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# Information-analytical system of environmental monitoring technologically disturbed landscapes

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## Abstract

The Russian Federation is one of the world leaders in the coal extraction. Most of the coal reserves are mined by the cheapest open way. There are a lot of open pits which are very harmful to the environment. The effective tool for reconstruction projects is a specialized system that allows handling required data. Developed information- analytical system for monitoring the impact of the coal industry on the environment includes a database, geoinformation system and software module of calculating the integral characteristics of the environment. Represented structure of a database contains twenty two related tables that take into account the work carried out on disturbed sites and monitoring data. Geoinformation system with a web interface includes graphical and thematic databases with environmental focus. The software module is designed to calculate the current integral characteristics of the environment of studied technogenic landscapes and predict the timing of pollution neutralization and restore the biological productivity of technogenic landscapes. The relationship between database and GIS provides additional opportunities for visual analysis and study of spatial relationships among coal mines, their remediation technologies and the characteristics of their ecological conditions.

**Key words:** Anthropogenic landscapes;neutralization of contamination; monitoring technologically disturbed landscapes; information system; the environment; GIS technology; forecasting periods neutralize contaminants; recovery of biological productivity

## 1 Coal mining in Russia

Coal mining is one of the most important industries. The significance of coal as a fuel is great. Coal is used as a raw material for the chemical industry (production of artificial fibers, plastics). A large number of special types of coal are used for the production of coke required for the steel industry. One promising direction is burning (hydrogenation) of coal to produce liquid fuels. According to the World Coal Institute, its share as the primary source of energy in the global energy sector is 25 % (this is the second place after oil)

Russia remains the largest coal power and one of the world leaders in the extraction and trade of coal. According to the British oil company British Petroleum (http://www.bp.com/content/dam/bp/pdf/statistical-review/statistical_review_of_world_energy_2013.pdf, 20.05.2014) Russia is among the top three leaders in terms of proven coal reserves (Fig. 1).
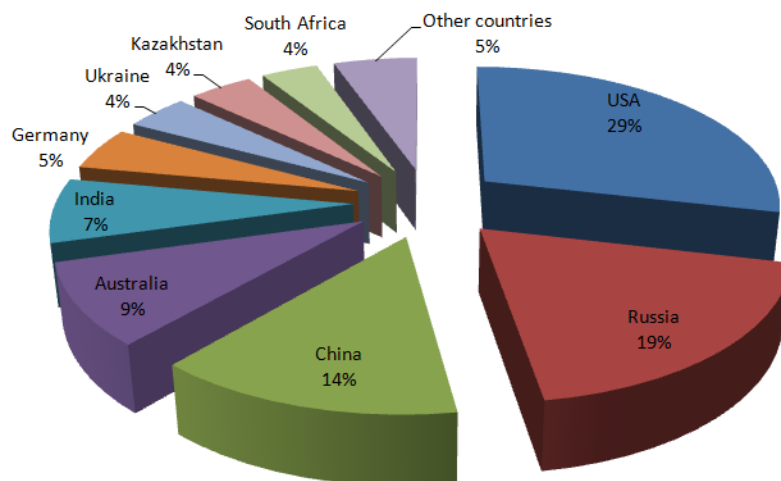


Figure 1: Percentage of proven coal reserves among countries

General conditioning Russian coal resources exceed 4 trillion tons, including balance reserves of commercial categories. There are about 200 billion tons. At the present level of coal extraction (about 300 million tons / year) Russian coal proven reserves will be used up in more than 400 years (http://www.eia.gov/countries/analysisbriefs/Russia/russia.pdf, 19.05.2014).

Figure 2 is a graph of coal mining in Russia since 2000. As the graph shows , most of the coal mined in Russia open way.
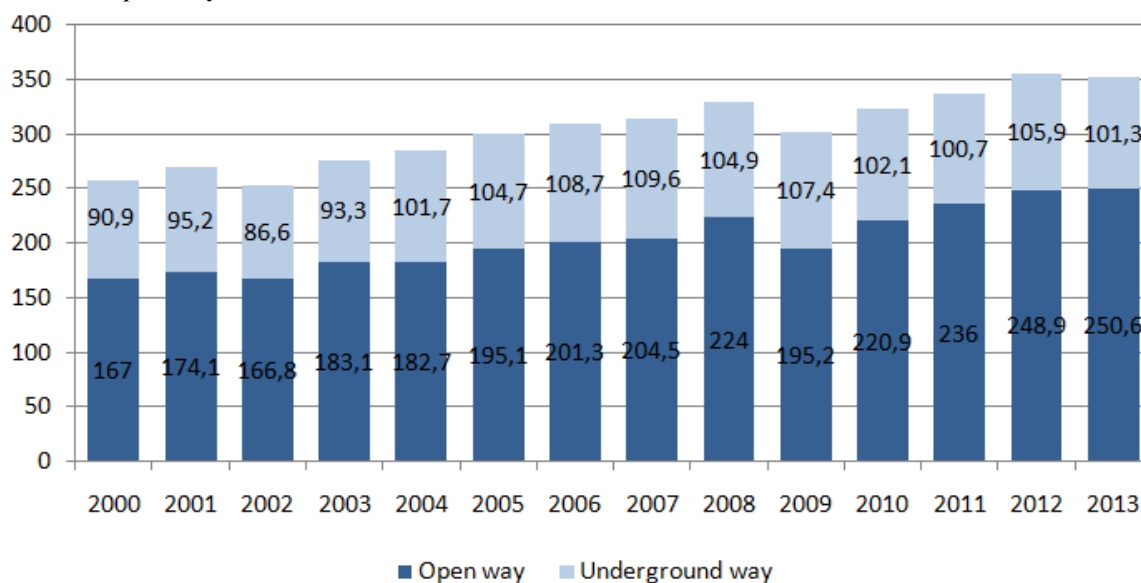


Figure 2: Coal mining in the USSR and Russia

The main part of coal reserves (about 80%) is concentrated in Siberia, mainly in the Kuznetsk Coal Basin (http://below2c.files.wordpress.com/2013/06/russian-coal-industry-preliminary-english-version.pdf, 20.05.2014). The leading way of coal mining in the Kemerovo region is open, which has a higher productivity and low cost. But this method of extraction causes water pollution and landscape changes that lead to the destruction of entire ecosystems. Surface mining of coal completely destroys existing vegetation including medicinal plants, destroys the genetic soil profile, displaces or destroys wildlife and their habitat, degrades air and groundwater quality, changes the current process of land use and to some extent constantly alters the overall profile of the earth's surface.

The main sources of air pollution in underground coal mining are refuse heaps, coal storages, ventilation shafts through which the methane emissions occur during degassing and ventilation. A large number of rock coming from the mines with a high content of coal lead to spontaneous combustion of waste heaps. Combustion is accompanied by liberation of carbon monoxide, sulfur dioxide and sublimation products of tarry substances. One of the main sources of dust and gas production in the pits is blasting and drilling work. The dust is the basic material fed into the air during various technological processes in coal mines. Table 1 shows the types of contaminants in the extraction of coal in various ways.

Table 1: Types of contaminants

| Phase characteristic of wastes | Method of coal mining | |
| --- | --- | --- |
| | Open | Underground |
| Solid | Overburden rock | Mine rock |
| Liquid (solutions and suspensions ) | - | Mine waters |
| Dust and gas | Dust | Methane ( during coal mining ); ventilation air |

2,642,698.721 tons of waste production and consumption was formed in the region according to the state statistical reporting for the year 2012. 99.8 % is waste from resources extraction (http://gosdoklad.kuzbasseco.ru/2012/?page_id=92, 15.09.2014). And every year the number of such wastes increases. Figure 3 is a graph showing the percentage of the amount of waste in the extraction of coal and other minerals.
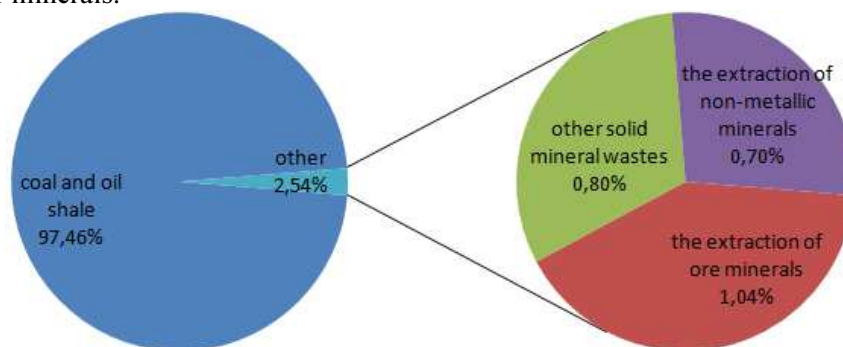


Figure 3: Waste in mining

The current situation is the result of mining and processing industries. Thus there is a replacement of natural landscapes to technogenic ones. But their naturally recovery is very slow. In connection with this the works related to the neutralization of environmental pollution and acceleration of the recovery process of the biological productivity of technogenic landscapes become very relevant.

## 2    Environmental monitoring of technogenic landscapes

Despite the carried out environmental work ecological situation in the coal regions is not improving. This is due to the fact that works on the restoration of disturbed lands are held without a comprehensive assessment of the soil and the ecosystem as a whole (Eidenzon et al. 2012). Under the monitoring of the environment of technogenic landscapes we understand monitoring system, evaluation and prediction of changes in their status, created to determine the timing of pollution neutralization and restore the biological productivity (Eidenzon et al. 2012). Technogenically disturbed landscapes are characterized by biogeocoenose inferiority when the most important constituent components fall out and the environment can be evaluated through available features. The monitoring methodology of integral assessment of the environment of technogenic landscapes includes a system of indicator parameters characterizing the flora, fauna and biogeochemistry (the content of toxic elements in the soil) (Eidenzon et al. 2012).

Vegetation (herbaceous, woody) as a leading component of landscapes including anthropogenic ones occupies the leading place among complex important signs for indicating and monitoring. It is also necessary to take into account the parameters characterizing the fauna of the landscape, such as the quantitative and qualitative composition of insects and warm-blooded animals. Soil and environmental monitoring is a scientific information system of monitoring, evaluation and prediction of soil changes

and its surface occurring under the influence of natural and anthropogenic factors. In addition, it is the basis for predicting and managing of soil fertility. The selection of diagnostic indicators (controllable parameters) is the most important thing in the soil and environmental monitoring.

In 2012 the staff of problem research laboratory of revegetation took soil samples for laboratory analysis, as well as conducted measurements of the temperature and density of the soil skeleton on a plot "Coke". Sampling for analysis was performed with a depth of 15 cm by spade in plastic gloves. Selected samples were placed in polyethylene bags and stored at 2-3 0 C (in refrigerator) up to analysis. Also vegetation monitoring according to the procedures specified in the book " The tallgrass restoration handbook: for prairies, savannas, and woodlands." published by the International Society for Environmental Remediation have been made on this plot (Packard and Mutel, 1997, 463).

In the process of observation such basic parameters as species composition, density, growth, coverage area and survival rate of woody plants were investigated. Based on these parameters, a series of coefficients were calculated for judging the occurrence and importance of species in the study cenosis, as well as the area of projective cover both individual species and vegetation as a whole.

## 3    Database Structure

Effective tool for solving environmental monitoring of technogenically disturbed land is a database with a graphical interface that allows to store, manage and provide the necessary data. This database will provide the information about the technogenic landscapes in the territory as a set of digital data, united by certain principles.

A properly designed database provides ease of its support. Data should be stored in tables. Each table should contain information of the same type. Then it will be enough to update specific data in only one place to update information that to be displayed in the entire database.

To develop an information system (database) on the state of the environment of technogenic landscapes conceptual and datalogic data models were designed. Figure 4 shows the structure of the database, "Technogenic landscape." The structure of the database contains twenty two related tables allowing to take into account the main activities carried out on technogenic landscape , including mining, land reclamation and monitoring of flora, fauna and soil.
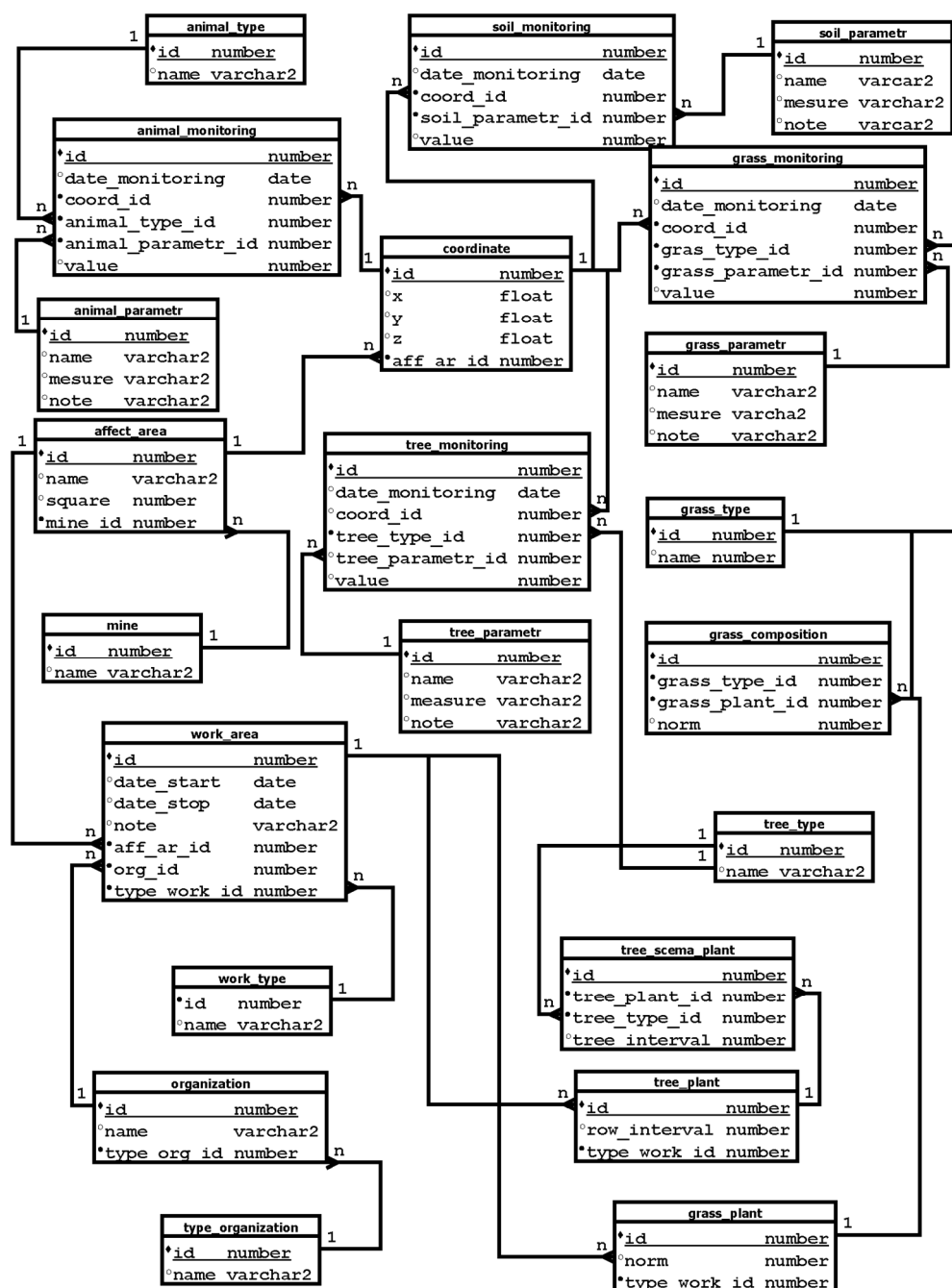
Figure 4: Structure of database IAS "Technogenic landscape"

Table **mine** is a directory of coal plots.

Table **organization** is a business directory. It stores the names of all organizations that are directly related to the test anthropogenic landscape.

Table **type_organization** is a reference of organizations work directions.

Table **affect_area** is a table with the disturbed areas of coal plots. It stores the names of plots, the plot area as well as data on the affiliation to one or another pit. Table **work_area** is a table with the works carried out in plots including the date of work and executing organization.

Table **work_type** is a directory of activity types.

In this table coordinates of the participants are stored.

Tables **tree_type, grass_type and animal_type** are references of trees, grasses and animals types.

**Tree_plant** table contains information about tree planting plots.

**Tree_scema_plant** table contains data on the species composition and tree planting scheme.

**Grass_plant** table contains data on sowing grass on plots.

**Grass_composition** table contains data on the species composition and percentage of grass mixtures.

Tables **grass_monitoring, tree_monitoring, soil_monitoring and animal_monitoring** contain monitoring data of technogenic plots: grass, trees, soil, animals.

The table **grass_monitoring** contains data on indicating parameters characterizing the herbaceous vegetation in different parts of technogenic landscapes.

## 4    Interface System

As a tool for the implementation of a physical model there was selected application Oracle Application Express (Apex). It is free environment of rapid development of application software based on DBMS OracleDatabase, entirely implemented as a Web application. The system interface is shown in Figure 5.
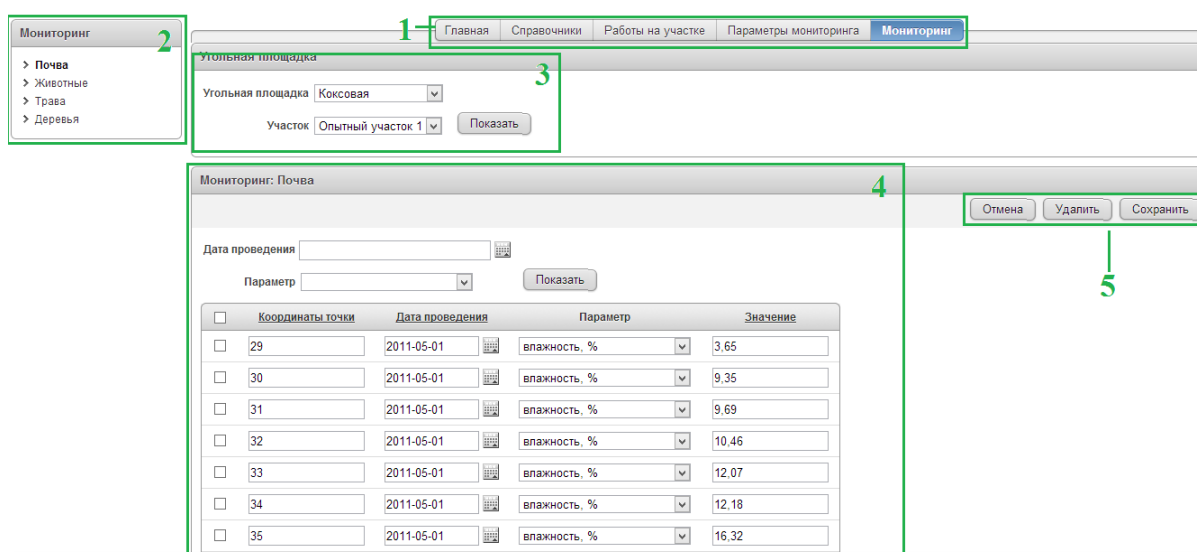


Figure 5: System Interface

Main navigation menu is presented as 1 in Figure 5. It allows changing the main sections of the system. At the moment the system is represented by four main sections: "references", "works on the plots," "monitoring parameters" and "monitoring". 2 is navigation to the selected section. 4 is system workspace. In the workspace there is a table we are working at the moment. 5 represents buttons for work with the data ("Add", "Delete", "Save" and "Cancel"). 3 represents filters for screening data.

For allocation of access rights in the system the authorization module was implemented. The system contains 4 types of roles, such as "Developer", "Administrator", "Moderator" and "Guest." These roles are presented in Figure 6. User "Developer" has full access to database management, roles and users. The role of "Administrator" includes data management capabilities in the system, and can also assign roles to other users. Users with the role of "Moderator" can enter, edit, and delete data associated with controlling and monitoring that is all data except for user accounts. User with the role "Guest" can view some system data associated with objects that have to do with it (for example an employee of public or administrative bodies on environmental protection can view data on the state of disturbed subordinated lands) . All types of roles are only for registered users.
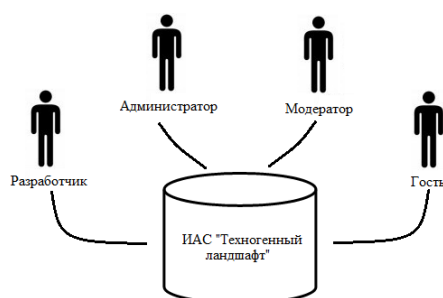
Figure 6: Distribution of roles in the system

## 5    Graphical representation of data

Multivariate stationary field experiment on the selection of plants for biological reclamation of disturbed lands was carried out on Kiselevskaya (coke) coal plot .
Stationary field experiment includes three options:
1.    The application of the fertile layer of soil - " Soil ";
2.    The application of a potentially fertile layer - " Loam ";
3.    Without application of fertile layers - " Tehnozem ."

The total area of pilot plots was 12,000 $m^2$ . Each option is divided into three sections: the trees; trees and grasses; grasses. Figure 7 shows a diagram of the experiment on Kiselevskaya (coke) coal plot.
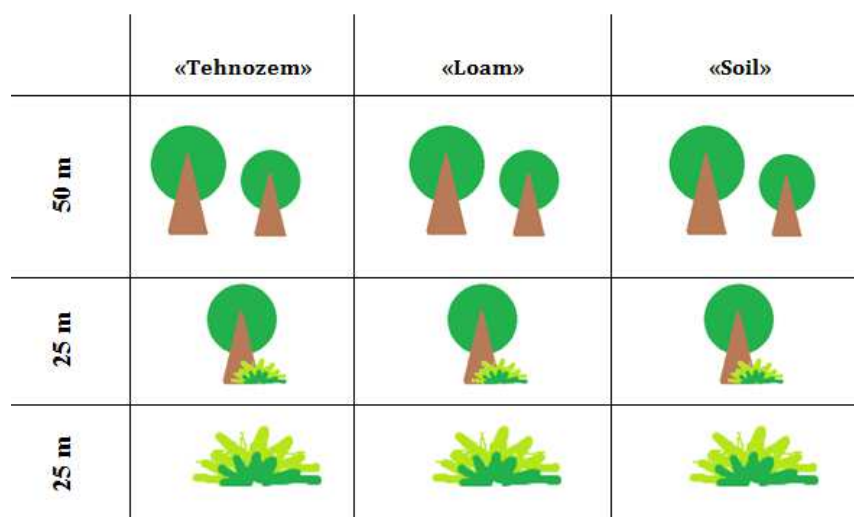


Figure 7: Diagram of the experiment

The trees were planted manually with the use of iron spade at a distance of 1.5 m from each other. The magnitude of the aisle was 2 meters. The assortment of plants on experimental plots was the following: Scots pine (Pinus sylvestris L.), white birch (Betula pendula Roth.), Wild apple (Malus silvestris Mill.), Sea buckthorn (Hippophae ramnoides L.) and poplar lavrolistny ( Populus laurifolia Ledeb.)
The grass cultivation was conducted in parallel with the trees landing. Mixture consisted of Melilotus officinalis            Pall            and            Bromopsis            inermis            Holub.
Herbaceous vegetation monitoring was conducted according to the procedures specified in the book " The tallgrass restoration handbook: for prairies, savannas, and woodlands." published by the International Society for Environmental Remediation. Table 2 provides a list of herbaceous plants and area of projective cover.
Table 2: Herbaceous vegetation plot

| Plant Species | Plant Species |
|---|---|
| | |

|  | Soil | Loam | Tehnozem |
|---|---|---|---|
| **The average area of projective cover, %** | | | |
| Melilotus officinalis Pall | 51,0 | 25,0 | 11 |
| Bromopsis inermis Holub | 49,0 | 20,0 | 9 |
| **Biomass, g/m$^3$** | | | |
| Melilotus officinalis Pall | 12,903 | 11,335 | 3,93 |
| Bromopsis inermis Holub | 6,188 | 4,219 | 2,911 |

The species composition of the studied area is represented by two grass species of different families - Melilotus officinalis Pall and Bromopsis inermis Holub. Graphical representation of the projective cover of grass mixtures in different soil types is shown in Figure 7. Dark gray in the figure denotes Melilotus officinalis, dark gray - Bromopsis inermis Holub and black denotes the land on which none of the species take roots.



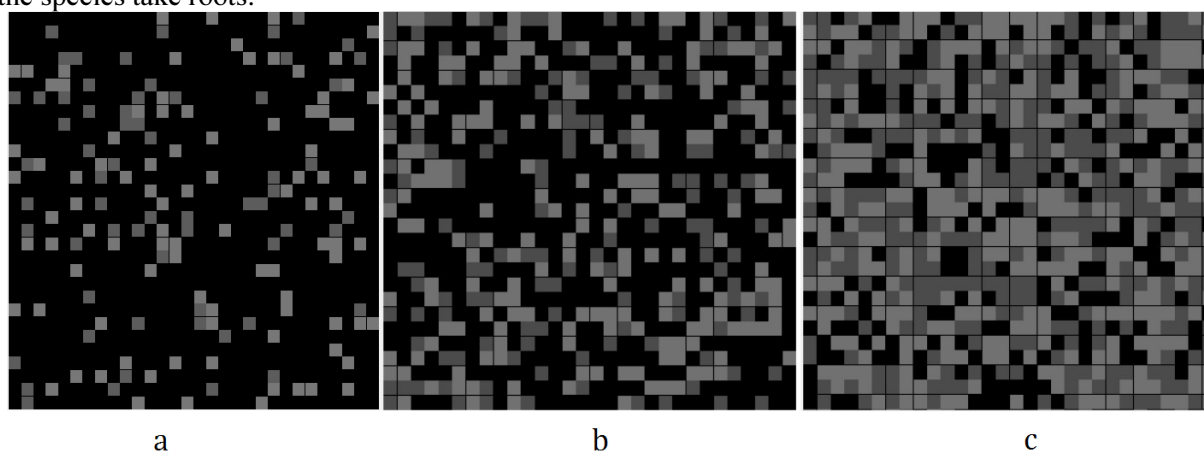a                                    b                                    c

Figure 7 : a) The projective cover of grass mixtures on the variations of field experiment "Tehnozem "; b) The projective cover of grass mixtures on the variations of field experiment " Loam "; c) The projective cover of grass mixtures on the variations of field experiment " Soil "

**Conclusion**

Designed database allows to store and process a variety of data about man-made landscapes, which have been influenced by the coal mining industry. Data processing will allow for a comprehensive assessment of the environmental man-made landscape. The database has a web interface that allows you to access the data through the Internet. The system provides visualization of the state of the natural environment of man-made landscapes. This service allows you to detect anomalies and perform a qualitative assessment of the dynamics of the monitoring system. In cooperation with the Laboratory of land reclamation we are actively working on filling the data base. In the future we plan to develop a prediction unit. It will allow us to forecast the timing of the restoration of the biological productivity of disturbed lands. In addition, the system can be adapted to other extractive industries.

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