Studying the Aspects of Biological Reclamation of Land Located in an Area with a High Concentration of Mining Enterprises

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Abstract. The importance of the biological reclamation issue is dictated by changes in the relief, violation of land use and the formation of technogenic landscape as a result of coal mining, both by open and underground methods. Under these conditions, the development of integrated mining and reclamation technologies for the restoration of anthropogenically disturbed agricultural landscapes, aimed at stabilizing the quality and preserving soil resources, is urgent. The article presents an analysis of the use of green technologies to improve the efficiency of land reclamation located in an area with a high concentration of mining enterprises. These studies will allow us to compare and evaluate the possibilities of using different types of plantings in the restoration of anthropogenic territories.

1. Introduction

For stable economic growth in all industries, including mining industry, and volume preservation of renewable resources, a competent strategy for their recovery is required. This issue can be resolved by updating and restoring the territories after mining - by means of reclamation. The reclamation process is represented by the technical and biological stages of work. At the first stage, the surface is planned, with further covering with a fertile layer, improvement or development of this territory in accordance with the project. The biological stage consists of a number of processes - agrotechnical and phytomeliorative, restoration of the fertile soil layer, acceleration of soil-forming processes, as well as restoration of the balance of biogeocenoses.

In recent years, reclamation methods are increasingly used, the biological stage of which is represented by independent active overgrowing of technogenic lands using organic, lime and mineral fertilizers, manure, liming of acid rocks and peat compost [1]. An approach to granulating a complex of organic fertilizers with seeds of perennial grasses is quite interesting. The authors of this method report on the peculiarities of such sowing - the seed material of perennial grasses is introduced into the mixture converted by the microbiota. To produce this compost in the form of granules, it is necessary to compost a mixture of lignin with sawdust and bird manure in the presence of the mycobiont Paecillomicesvariottii [2]. There was demonstrated the use of coal waste as fertilizers to accelerate the accumulation of humus in dumps, which affects the rate of restoration of ecological biodiversity. The
positive effect of humates on the growth and development of plant organisms in soil disturbed by mining has been established [3]. The use of microorganisms for converting complex forms of nutrition into easily digestible ones has gained popularity both in Russia and abroad. Studies have shown that as a result of the surface inoculation with active microflora of dumps, conditions are created for the formation of stable phytocenoses. To provide microorganisms with nutrients, the composition of biological products includes substances that stimulate their active development. To improve the access of nutrients, mycorrhizal fungi are sometimes used together with earthworms. The introduction of colonies of microorganisms also affects the agrochemical properties of the soil: the amount of assimilable forms of nitrogen, potassium and phosphorus increased [4, 5].

Green technologies - planting trees and shrubs, sowing perennial grasses, carrying out agrotechnical and phytomeliorative measures, the process of restoring disturbed lands, as a rule - are used at the biological stage of reclamation and are aimed at restoring plant and animal ecosystems [6]. Some sources note that it takes 1500-7000 years to form a soil layer 18 cm thick, since the process of soil formation in different parts of the Earth proceeds at a speed of 0.5-2.0 cm per 100 years. The use of green technologies will accelerate the process of soil formation of technogenic lands [7].

Due to the shortage of land resources and the negative impact of industrial development on the environment, the reclamation of disturbed lands is of great economic and environmental importance. When choosing the direction of restoration measures, it is necessary to take into account a number of factors: the need for reclamation of disturbed lands in this region, technical capabilities and properties of the restored territory. Modernization of technological methods of restoration is required due to the variety of methods and conditions of coal mining at coal enterprises [8].

In Kuzbass, coal mining is one of the main extractive industries. There is a constant renewal of the material and technical base of coal mining enterprises, the introduction of new technologies. Industrial development in Kuzbass, at the same time, led to irreversible changes in the landscape and natural vegetation, changes in the physicochemical and mechanical properties of the soil, as a result of which there is a change in its main regimes, disruption of biogeocenosis, which leads to the formation of an anthropogenic landscape. To prevent harmful environmental effects, it is necessary to organize a set of measures for biological reclamation in our region. The aim of the work was to carry out biological reclamation of the disturbed land areas of the coal mine of “Plot Koksovyy” LTD in the Kemerovo Region by transforming lands through biogeocenoses into productive zones for agriculture, forestry and recreation. To conduct a comparative analysis and evaluate the possibilities of using different types of plantings in the restoration of disturbed mountainous land works.

2. Materials and methods

The experimental site is located on the territory of a coal mine of “Plot Koksovyy” LTD with a total area of 12,000 m². For biological reclamation, a multifactorial stationary field experiment was laid on the selection of crops. The stationary field experiment is represented by 3 points: with the application of a fertile soil layer - "Soil"; with the application of a potentially fertile layer - "Loam"; without the application of fertile layers - "Technozem". Each option is divided into three areas: trees; trees and herbs; herbs.

Trees were planted by hand, using an iron shovel, at a distance of 1.5 m from each other. The row spacing was 2 m. The assortment of plants in the experimental plots is the following: Scots pine (Pinussylvestris L.), Betula pendula (Betulapendula Roth.), European crab apple (Malussilvestris Mill.), Sea-buckthorn (Hippophaeramnoides L.) and Populus laurifolia (PopuluslaurifoliaLedeb.) was carried out manually in parallel with tree planting. The herb mixture consisted of Sweet Clover (MelilotusofficinalisPall.) and Awnless Rump (BromopsisinermisHolub.).

Soil samples were taken at 108 stationary points, temperature and soil density were measured. Samples for analysis were taken from a depth of 15 cm with a shovel in polyethylene gloves. The selected samples were placed in plastic bags and stored at a temperature of 2-3°C (in a refrigerator) until the analysis. An assessment of the quality of the vegetation cover was carried out, including measuring the height of plants and the percentage of survival. Plants were selected in ten transects on each variant.
of the experiment in August. The number and species composition of plants in each sample was taken into account, and the root system was measured. The analysis of the samples was carried out in the Problem Research Laboratory for the Reclamation of Disturbed Lands of the Kuzbass State Agricultural Academy together with the Testing Center for Agrochemical Services of Agricultural Production of the Federal State Institution CAC "Kemerovskiy".

3. Results and discussion
At the initial stage of the study, the temperature of the substrate, which is an important physical characteristic, was measured. During the growing season, the indicators were taken three times and the average value was calculated (Figure 1).

![Figure 1. Average soil temperatures at stationary points.](image)

For the growth and development of soil microbiota, as well as herbal and woody plants, a temperature of 20 - 25°C is considered optimal.

The data obtained from the samples of the Technozem experimental site showed values of 6 - 6.50°C more than similar indicators of other options. The average temperature for the variant was 28.60°C. The temperature maximum of the soil is 34.40°C, the minimum is 23.80°C, and the temperature variability was 10.60°C. These indicators testify to the uneven heating of the substrate as a result of continuing exogenous processes in some rocks. When exposed to elevated temperatures, the denitrification process takes place in the soil - a loss of nitrogen in gaseous form occurs, which corresponds to measurements at stationary points. Nitrogen nutrition plays an important role in plant growth and development. The results are shown in Figure 2. It is known that the organic nitrogen contained in humus is inaccessible to plants. It is possible to draw conclusions about the presence of nitrogenous substances most easily assimilated for plants by determining the amount of mineral compounds of nitrogen and nitrates. The highest content of nitrate nitrogen was found in the samples of the Soil variant, average value 29.27 mg/kg. The amount of nitrate nitrogen for this option ranges from 19.9 mg/kg to 41.7 mg/kg, which is considered optimal for plant life.
Figure 2. Content of nitrate nitrogen at stationary points according to experimental options.

The nitrogen content according to the **Loam** option is on average 18.1 mg/kg, which indicates the average provision of the potentially fertile layer with nitrate nitrogen and the possibility of its use for planting. The content of nitrate nitrogen at the points of the soil of the **Technozem** option is low, averaging 5.7 mg/kg with a minimum value of 0.7 mg/kg, which does not allow the use of this soil for reclamation processes.

Soil moisture is another important indicator, since not all of the soil moisture is available to plants. It is necessary to take into account two main forms of soil moisture: bound and free or productive moisture. Figure 3 shows the averaged data of threefold determinations of the productive soil moisture during the growing season.

For all stationary points of the **Technozem** option, the soil moisture is by 7 - 9.6% lower than the values for the **Loam** and **Soil** options. The average moisture content for the variant was 2.9%. The maximum soil moisture is 6.06%, the minimum is 0.69%, and thus, the change in the soil moisture index is 5.37%, which indicates the uneven moisture content of the substrate. It is possible to note the uneven distribution of vegetation on the counting site, which directly depends on this factor.

The reaction of the soil solution affects all biological and chemical processes in the soil, and is of great importance for plants and microorganisms living in the soil; therefore it is necessary to assess the level of its acidity. The nature of the supply of nutrients to the plant depends on it. The results of the study of the substrate acidity level of the soil are presented in Figure 4.

Figure 3. Soil moisture at stationary points according to experimental options.
Acidity, like other physical and chemical properties, primarily depends on the origin of the soil itself (natural or artificial bulk). Most plants thrive best with neutral or slightly acid / alkaline soil extracts. Strongly acidic or strongly alkaline environments are destructive for them. The smallest range of fluctuations at stationary points was established in the Soil experimental plot, average pH = 7.6, min = 7.5, max = 7.9. For most plants, pH = 7.5 is favorable, such a substrate is suitable for biological reclamation without preliminary measures to improve it. The reaction of the soil extract medium according to the Loam option averaged 7.9, which indicates alkalization of the substrate; the maximum pH level is 8.2 units. On the territory of the experimental site, the acidity of the substrate is not uniform and fluctuates by 0.55 pH units, which is 2 times wider than the range of fluctuations of the Soil plot. The Technozem plot has an average pH of 7.97, with a maximum value of 8.2 and a range of fluctuations within the experimental site is 0.76 pH units, which is 3 times higher than this indicator for "Soil". Stronger alkalization of the soil requires acidification measures, and the uneven distribution of the acid-base balance on the site creates certain difficulties and requires measures to equalize the general background pH.

The mechanical structure of the soil is also very important for agriculture, determines the effort required to till the soil, the required amount of irrigation. The particle size distribution influences not only the anti-deflation resistance, but also the nature of the development of the wind erosion process. During the transfer of soil particles by the wind, they are destroyed, as well as abrasion of the soil surface by jumping particles. Both processes lead to an increase in the content of small particles easily transported by the wind in the deflation zone, and both depend on the strength (cohesion) of soil aggregates.

In terms of particle size distribution, the studied variants are very different from each other Table1. So the Technozem option - without applying soil, is characterized as medium loam; options Loam and Soil are light clay and heavy loam, respectively. The best soil is considered to be heavy loam.

It is not enough to confine oneself at the study of the soil granulometric composition without taking into account its structure. Unstructured soil is characterized by the worst water, air and other regimes that ensure the formation and accumulation of humic substances.

Macro-structural units (aggregates 10-0.25 mm in size) of the arable soil layer are more susceptible to the influence of bioclimatic and anthropogenic factors; micro-structural components (aggregates <0.25 mm) are relatively more stable. Therefore, the enrichment of the soil with organic matter, first of all, causes an improvement in the macro-structural state of the soil, increasing the number of agronomically valuable aggregates (from 10 to 0.25 mm).
Table 1. Granulometric composition.

| Option   | Content of fractions, % of absolutely dry soil |
|----------|-----------------------------------------------|
|          | 1-0.25 | 0.25-0.05 | 0.05-0.01 | 0.01-0.005 | 0.005-0.001 | <0.001 |
| Soil     | 8.5     | 18.4      | 27.5      | 22.8       | 8.2         | 19.7   |
| Loam     | 0.9     | 14.4      | 23.2      | 12.5       | 17.0        | 32.0   |
| Technozem| 17.0    | 30.0      | 19.5      | 9.3        | 8.6         | 15.0   |

The data presented (Figure.5) indicate that the substrate of the Soil option in the dry state has a good structure, which is also confirmed by the structural coefficient. This option contains approximately 30% of aggregates > 5 mm, 30% of aggregates 5-1 mm, and 20% of aggregates <1.0 mm in diameter. The share of microaggregates (<0.25 mm) accounts for only 5.5%. In the soil samples of the Loam and Technozem options, the distribution between the structural fractions is noticeably different than in the Soil option.

Humus is food for plants. It contains 98% of soil nitrogen reserves, 60% of phosphorus, 80% of potassium, as well as other mineral elements in a balanced amount. The inert humus of the arable layer contains up to 87.5% of the energy.

The minimum amount of organic carbon was noted in the Technozem option and amounted to 2.3%; the maximum was recorded in the Soil option and amounted to 19.2%, in the Loam option the humus content was within 11.7%. Based on the definition of soil grouping by humus content, this indicator in the option Technozem belongs to the 2nd group - low humus content. Options Soil and Loam have high humus content.

The use of multi-layered plantations of plants of various types of grasses, shrubs and trees is one of the most effective methods of green technologies used on waste land. Such a structure helps to protect disturbed lands from erosion and deflation processes, in addition, the root system is provided with a set of organic matter due to leaf litter.

The planting of woody plants was carried out by hand, using a forest-planting shovel, 2 and 3 year old seedlings and rooted annual poplar cuttings were used. For further monitoring, each tree was assigned a serial number. Table 2 shows the height of plants and the survival rate of woody crops according to the variants of the experiment.
Table 2. Spring planting woody plants by experimental options.

| Species               | Plant height, cm | Survival rate, % |
|-----------------------|------------------|------------------|
|                       | Technozem | Loam | Soil | Technozem | Loam | Soil |
| Pinus sylvestris L    | 20.11      | 27.02 | 22.25 | 25.00      | 38.80 | 66.60 |
| Betula pendula Roth.  | 96.52      | 121.43 | 92.62 | 7.00       | 77.70 | 87.50 |
| Malus sylvestris Mill.| 90.31      | 92.58 | 89.53 | 14.00      | 44.40 | 43.70 |
| Hippophae rhamnoides L| 40.96      | 42.55 | 50.50 | 20.00      | 33.30 | 42.80 |
| Populus laurifolia Ledeb. | 27.69 | 29.83 | 27.96 | 1.00       | 5.50  | 12.50 |

The height of plants in the first year of the study does not differ significantly according to the options of the experiment, this is due to the recent planting of trees and the insufficient amount of time to grow under the given conditions. The nesting rate of trees by the end of the first growing season in the Soil and Loam plots is significantly higher than the Technozem plot. The survival rate of the Betula pendula was 77.7 and 87.5% in areas with loam and soil, respectively. The worst survival rate was noted in the Populus laurifolia Ledeb.

Sowing of grasses was carried out manually, in parallel with planting trees, seeding rate - 30 kg/ha, followed by seeding with a rake. Data on plant height, biomass (dry matter) and projective cover are presented in Figure 6. By the end of the growing season of the first year of life, the largest area of the projective cover of crops was revealed on the site with soil application, here the highest biomass and height of plants.

![Figure 6. Herbaceous plants of spring planting by experience options: a) Plant height, cm; b) Biomass, g/m²; c) Projective cover, %](image-url)

The Technozem option, without applying fertile layers, had the lowest biomass, plant height and a total projective cover of 6%. In the second year of the experiment, an increase in the percentage of projective cover is expected, which is associated with the use of biennial plants.
4. Conclusion

The studies carried out made it possible to compare and assess the possibility of using different types of plantings and soil types in the restoration of lands disturbed by mining. The main tasks of using green technologies are the renewal of the process of soil formation and reproduction of biocenoses, which contributes to the formation of a cultural landscape on waste lands.

In the course of the research, it was found that the height of plants in the first year of the study did not differ significantly according to the variants of the experiment; this is due to the recent planting of trees and the insufficient amount of time for growth in the given conditions. The survival rate of trees by the end of the first growing season in the Soil and Loam plots is significantly higher than the Technozem plot. The best results were shown by Betula pendula - the survival rate of this culture was 77.7 and 87.5% in areas with loam and soil, respectively. The worst survival rate was determined in Populus laurifolia, which is probably due to the use of rooted cuttings for planting and insufficient substrate moisture. Sowing of herbs was carried out in parallel with planting trees. By the end of the growing season of the first year of life, the largest area of the projective cover of crops was revealed in the area with soil application, here the highest biomass and height of plants. The Technozem option, without applying fertile layers, had the lowest biomass, plant height and total cover 7.5 and 16.6 times less than the cover in areas with loam and soil, respectively. In the second year of the experiment, an increase in the percentage of planting cover is expected, which is associated with the use of biennial plants.

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