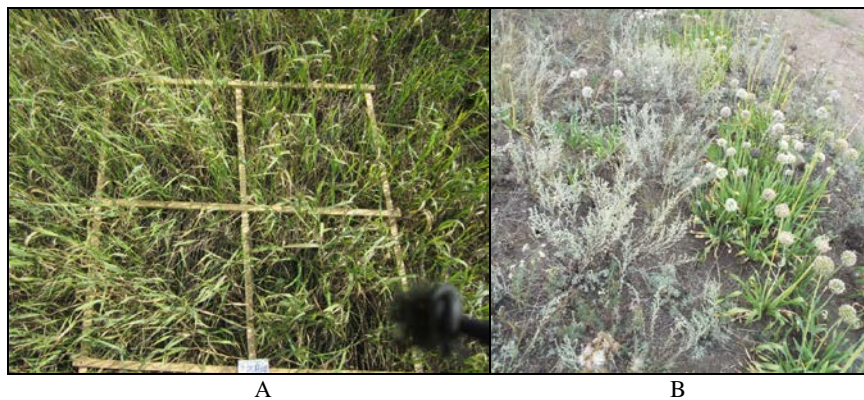


Fig 3: 2FSL Option: A –2017, B – 2020

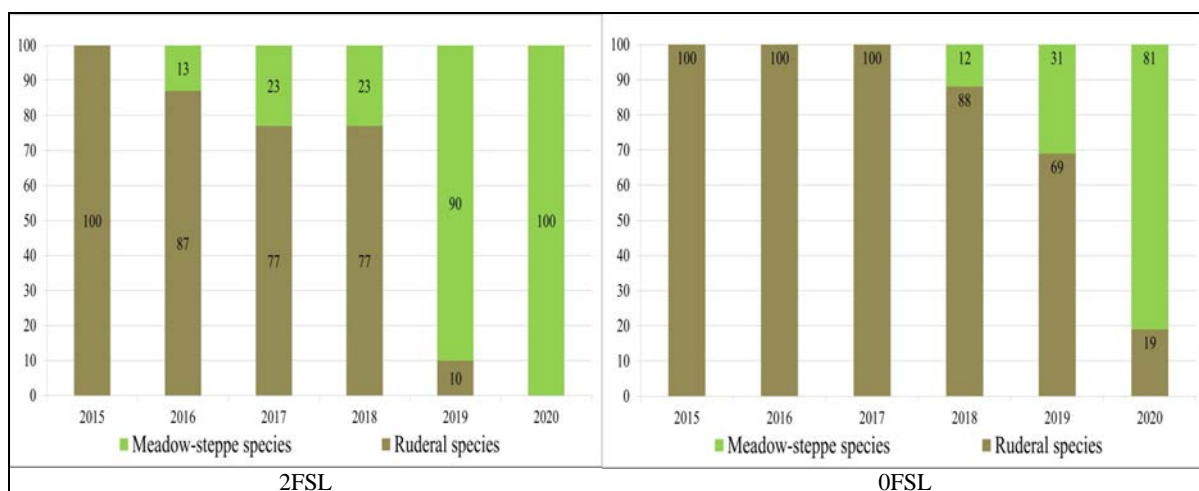


Fig 4: Change in the proportion of ruderal plants in options with the application of fertile soil, %.

In the first four years, in the option with the application of FSL, but without the introduction of HSM, exclusively *Elytrigia repens* and some specimens of ruderal plants dominated (*Artemisia sieversiana*, *Chenopodium album*, *Conyza canadensis*, *Linaria vulgaris*, *Vicia cracca*) (Fig. 5A). At the 5th-6th year, *Elytrigia repens* practically dropped out of the herbage and the share of ruderal plants

began to decrease sharply (fig. 4); the main share in the biomass belonged to (*Artemisia austriaca*, *A. frigida*, *Dactylis glomerata*, *Goniolimon speciosum* (fig. 4). The biomass in this option reached its maximum values in 2017–2018 and amounted to 224–285 g / m²; then it decreased and in 2020 amounted to 39% of the maximum value in 2018. Compared with the 2FSL option, the biomass was 20% less for six years of observations (see table).



Fig 5: Option 0FSL: A – 2017; B – 2020

Here we see the results of application to the bank surface of loam, which at the time of their application to the bank had practically no ovules: they could appear on the dump surface after the introduction of HSM or in winter period as a result of aeolian transfer of seeds from nearby territories. In the first year the grass stand was made up of meadow-steppe plants such as: *Artemisia austriaca*, *Dianthus versicolor*, *Elisanthe noctiflora*, *Galium verum*, *Goniolimon speciosum*, *Gypsophila patrinii*, *Hedysarum gmelinii*, *Medicago falcata*, *Seseli ledebourii*, *Stipa capillata* and ruderal plants *Cirsium setosum*, *Lactuca serriola*, *Elytrigia repens* (fig. 6A). A distinctive feature was the very rapid development of ontogenesis in some plants: in the first year,

earring was noted in *Stipa capillata*, flowering in *Dianthus versicolor*, *Gypsophila patrinii*, *Hedysarum gmelinii*. Such ruderal plants as *Cirsium setosum*, *C. vulgare*, *Bunias orientalis* and some others were observed during all years of observation, but their share was 6-11% of the total biomass (fig. 7). In the 2PFR option, the maximum productivity was obtained in 2017 – 555.2 g / m² and it was due to the powerful development of *Stipa capillata* (see table). In subsequent years, small sod and rhizome cereals began to develop: *Festuca pseudovina*, *Poa angustifolia*, *Dactylis glomerata* (Fig. 6B) and productivity began to decline; in the sixth year, it decreased by 41% compared to 2017 and amounted to 325.6 g / m² (see table).



Fig 6: Option 2FSL: A – 2017; B – 2020

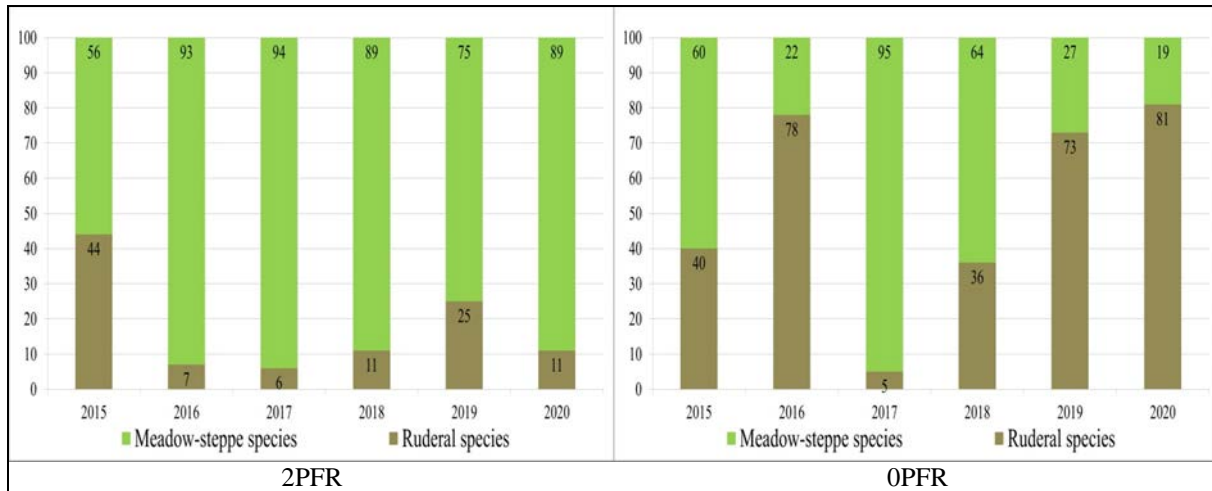


Fig 7: Change in the proportion of ruderal plants in options with the application of loam, %.

In the option with PFR application, but without HSM application, the settlement of plants was greatly influenced by other experimental options. Despite the fact that the application of HSM took place in late autumn before the establishment of the snow cover, some of the HSM along with the seeds fell on the 0 PFR site. In the first year, mainly ruderal plants are noted here such as *Bunias orientalis*, *Galeopsis bifida*, *Lactuca*

serriola, *Salsola collina*, *Viola arvensis*, meadow-steppe plants were presented by *Artemisia austriaca*, *Goniolimon speciosum*, *Heteropappus altaicus*. (Fig. 6A). By the sixth year, the share of ruderal plants in the total biomass had decreased to 20%. Floristic composition was presented by *Artemisia austriaca*, *Galatella angustissima*, *Goniolimon speciosum*, *Stipa capillata* (Fig. 8B).



Fig 8: Option OPFR: A – 2017; B – 2020

In the option with the application of HSM on the levelled surface of the bank, the settlement of plants was noted only after a year. These were seedlings of meadow-steppe plants *Stipa capillata*, *Oxitropis pilosa*, *O. campanulata* and the annual weed *Salsola collina*, which share in the biomass was more than 95%. (fig. 9A). *Salsola collina* is a pioneer of bank overgrowing in the forest-steppe zone [Kupriyanov, Morsakova, 2008] and has been present in the control plot for

six years. The maximum productivity was noted in 2017, 134.8 g / m² (table). The main share in productivity was made by steppe legumes *Oxitropis pilosa*, *O. campanulata*, *Medicago falcata*, with the exception of 2017, when favourable conditions were for the development of *Salsola collina* (fig. 10). After six years, these plants remained dominant on the surveyed sites (Fig. 9B). Productivity in this option is 12 times less on average for six years than in the 2PFR option and seven times less than in the 2PFR option (see table).



Fig 9: 2Ref: A – 2017; B – 2020

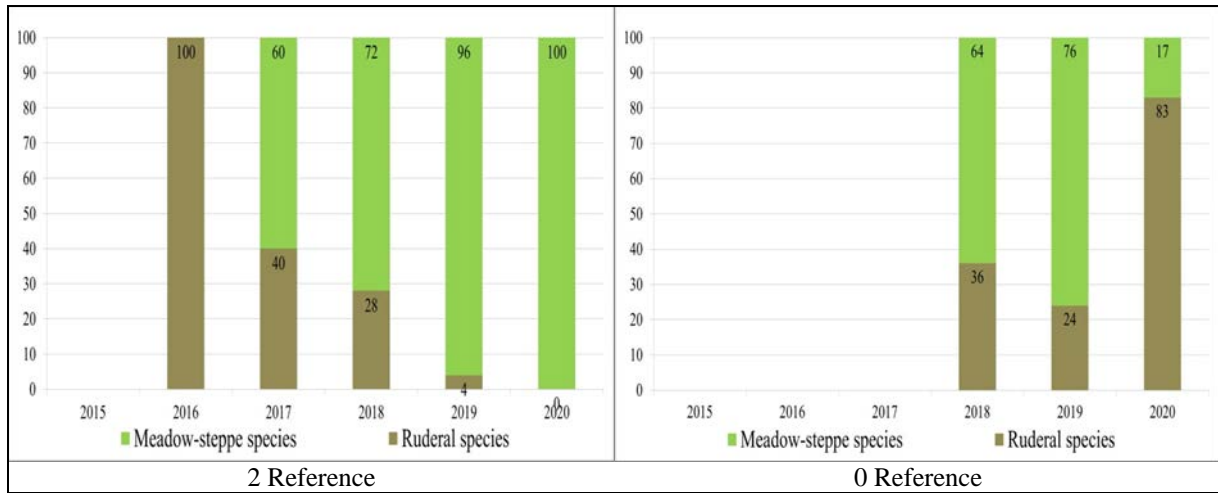


Figure 10: Change in the proportion of ruderal plants in the Reference sites with the application of HSM, %.

In the option without the introduction of HSM on the dump surface, overgrowth was extremely slow. In the first two years, *Stipa capillata* shoots were observed, but they died in the summer period. In 2017, two species of *Oxotropis pilosa* were registered, which had the main share in productivity,

and *Salsola collina* represented by seedlings with vanishingly low productivity (fig. 9A). In subsequent years, a sparse community of *Salsola collina* and *Oxotropis pilosa* formed (fig.11B). Almost all biomass in this option is associated with development, which has increased vitality on the dump.



Fig 11: Reference site without applying HSM: A - 2017; B – 2020

Table 1: The productivity of plant communities on the dump, g / m²

Years	Total	Ruderal plants	Meadow-steppe plants	Years	Total	Ruderal plants	Meadow-steppe plants
2FSL				0FSL			
2015	108,8	108,8	0	2015	92,4	92,4	0
2016	270,8±93,2	236,8±66,0	34,0±22,8	2016	163,6±30,8	163,6±30,8	0
2017	365,6±69,6	282,0±40,0	83,6±58,0	2017	224,0±23,2	224,0±23,2	0
2018	259,6±49,6	200,0±49,6	59,6±15,6	2018	285,6±7,2	251,6±10,0	34,0±15,2
2019	128,0±30,4	12,8±1,6	115,2±31,2	2019	92,8±11,6	64,8±5,2	28,0±7,6
2020	72,4±5,2	0	72,4±5,2	2020	111,2±4,8	20,6±4,8	90,6±5,9
2 PFR				0 PFR			
2015	114,8	51,2	63,6	2015	92,4	92,4	0
2016	266,0±77,2	18,4±6,0	247,6±88,4	2016	163,6±30,8	163,6±30,8	0
2017	555,2±86,8	35,6±19,6	519,6±100,4	2017	224,0±23,2	224,0±23,2	0
2018	453,2±54,8	48,4±7,2	404,8±61,2	2018	285,6±7,2	251,6±10,0	34,0±15,2
2019	216,4±24,8	54,8±7,6	161,6±16,0	2019	92,8±11,6	64,8±5,2	28,0±7,6
2020	325,6±20,7	35,6±11,6	290±24,8	2020	111,2±4,8	20,6±4,8	90,6±5,9
2 Reference				0 Reference			
2015	0	0	0	2015	0	0	0

2016	6,4±6,4	6,4±6,4	0	2016	0	0	0
2017	134,8±36,4	53,6±22,8	81,2±34,4	2017	104,0±34,4	0	104,0±34,4
2018	126,0±14,0	35,6±5,6	90,4±10,0	2018	86,8±7,2	31,6±16,0	55,2±10,4
2019	120,0±24,6	5,2±3,2	114,8±45,6	2019	164,8±15,2	39,2±4,8	125,6±11,2
2020	77,2±23,2	0	77,2±23,2	2020	45,2±4,8	35,2±1,2	10,0±10,0

Discussion

The formation of the vegetation cover of technogenic landscapes occurs in the process of natural settlement and artificial introduction of plant seeds. The process of dump overgrowth in both cases is the result of a complex

interaction of zonal-climatic and specific ecological conditions, such as the properties of substrates, microrelief, etc., with the decisive role of the surrounding natural vegetation, which is the source of the introduction of diaspores, and reclamation technologies (fig. 12).

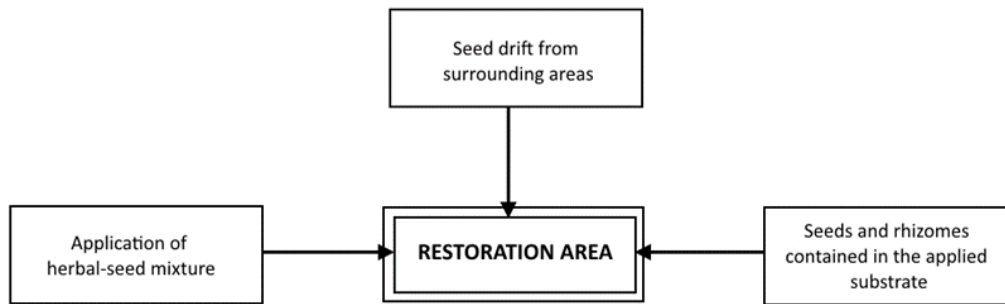


Fig 12: Sources of seed supply to the restoration site

The variety of strategies for the formation of vegetation depends on a very large number of biotic and abiotic factors that affect the nature and composition of pioneer groups, and the rate of passage through the syngensis stages is due to the possibility of bringing in ovules from the surrounding phytocenoses and is rigidly determined, on the one hand, by biological characteristics, and on the other, by ecological conditions [Grime, Hodgson, 1988] [17]. Very often, in the first years, ecotopes with favourable ecological conditions are actively overgrown with only one or a few species, the seeds of which came in faster than the others and had an advantage in creating a pioneer community [Kupriyanov and Morsakova, 2008] [1, 18]. The selectivity of seed germination of plants is determined by a complex of edaphic factors that have developed in a particular ecotope; it determines the further development of the vegetation cover of technogenic habitats. As a rule, the species with high germination energy are the first to settle. Ecological-cenotic strategies and plant competitiveness in syngenetic successions in Russia were determined by L.G. Ramensky [1938], and then almost rediscovered by F. Grime [Grime, 1977] [16]. As phytocenotypes, L.G. Ramenskiy [1935] identifies (1) explorers, "jackals of the plant world", species with low competitiveness, but due to their biological characteristics, they are capable of quickly conquering new territories ("ruderals" according to F. Grime, 1977) [16]; (2) patients, or "camels of the plant world", plants that hold captured territories due to their endurance (stress-tolerants according to F. Grime [1977] [16]; and (3) violents, or "lions of the plant world", plants capable of seizing territories and suppressing rivals due to their superior vital energy (approximately corresponds to stress-tolerant competitors according to F. Grime [1977]) [16].

As a result of the application of HSM formed from mowings from the territory of meadow and large-sod steppes, a nature-like plant community is formed. We mean by it a stable self-sustaining long-term plant community reproduced according to the model of the original natural

communities that previously existed in a given territory or taken as a basis as seed donors. The main criterion for nature-like communities is their high species diversity, to one degree or another corresponding to the structure of the original or uterine communities. At the same time, the purpose of the restoration is not so much to achieve a portrait resemblance of real virgin steppes, but to form erosion-resistant species-rich productive communities, which include 30-40 zonal meadow-steppe species. The experiment clearly showed that in the presence of a sufficient number of ovules of meadow-steppe plants, the rate of syngensis accelerates, and by the sixth year, ruderal and stress-tolerant plants give way to competing stress-tolerants, for which the xerophytic conditions of the banks satisfy their vital needs. In those cases when the application of HSM did not occur, the stages of syngensis are carried out in the usual order; in the sixth year, they are represented by group-overgrown communities; as without application of PFR and FSL and with the introduction of HSM, the community is just at the stage of pioneer grouping on the surface of a bank [Kupriyanov, Morsakova, 2005]. When HSM is applied, sparse pioneer groups of legumes are formed, regardless of the applied substrate. The most surprising thing is that *Oxitropis pilosa* and *O. campanulata* were singly recorded in experimental options and are rather rare in the steppe areas [Strelnikova and Manakov, 2017] [12]. Here, the selectivity of plant selection for a certain type of habitat is manifested, and legumes in a waste bank have significant advantages.

An important point for the formation of nature-like plant community is the quality of the applied substrate. Long-term storage leads to intensive overgrowth with ruderal plants and, above all, with rhizomes of *Elytrigia repens*, which complicates the creation of nature-like plant communities. It is not recommended to use this soil, since the competition of steppe plants with ruderal plants will negate all the benefits

from the use of this agricultural technique. The use of quaternary loams and bank clays provides a faster formation of nature-like communities with high productivity.

Conclusion

The results of a long-term experiment (2014-2020) on the creation of a natural meadow-steppe community and the dynamics of weed and meadow-steppe plants productivity in a long-term experiment in the forest-steppe zone of southern Siberia are summed up.

Two options for the preparation of the bank surface were studied: the application of fertile soil (FSL) and the application of clays and loams of the bank rocks (PFR); the surface of the bank was used as a reference without its improvement. The herb-seed mixture (HSM) was harvested in meadow-steppe areas located 40 km west of the bank. The highest productivity was obtained in areas with PFR application (555.2 g / m² in 2017); the share of ruderal plants was 6-25% of the total biomass. Application of FSL for four years leads to the intensive development of *Elytrigia repens*; by the sixth year, *Allium nutans* and *Artemisia frigida* become dominants of the nature-like community. In the reference sites, a pioneering group of legumes *Oxirhiza pilosa* and *O. campanulata* was formed. Plots without the introduction of HSM are at the pioneer and group-overgrown stage of syngeneses, with the exception of the option with the application of loams, on which the proportion of meadow-steppe plants increases due to the transfer of ovules of meadow-steppe plants by the sixth year; the proportion of ruderal plants decreases. Studies have shown that for more rapid creation of nature-like plant communities, it is more rational to use a potentially fertile layer of loam and overburden clays.

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