Circular economy for restoration of disturbed areas

Assessment of restoration processes in reclaimed lands disturbed by copper ore mining

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Chapter I

Disturbed areas and land degradation

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Disturbed areas

Area's disturbance can be caused both by naturally occurring processes in nature (landslides, fires, floods, storms, etc.) and by humans (mining of minerals, construction activities, infrastructure facilities, etc.).

Area's disturbance leads to a change in the landscape, destruction of the soil surface, vegetation and adjacent habitats. As a result, ecosystem services in the area are completely changed.

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Factors,

that cause land disturbance and land degradation

Removal of vegetation cover and deforestation.	Poor agricultural practices.	Livestock breeding, including overgrazing.	Improper crop irrigation.	Urbanization and economic development.
Transportation infrastructure.	Extraction of minerals.	Expansion of agricultural areas.	Tillage with heavy machinery.	Cultivation of monocultures.
Invasive species	The disposal of solid waste or their unregulated disposal.	Climate changes.	Soil carbon loss.	

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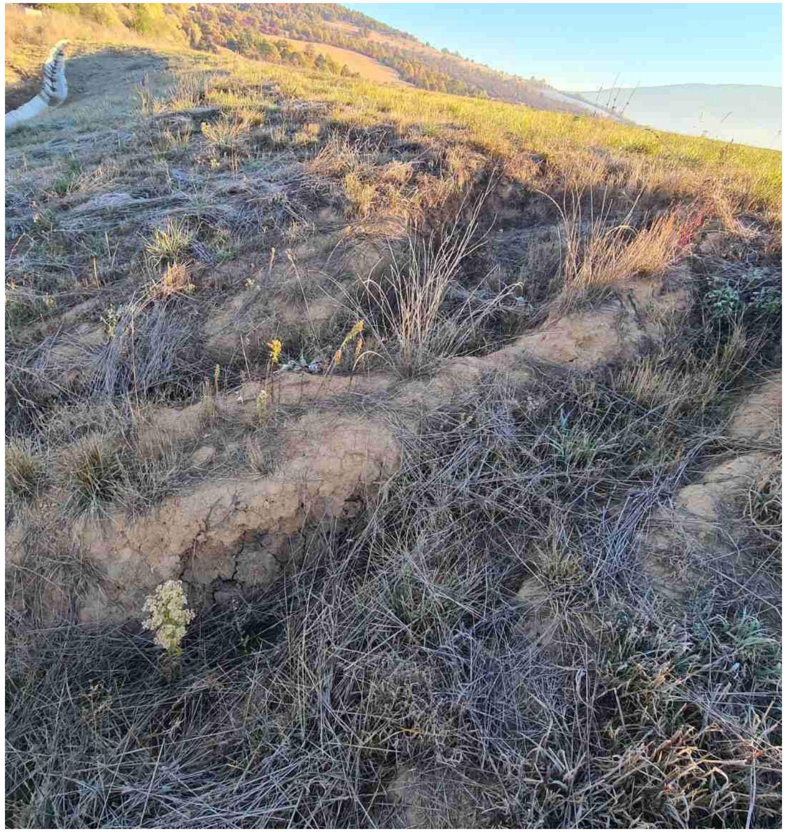

Types of disturbed lands

Disturbed lands as a result of erosion

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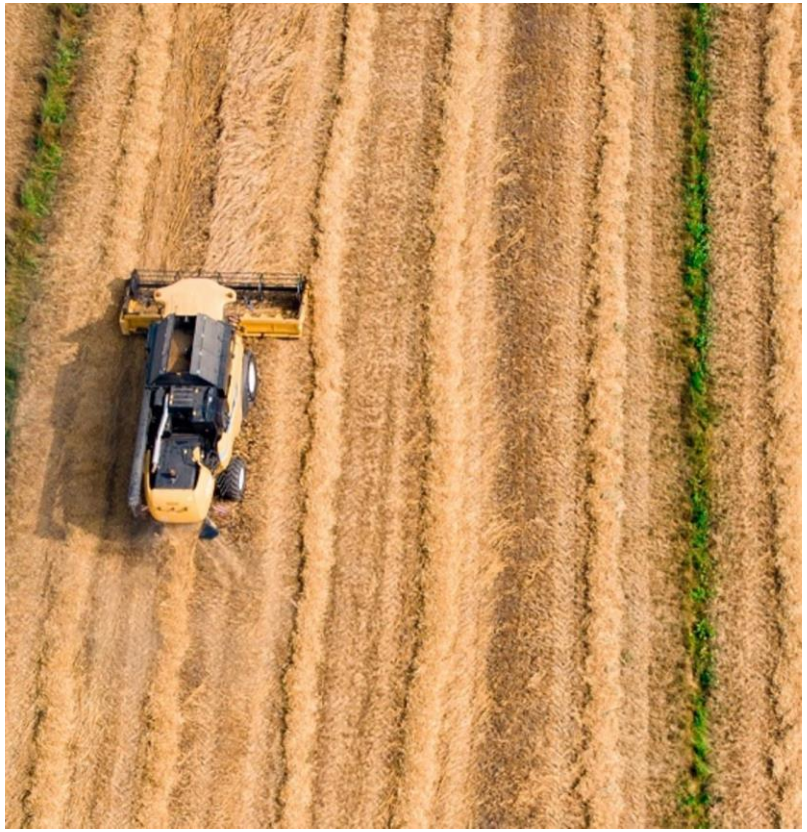

Types of disturbed lands

Disturbed lands as a result of loss of soil fertility

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Types of disturbed lands

Disturbed lands as a result of waterlogging

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Types of disturbed lands

Disturbed lands due to salinization

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Types of disturbed lands

Disturbed lands due to industrial activity

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47%

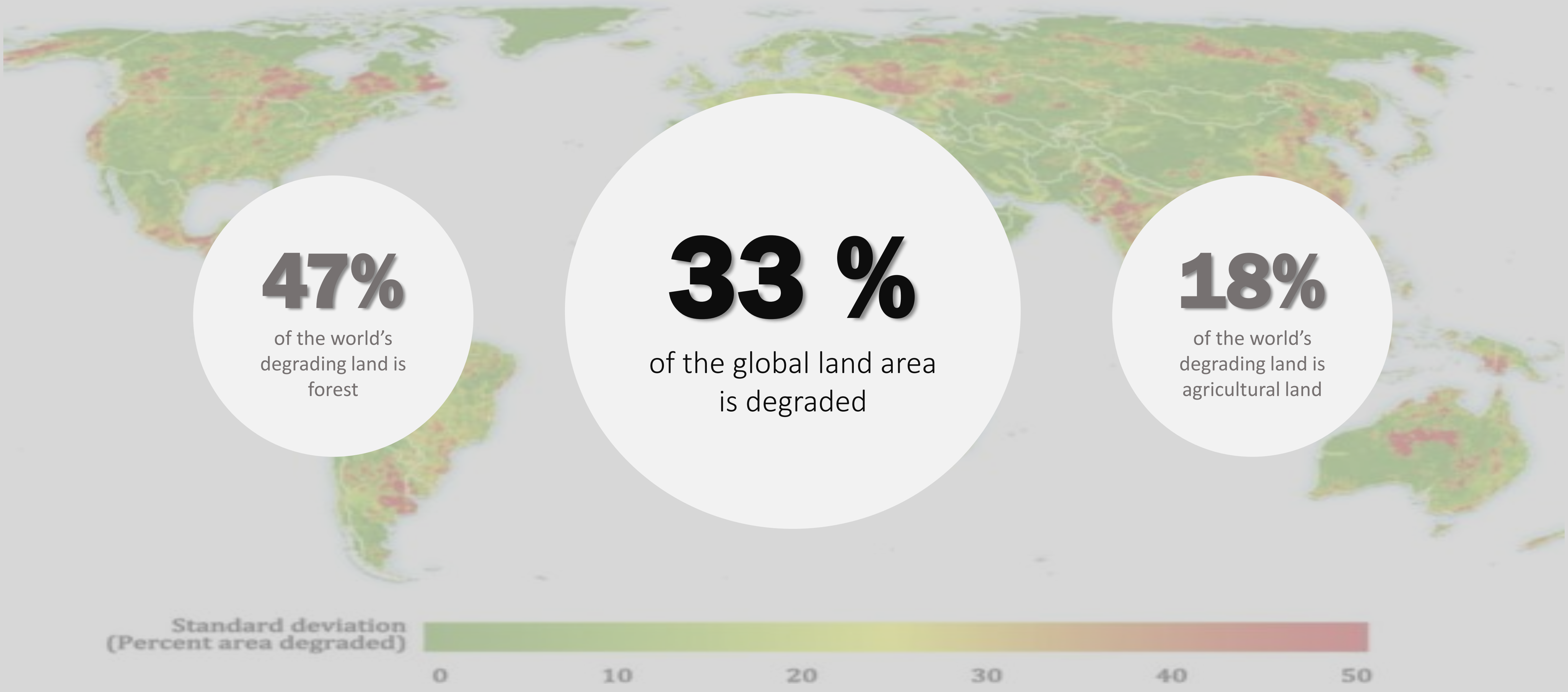
of the world's degrading land is forest

33 %

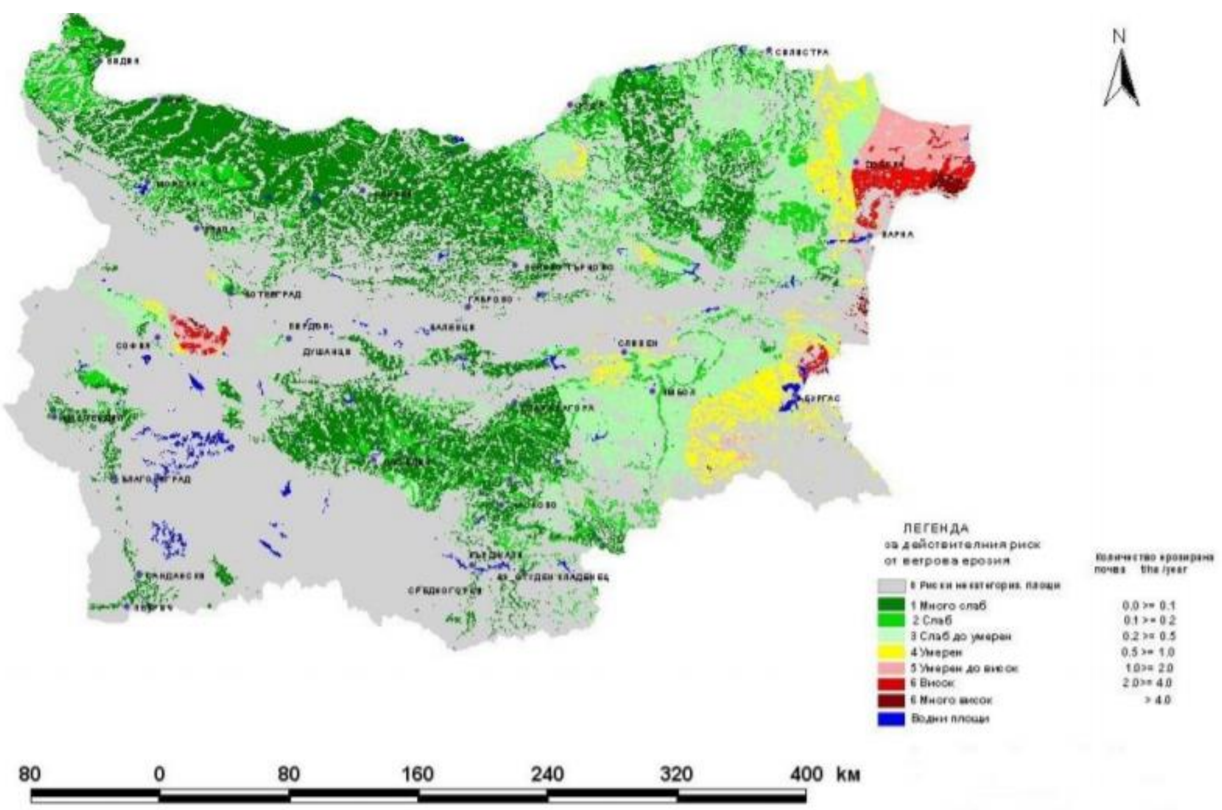
of the global land area is degraded

18%

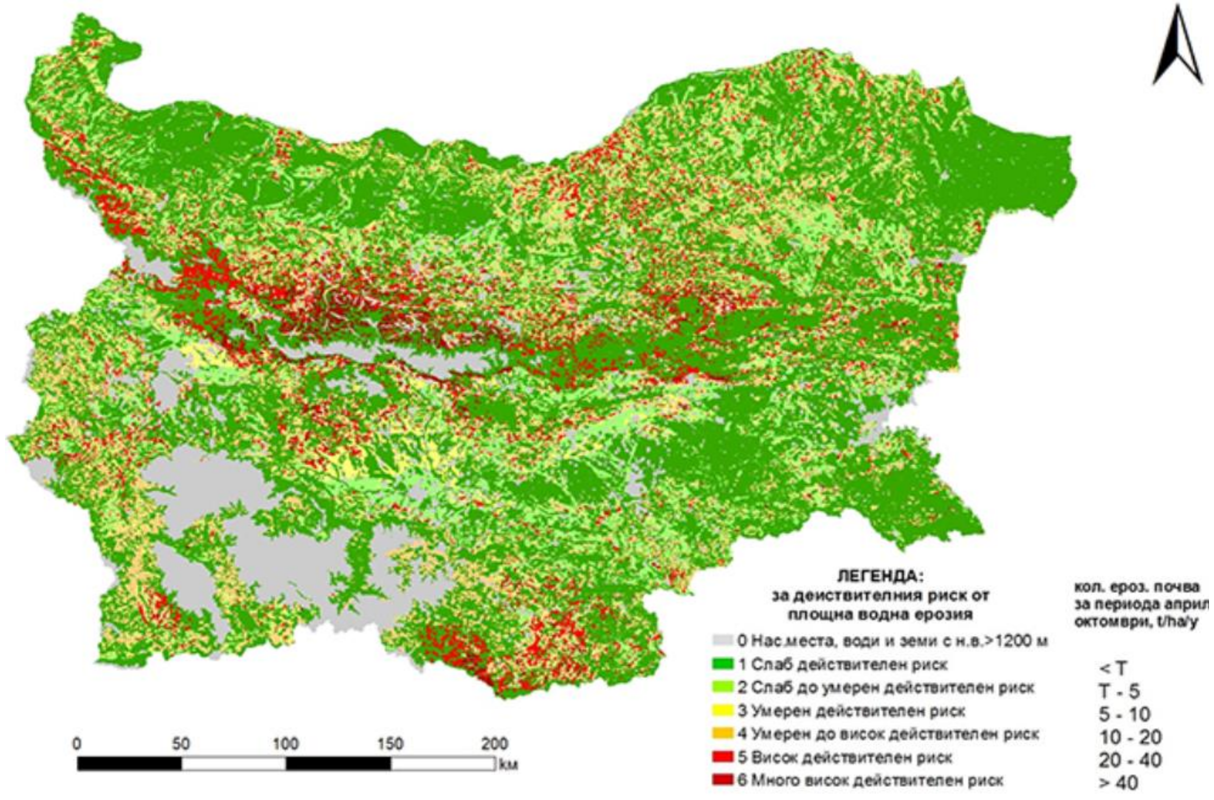
of the world's degrading land is agricultural land



Condition of the Bulgarian lands



Actual risk of soil erosion by wind of soil for the year 2020



Actual risk of soil erosion by water for the year 2020

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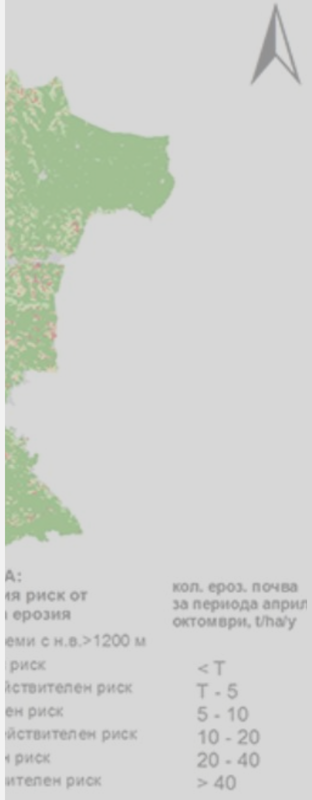
Condition of the Bulgarian lands



The most serious threat to soil degradation in Bulgaria is **erosion**, which results from natural conditions, the way land is used, the cultivation of the soil inconsistent with its specific characteristics, the technology of growing agricultural crops, the application of unreasonable crop rotations and anti-erosion measures. About 85% of the soils in the country are affected by erosion processes, and about 30% of them are subjected to soil erosion by wind. The risk of wind erosion is observed in the regions of Dobrich, Sofia City, Varna and Burgas.

The most areas with a high risk of sheet soil erosion by water - "strong to very strong" - are in the districts of Lovech, Sofia region, Gabrovo, Targovishte and Kardzhali, and the least - in the districts of Dobrich and Yambol.

Actual risk of soil erosion by wind of soil for the year 2020

Actual risk of soil erosion by water for the year 2020

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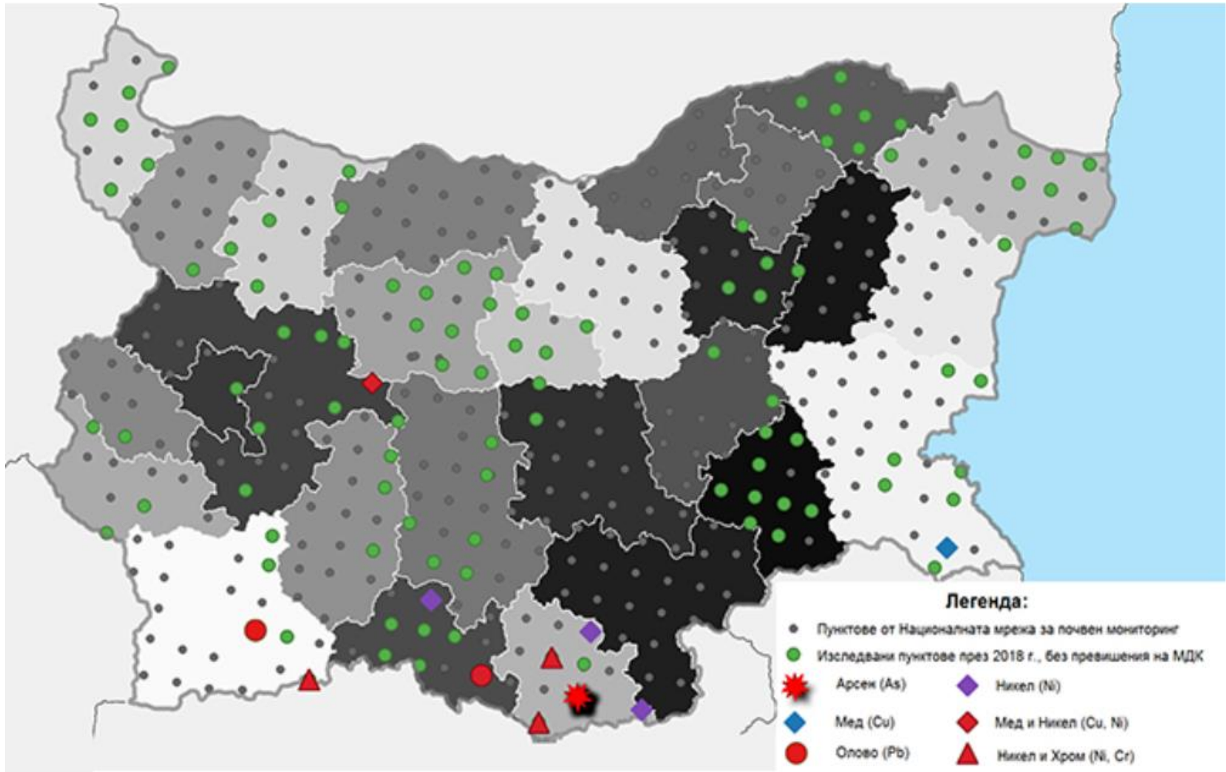
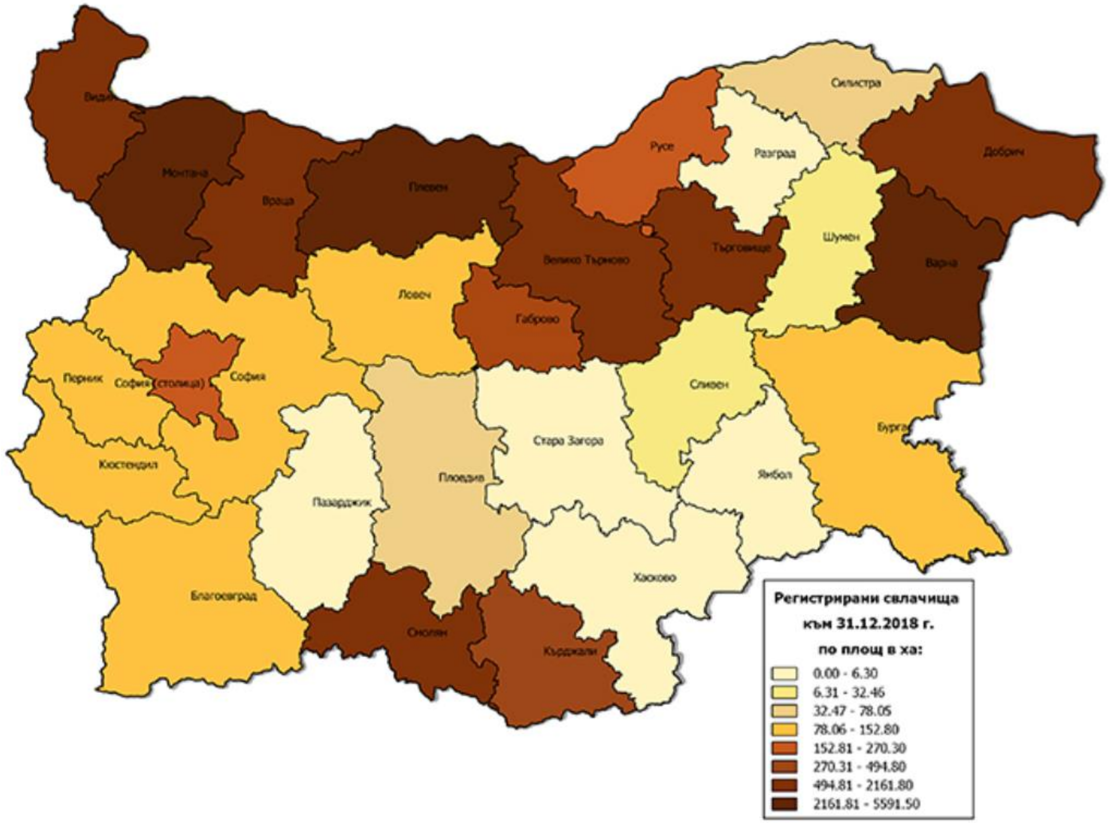
Condition of the Bulgarian lands



Spatial distribution of points from the National Soil Monitoring Network with established exceedances of the MPC of heavy metals and metalloids



Distribution of lads affected by landslide processes, ha

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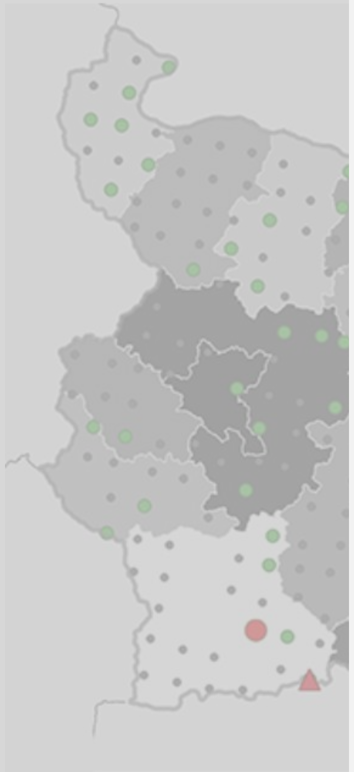
Condition of the Bulgarian lands

Acidic soils (genetically acidic and acidified) do not represent a significant problem for Bulgaria, except for areas with point sources of impact (Devnia, Obruchishte, Zlatitsa-Pirdop, Vratsa) or soils in areas with strong anthropogenic influence (Southwestern Bulgaria).

Saline soils are the result of accidents around industrial enterprises or the use of saline water for irrigation. A large part of the saline soils in Bulgaria are in the form of patches mainly in the regions of Burgas, Varna, Veliko Tarnovo, Pleven, Plovdiv, Sliven, Stara Zagora and Yambol.

The growth rate of soil sealing in the Republic of Bulgaria compared to other European countries is lower. The processes of soil sealing are more pronounced in the coastal and resort villages, where the construction marks the highest growth in the country.

Soils in the country are in good ecological condition about contamination with heavy metals, metalloids and persistent organic pollutants: polyaromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB) and organochlorine pesticides. Pollution with TMM is found locally around mining and metal processing enterprises in the regions of Sofia, Kardzhali, Smolyan, Burgas, Blagoevgrad.



Spatial distribution of points from the National Soil Monitoring Network with established exceedances of the MPC of heavy metals and metalloids

Distribution of areas affected by landslide processes, ha

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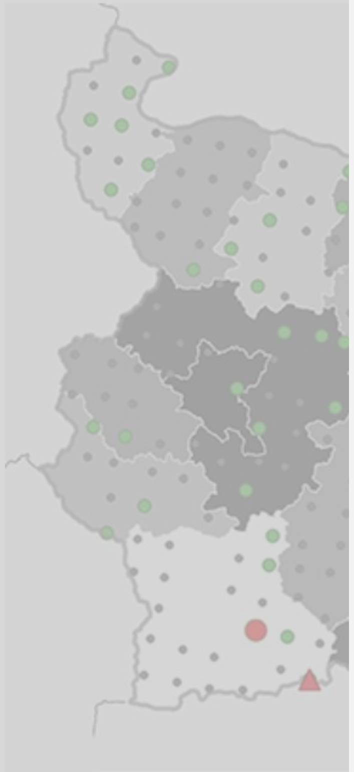
Condition of the Bulgarian lands

- The trend in 2018 is for an increase in the number of new landslides compared to 2017.
- On the territory of the country as of 31.12.2018, 2 170 landslides with a total area of about 21 758.2 ha were registered, of which: active/periodically active landslides on the territory of the country are 851 with an affected area of about 6,242.6 ha;
- The potential/temporarily stabilized landslides are 875 with an affected area of about 10,152.4 ha;
- Subsided/stabilized landslides – 444 landslides with an affected area of about 5,363.2 ha.



Spatial distribution of points from the National Soil Monitoring Network with established exceedances of the MPC of heavy metals and metalloids

Distribution of areas affected by landslide processes, ha

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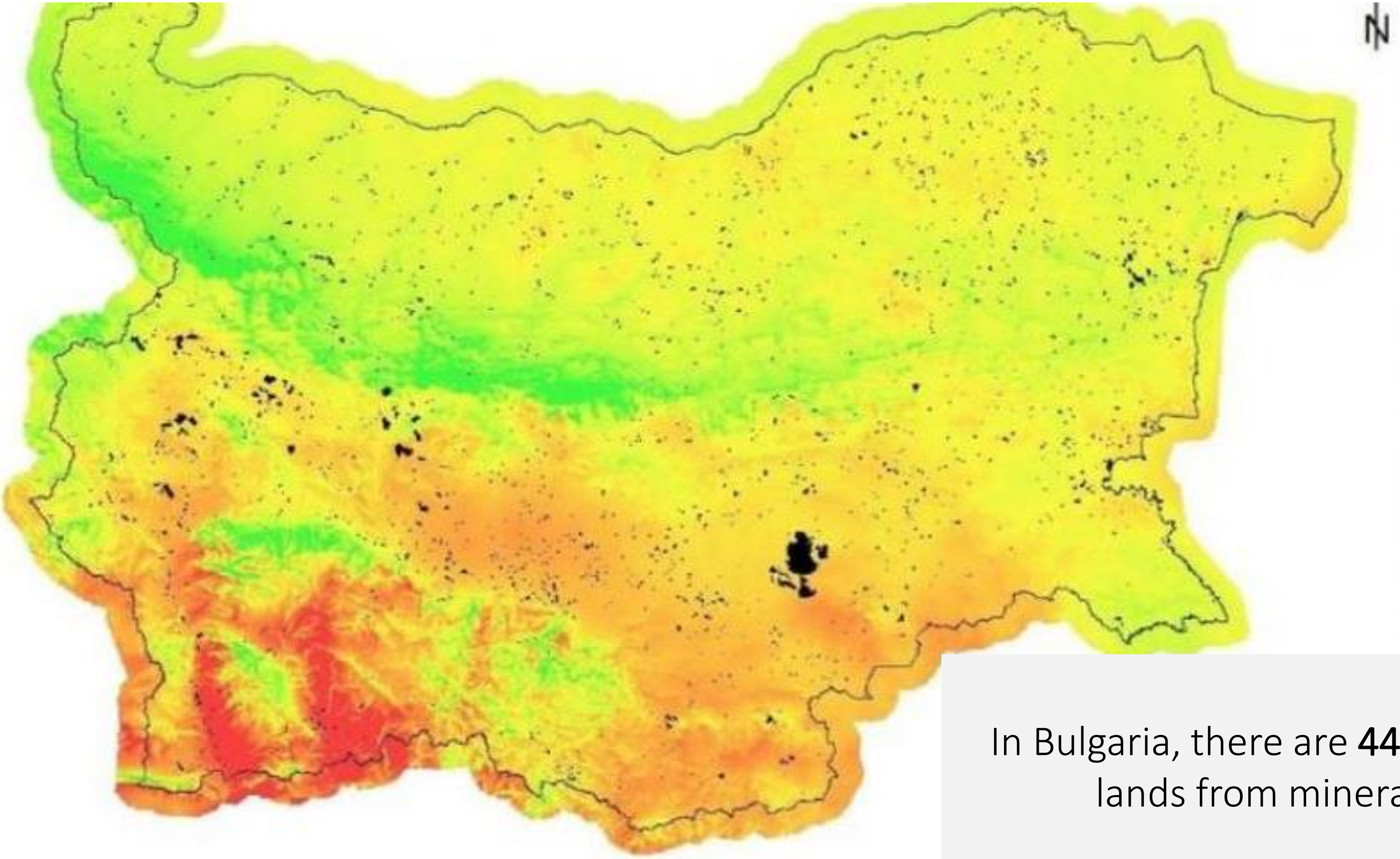

In Bulgaria, there are **445 km^2** of disturbed lands from mineral extraction.

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Chapter II

Circular economy for restoration of the disturbed areas

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Circular economy

The circular economy is a model aimed at extending the life cycle of products.

When a product reaches the end of its life, the materials from which it is composed continue to be used in another way. This is done repeatedly to minimize waste disposal.

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Circular economy
for restoration of the disturbed areas

Use of waste in restoration of disturbed areas

Phytoremediation/ phytomining

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Use of waste in restoration of disturbed areas

Sustainable waste management is an important prerequisite for the development of the circular economy and supporting the environmental, social and economic aspects related to waste treatment.

From the point of view of the introduction of the best available technologies, it is necessary that they comply with the requirements of the Bulgarian legislation, as well as the legislation in the European Union (EU).

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Use of waste in restoration of disturbed areas

The increasing trend towards **a negative humus balance** leads to the need to investigate the possibilities in the field of **humus-free restoration** as a technological approach to manage the restoration of the environment.

To solve the problem, several studies are being conducted on the use of various soil improvers and additives from waste. Among them are activated sludge from wastewater treatment plants (WWTP), fly ash from the incineration of biowaste, lignite ash and others as successful ameliorants for humus-free reclamation.

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Use of waste in restoration of disturbed areas

Prerequisites for the use of waste:

- Nutrient content;
- Organic matter content;
- Regulation of soil acidity;
- Lack of harmful substances that would further pollute the soil;
- Lack of harmful microorganisms.

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Use of waste
in restoration of disturbed areas

Biomass bottom ash

Biomass bottom ash is waste that is produced in the process of burning plant materials such as wood, straw and other plant parts and remains at the bottom of combustion boilers. It represents 10% of the total incineration waste.

The waste is characterized by higher porosity, permeability and high nutrient content. Biomass bottom ash is often used as a soil enhancer because it is a valuable source of potassium (K), calcium (Ca), sodium (Na) and magnesium (Mg), as well as other macro- and micronutrients that are necessary for the complete plant development and growth.

Bottom ash

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Use of waste
in restoration of disturbed terrains

Biomass bottom ash

The use of biomass bottom ash:

- increases the content of C, N and P as well as Ca, Mg and Zn;
- regulates soil acidity;
- immobilizes heavy metals and reduces their leaching into the solution;
- reduces the phytotoxicity of heavy metals.

Bottom ash

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Use of waste
in restoration of disturbed terrains

Biomass fly ash

Fly ash is the lightest type of ash when incinerated. It consists of the light particles that fly out during combustion and are caught in the filters.

The ash contains elements in ratios as well as elements that were also in the structure of the used biomass. Due to the high content of soluble salts and readily available macro and microelements, fly ash can be used to improve the structure and stockability of soils.

Fly ash

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Use of waste
in restoration of disturbed terrains

Biomass fly ash

The use of biomass fly ash:

- increases soil acidity to neutral;
- improves the physical properties of the soil, due to an increase in dust and sand fractions, which helps aggregation, infiltration and water holding capacity.

Fly ash

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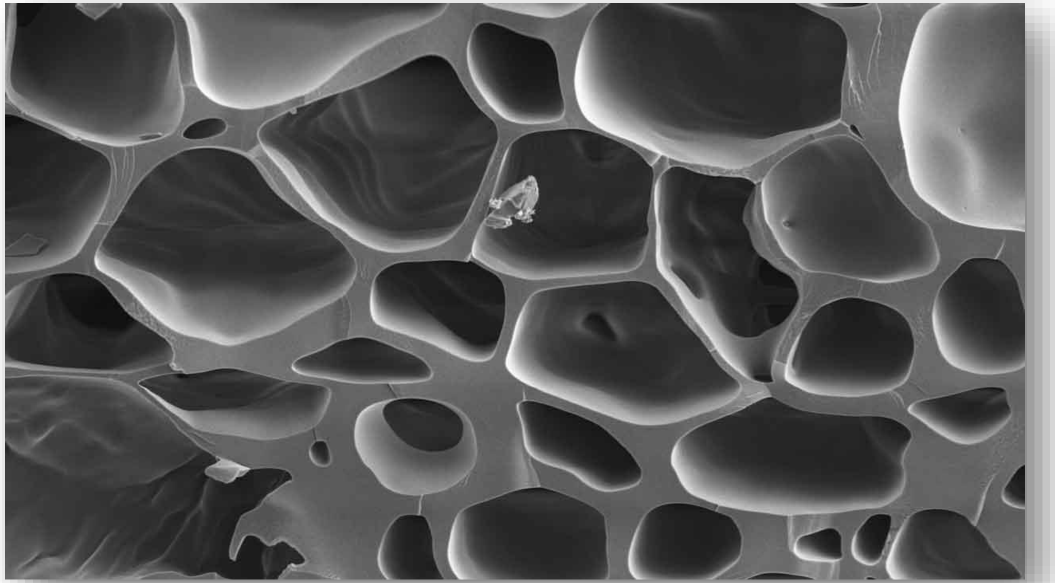
Use of waste
in restoration of disturbed terrains

Biochar

Biochar is the charred residue of organic materials such as plants or manure. The special raw material has a porous surface. It acts as a sponge and can absorb significant amounts of water and nutrients. It is obtained through: pyrolysis of raw plant materials; processing biomass into fine pore coal at temperatures above 300 degrees Celsius.

Combustion takes place without or with very little oxygen (biomass does not burn with a flame, but smolders).



Biochar

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Use of waste
in restoration of disturbed terrains

Biochar

Biochar

The use of biochar:

- increases organic carbon content;
- when it is applied to the soil, it improves its properties.

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Use of waste
in restoration of disturbed terrains

Sludge from Wastewater treatment plants (WWTP)

In the process of purification of different types of wastewater, sludge is obtained, differing significantly in quantity, composition and properties.

Their classification is based on various signs, such as origin, qualities and properties that they possess depending on the places of their disposal, the method and degree of treatment, etc.

Depending on their origin, sludge are defined as domestic, industrial, agricultural and rainwater.

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Use of waste
in restoration of disturbed terrains

Sludge from WWTP

The sludges released during the participation of domestic wastewater in settlements, resort complexes and industrial enterprises are domestic.

When industrial sites are not included within the settlement, they contain mostly organic substances, as well as a high concentration of microorganisms. This enables them to be used as soil enhancers.

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Use of waste
in restoration of disturbed terrains

Sludge from WWTP

In the presence of industrial enterprises, domestic wastewater and wastewater from the enterprise are mixed.

It is possible that the sediments contain toxic substances above the permissible norms, in which cases they can not be used for fertilizing.

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Use of waste
in restoration of disturbed terrains

A mixture of WWTP sludge and biomass ash

A mixture of the two types of waste leads to the production of granules with higher strength, which facilitates the storage and use of the soil conditioner.

Applying a similar soil conditioner leads to:

- a decrease in the bioavailability and eco-toxicity of heavy metals;
- regulation of soil acidity;
- increasing the biomass of the cultivated vegetation.

Pellets of Sludge mixed with Biomass Fly Ash

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Use of waste
in restoration of disturbed terrains

Sludge from farm wastewater

Farm sludge

The waste is obtained during the treatment of wastewater generated by the activity of livestock farms. The waste is rich in organic substances, micro- and macro elements.

The soil enhancer is characterized by:

- high alkalinity and high carbonate content;
- high adsorption capacity;
- high content of organic matter;
- immobilization of Cu, Fe, Mn, Ni and Zn.

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Use of waste
in restoration of disturbed terrains

Processed animal waste

Processed Animal waste

Application of manure and bone meal to contaminated soil has been found to significantly reduce leaching and phytoavailability of heavy metals.

The reason for this is the high alkalinity and the high content of carbonates in these improvers, which adsorb and retain heavy metals and metalloids in an invariable form.

Also, the high content of organic matter, especially in cow manure, can bind heavy metals and metalloids by chemisorption and reduce their mobility.

Increased amounts of ameliorant can acidify soils and lead to the release of heavy metals and metalloids.

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Use of waste
in restoration of disturbed terrains

Compost

Compost is a humus-like material obtained by the controlled decomposition of organic materials through an aerobic or anaerobic biological process.

The use of compost in restoration:

- creates conditions for partial binding of heavy metals with organic matter and blocking the biological assimilability of pollutants;
- decreases water runoff;
- protects against erosion.

Compost

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Use of waste
in restoration of disturbed terrains

Waste from geological exploration and excavation works

In some cases, it is possible to use waste due to geological exploration and mining activities for the restoration of disturbed areas.

A preliminary characterization of that waste is necessary before its disposal.

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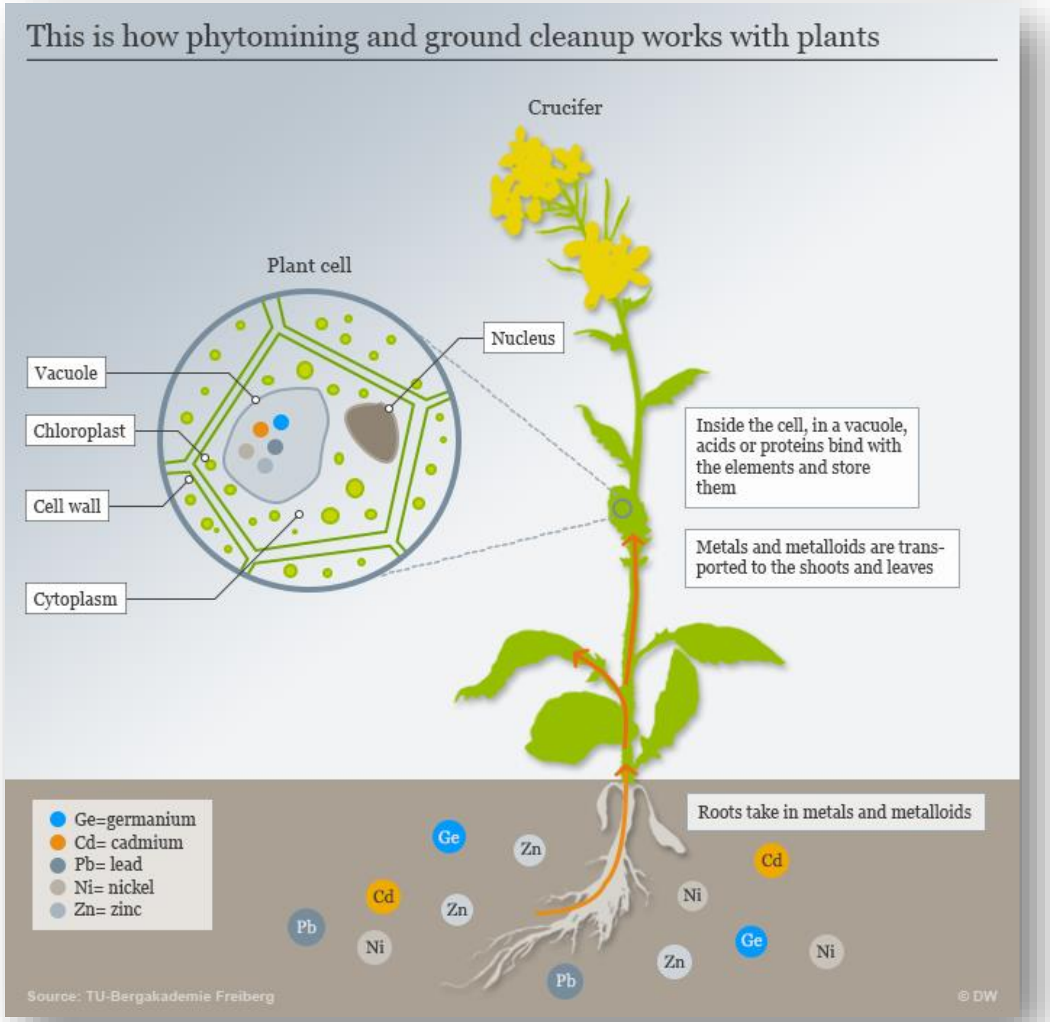

Phyto-mining

Phyto-mining is a relatively new and rapidly developing technology that can be used to extract metals from waste and soil by using two types of plants – hyperaccumulators (phyto-mining) or fast-growing species that accumulate a large amount of biomass (agromining).

Although it is still a pioneering direction, the phyto-mining of metals will give the opportunity to realize the additional potential of mining waste exploitation, which is uneconomically profitable by applying conventional methods.

Bonus: Helps clean up contaminated soils

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Chapter III

Methodology for assessment of restoration processes in restoration areas

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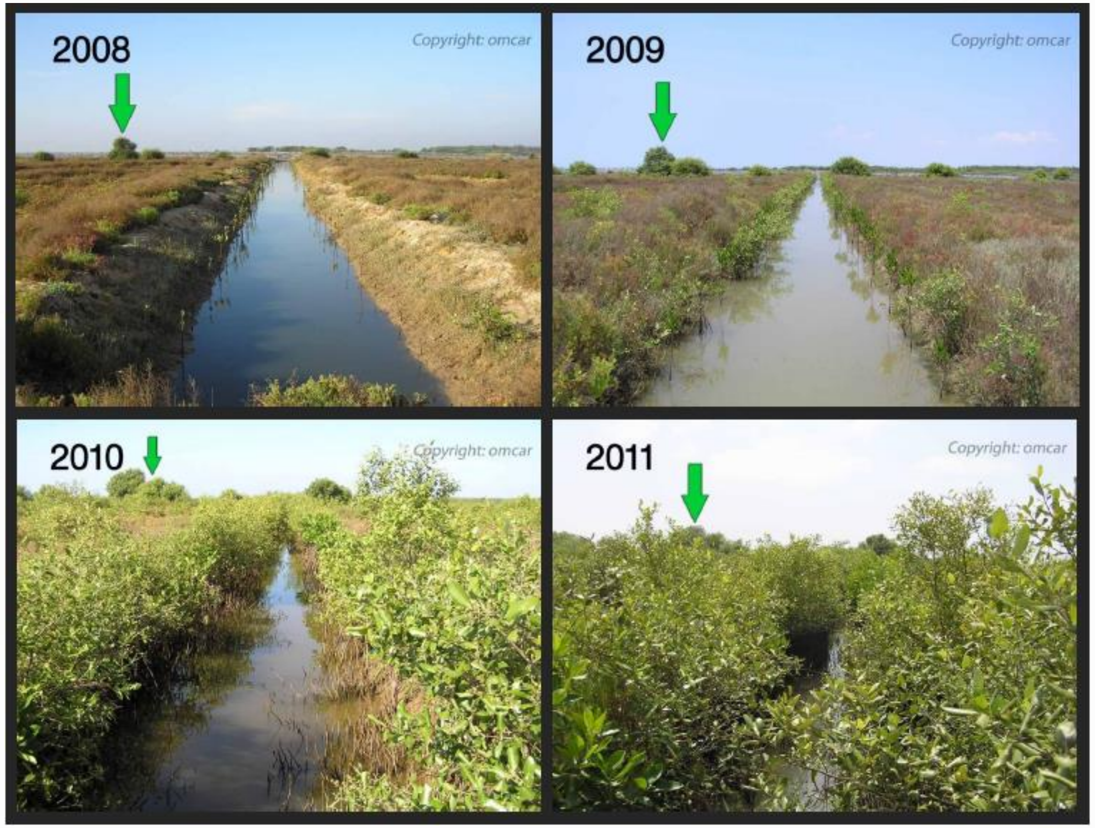
Assessment of restoration processes in recultivated terrain

Two approaches

In the literature, now, two main approaches are known for assessing the success of the restoration of disturbed ecosystems:

- the first is by comparison with a selected reference object (terrain) near the evaluated terrain or an analogical one (which is in the same ecological conditions, but is not affected by mining)
- the second is by assessing restoration processes that concern ecosystem services and ecosystem sustainability through criteria/scales.



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Methodology for assessment of restoration processes in restored areas

Reference object	Recovery indicators
Located near the research site.	Soils
Exposed to the same environmental factors as the research object.	Microflora
Similar features to the studied object.	Lack of threats

- Formation of soil profile
- Layer of accumulated dead forest cover
- Clay fraction
- Humus content
- Nitrogen content
- Content of absorbable phosphorus and potassium
- General microflora
- Microflora composition
- Mineralization coefficient
- Heavy metal and metalloid contamination
- Salinization
- Acidification

Data on recovery indicators is collected from the reference object. This can be done through sampling or through databases (monitoring of the Companies, large-scale monitoring, etc.)

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Methodology for assessment of restoration processes in restored areas

Gathering data about the state of the reference object

Sampling and follow-up testing → Laboratory testing → Statistical data processing → Reference value of the object

Database → Collecting reliable information - monitoring of the Companies, large-scale monitoring, etc. → Statistical data processing → Reference value of the object

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Reference value - the average value regarding the studied indicator in the reference object after statistical processing.

Methodology for assessment of restoration processes in restored areas

Assessment of the recovery processes.

Soils

Microflora

$$\text{Coefficient of restoration} = \frac{\textit{Value of the indicator in the studied object}}{\textit{Reference value of the object}}$$

Lack of threats

$$\text{Coefficient of threat} = 1 - \frac{\textit{Value of the indicator in the studied object}}{\textit{Reference value according to regulations}}$$

The maximal result we can get when applying the formula is 1, and the minimum is 0. If the value of the coefficient exceeds 1, then it is equated to one, and values lower than 0 are equated to zero.
The closer the value is to 0, the greater the threat is according to the corresponding indicator.

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Methodology for assessment of restoration processes in restored areas

Coefficient of restoration

Coefficient of threat

Rcovery card						
Site		....				
Indicator		**Soil layer**	**C I (0.1)**	**C II (0.2-0.4)**	**C III (0.5-0.8)**	**C IV (0.9-1.0)**
Soil	Soil profile					
	Leaf litter					
	Clay content					
	Humus content	surface				
		subsurface				
	Content of Total N	surface				
		subsurface				
	P_2O_5 content	surface				
		subsurface				
	K_2O content	surface				
		subsurface				
Microflora	General microflora	surface				
		subsurface				
	Bacilli	surface				
		subsurface				
	Non-spore-forming bacteria	surface				
		subsurface				
	Mold fungi	surface				
		subsurface				
	Actinomycetes	surface				
		subsurface				
	Bacteria assimilating mineral nitrogen	surface				
		subsurface				
	Mineralization coefficient	surface				
		subsurface				
lack of treats	Contamination with heavy metals and metalloids	surface				
		subsurface				
	Salinization	surface				
		subsurface				
	Acidification	surface				
		subsurface				
Total number of restored parameters						
Recovery category						

- Class I (C I) - The coefficient value up to 0.10;
- Class II (C II) - The coefficient value 0.20 - 0.40;
- Class III (C III) - The coefficient value 0.50 - 0.80;
- Class IV (C IV) - The coefficient with value 0.90 - 1.00.

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Methodology for assessment of restoration processes in restored areas

Rcovery card						
Site		....				
	Indicator	Soil layer	C I (0.1)	C II (0.2-0.4)	C III (0.5-0.8)	C IV (0.9-1.0)
Soil	Soil profile					
	Leaf litter					
	Clay content					
	Humus content	surface				
		subsurface				
	Content of Total N	surface				
		subsurface				
	P_2O_5 content	surface				
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	Actinomycetes	surface				
		subsurface				
	Bacteria assimilating mineral nitrogen	surface				
		subsurface				
	Mineralization coefficient	surface				
		subsurface				
lack of treats	Contamination with heavy metals and metalloids	surface				
		subsurface				
	Salinization	surface				
		subsurface				
	Acidification	surface				
		subsurface				
Total number of restored parameters			26	25	15	11
Recovery category			Class II - Initial stage of restoration			

70% of indicators

Class I - Disturbed area	Class II - Initial stage of restoration	Class III- Advanced stage of restoration	Class IV - Restored area

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Thank you for your attention!

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