Book of abstracts

Forest and landscape restoration of post-mining sites

International conference 3rd – 6th of June 2021, Prague

Charles University Environmental Center

Book of abstracts from 3rd International Conference Forest and Landscape Restoration of Post-mining Sites held 3. - 6.6.2021 in Prague

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Youtube stream Day 1: https://youtu.be/JSJXZ9AU7Ws

Youtube stream Day 2: https://youtu.be/TvJBuA-SN5c

Microbial biodiversity of different aged contrast post mining soils of the Russian North-West

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The post-technogenic ecosystems of quarry-mining complexes of various age and different types of heap mineral materials have been investigated in terms of initial soil formation rate, soil chemical properties and taxonomy composition of microbiome. The study was conducted on the the quarry and mining complexes of the North-West region of the Russian Federation, which is of particular interest, since extremely intensive mining took place here, mainly in an open mining and resulted in formation of various heaps. Two contrast chronoseries (acid sand vs limestones) were studied. The chronoseries of Podzols, formed on different aged heaps of fluvioglacial sands showed sharp differentiation of soil microbiome, both with age and within soil horizons. Thus, the copiotrophic microorganisms were dominant on very initial stages, while oligotrophic ones appeared on the stage of soil profile differentiation to O, E and B layers. This fact indicated that soil ontogenesis is accompanied by the development and diversification of microbial community in fast models of soil regeneration. A different trend was observed in the case of chronoseries of soils developing on limestone containing heaps. The initial set of OTUs for the entire soil formation period remains unchanged, forming more than 98 % of the total microbiome at each time point. This can be explained by the fact that at the initial stage of soil formation, the initial mineral material is inoculated with the entire set of microbiome transferred from neighboring reference areas of the soil, probably by aerosols. At the same time, soil profile differentiation rate is low, there is no leaching and changing of chemical properties of pedo environment within the time. As a result, soil microbiome stay stable during 70 years of ecogenesis.

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Lessons learned from an agricultural post-mining chronosequence on microbial stoichiometry and organic matter formation

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Key challenges in soil science are to understand what drives shifts in soil fertility and limits the effectiveness of soil organic carbon (SOC) storage. We investigated shifts in soil microbial stoichiometry (Cmic:Nmic:Pmic) and microbial maintenance respiration (i.e. metabolic quotient, qCO2) along a nutrient gradient in soils from a 52 year space-for-time chronosequence of reclaimed agricultural land after brown-coal mining. Land reclamation produced loess soils of initially low (0.2 %) SOC. Consecutive agricultural land management led to a gradual recovery of SOC contents. Our data revealed sudden shifts in microbial stoichiometry and metabolic quotient with increasing SOC at a critical value of 1 % SOC. As SOC increased, microbial C limitation decreased, whereas N limitation increased. Simultaneously, metabolic quotient strongly decreased until the same critical value of 1 % SOC and remained at a constant low. The microbial fractions of the soil in samples containing <1 % SOC were out of stoichiometric equilibrium and were inefficient at immobilising C due to high maintenance respiration. Increasing SOC above the threshold value shifted the soil microbes towards a new equilibrium where N became growth limiting, leading to a more efficient acquisition of C. The shift in microbial N limitation was preluded by high variation in microbial biomass N in soils containing 0.5-0.9 % SOC indicative of a regime shift between microbial stoichiometric equilibria. Our data may help establishing a quantitative framework for SOC targets that, along with agricultural intensification, may better support feedback mechanisms for a sustainable accrual of C in soils.

Ecorestoration of coalmine degraded lands

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India is the 2nd largest producer of Coal (729 million tonnes) and planned to reach 1 billion tonnes by 2023-24. Unfortunately, more than 94 % of coal produced by opencast mining, which causes massive degradation of ecology and landscape, and produced a unique post – mining sites. Hence, restoration of mine degraded lands is a challenging task to the restoration ecologist. Ecological restoration (ER) now deals with sustainable development, biodiversity conservation, carbon sequestration, improves public perception via Coal Mine Tourism and develops ecoparks. Success of ecological restoration (ER) influenced by technical reclamation (topsoil management, bench height, geo-mining conditions, climate), which is highly cost intensive but it must foster the "building the cradle for nature". ER starts with development of 3-tier (herbs-shrubs- trees) vegetation cover. The aims of ER will be to produce a better post-mining landscape with improved ecosystem goods and services from previous one. The restored land This lecture would deals with various aspects of ER of coalmine degraded lands in Indian coalmines.

Estimating potential soil water retention using soil physicochemical properties

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In degraded ecosystems, function of soil water retention is reduced compared to the undisturbed ecosystems. To predict key properties regulating soil water retention, we analyzed soil water retention in each pF regimes and soil constituents that are responsible for water retention [organic matter, clay (crystalline clays, allophane + ferrihydrite)], using soil samples from Japan, Thailand, and Indonesia. Soil properties can not predict Van Genucheten parameters except for n value, which increases acutely above sand > 80% threshold. Saturated water content increases with soil carbon content. Soil water retention was contributed by allophane in pF 1.0-2.0, carbon and crystalline clay contents in pF 2.5-3.0, carbon and allophane contents in pF 3.0-4.2, and allophane contents in pF 4.2-7.0. The soil water retention in coal mining site in Indonesia is found to be limited by low organic matter and heavy clayey texture. Amendment of sand and organic matter, as well as biological activity that promotes aggregate development, is required to improve soil water retention in Indonesian mining sites.

Changes of root microbial populations of natively grown Bothriochloa ischaemum and Typha angustifolia during natural attenuation of V–Ti magnetite tailings

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Mine tailings contain high levels of toxic metals and the root-associated microbial populations of the native plants grown in the mining region are poorly understood. The objectives of this study were to show the changes of root microbiota of two native plants during natural attenuation of abandoned V–Ti magnetite mine tailings, and to investigate the potential of using these plants for bioremediation purposes. In the present work, we found that the two dominant plant species, i.e., Bothriochloa ischaemum and Typha angustifolia, were able to increase available nitrogen in the rhizosphere soil of the V-Ti mine tailings by 23.3 % and 53.7 % respectively. The translocation factors (TF) for both plants indicated that B. ischaemum was able to accumulate Pb (TF = 1.212), while T. angustifolia was an accumulator of Mn (TF = 2.502). The microbial community structure was more complex in the soil associated with T. angustifolia than with B. ischaemum. The presence of both plants significantly reduced the population of Acinetobacter. Specifically, B. ischaemum enriched Massilia, Opitutus and Hydrogenophaga species while T. angustifolia significantly increased rhizobia species. Multivariate analyses revealed that among all tested soil variables Fe and total organic carbon (TOC) could be the key factors in shaping the microbial structure. The putative functional analysis indicated that the soil sample of B. ischaemum was closely associated with nitrate/nitrite reduction-related functions while that of T. angustifolia was rich in nitrogen fixing functions. These results indicate that these native plants host a diverse range of soil microbes, whose community structure can be shaped by plant types and some soil variables. It is also possible that these plants can be used to improve soil nitrogen content and serve as bioaccumulators for Pb or Mn for the phytoremediation of the V-Ti mine tailings.

Visible examples of restoration of post-mining sites in India

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The history of mining for precious minerals dates back to several centuries. Mining is important for economy but causes environmental contamination. However, mine waste reclamation and mine environment cleanup, is a subject of recent origin focusing various aspects of bio-geo-technologies. In general, the subject of environmental remediation is about three decades old and today the advances in this field are capable of handling a variety of toxic waste. Different strategies and approaches are employed to render mine waste less toxic. Mining had negative effects on natural resources (biotic and abiotic) and deteriorate the quality of environment. Different types of mine industries are implicated in promoting “Industrial deserts” or “Lunar scapes” which are over loaded with technogenic waste. Soil washing and cleaning in such situation is cost prohibitive. This lecture would deal with reclamation of mine waste with special reference to visible examples from India.

Ecological factors of the biotope and ecological rehabilitation of Jiu Valley tailings dumps

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The activity of extracting coal in the Jiu Valley resulted in sterile material, which is stored in dumps, which occupies an area of over 200 ha of land. The tailings dumps are located on the valleys near the mining operations or near the precinct. Due to the height and exposure on the slopes, the naturally installed vegetation developed differently from the microclimatic conditions. The paper aims to make a correlation between the ecological factors of the biotope and the species that will be used in the ecological rehabilitation of tailings dumps.

Comparison of physical and chemical properties of soils formed under 22 different tree species on a 50 – year – old forest reclamation site in the Czech Republic

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In the Czech Republic, coal mining was, and still is, a very important part of the national economy. Ever since a Mining Act was introduced in 1957, organizations with granted mining permissions have been legally bound to perform restoration work after the mining ceased. Antonin, located in the Sokolov mining district, is an area that was experimentally afforested in the period 1968-1972 with multiple tree species. Undisturbed soil samples were taken approximately 50 years later (in 2018) from the A horizons formed under homogenous tree stands made out of 22 different tree species, both native and introduced (10 broadleaved, 12 coniferous). Samples were analyzed in the laboratory for determination of bulk and specific density, porosity, water retention capacity, pH, soil oxidizable carbon (SOC), total carbon, nitrogen and sulfur content, heavy metals & plant available nutrients. Some of the species that have shown a combination of properties that are generally considered favourable were maples (Acer pseudoplatanus & A. platanoides), Scots elm (Ulmus glabra), pear (Pyrus communis) and small-leaved linden (Tilia cordata). On the contrary, hornbeam (Carpinus betulus), Weymouth pine (Pinus strobus) and Scots pine (Pinus sylvestris) have shown a significantly less favourable combination of physical and chemical soil properties.

Tree species as main drivers of afforested post-mining sites restoration

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A common method of reclamation for post-mining sites is afforestation aimed at creating a whole forest ecosystem. Trees are great forest ecosystem promotors and lead to the establishment of favorable conditions for colonization by forest-specific species. The main aim of the study was to assess the effect of tree species on the herbaceous layer, especially its diversity and aboveground biomass. The study was conducted on 227 randomly selected research plots in seven types of forest stands: pure with Alnus glutinosa, Betula pendula, Pinus sylvestris, Quercus petraea and Robinia pseudoacacia, and mixed with dominance of Acer pseudoplatanus or Betula pendula evenly distributed on a reclaimed, afforested post-mining spoil heap near Bełchatów Brown Coal Mine. Herb layer was composed mainly of synanthropic species (over 70 %) and was clearly related to the overstory tree species composition of forest stands. The diversity of herb layer species is divided into two contrasting groups connected with overstory composition: first group – Betula pendula, Pinus sylvestris, Quercus petraea, and mixed stands with dominant Betula pendula; and second group – Alnus glutinosa, Robinia pseudoacacia, and mixed stands dominated by Acer pseudoplatanus. In the case of the aboveground herb layer biomass the type of forest tree stand was also the best predictor. The mean aboveground biomass was significantly higher (nearly four times) under canopies of A. glutinosa, R. pseudoacacia, B. pendula and Q. petraea, in comparison to the herb layer biomass under canopies of P. sylvestris and mixed with A. pseudoplatanus. Our data revealed that tree species composition is a key factor shaping site conditions beneath forest stands and – as a consequence – herb layer species composition and biomass despite initial habitat variability on the spoil heap. Despite diverse primary site conditions, the canopy tree species composition was a crucial factor, which explains observed spontaneous differentiation of herb layer composition and biomass.

Effect of tree species on carbon, nitrogen, and phosphorus stock and their relationships under reclaimed mine and reforested post-fire soil regeneration scenarios

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This study aimed to compare the impact of Scots pine, common birch, and black alder on the C, N, and P stock and stoichiometry in soils at post-mining sand pit and post-fire sites. These results were compared to undisturbed soils. Soils at the post-fire site had similar Cstock and Nstock to those of the undisturbed sites, while those at the post-mining site had lower Ctstock and Ntstock. Tree species had a stronger impact on Cstock in the young (post-mining) soils, in which there was higher Cstock under pine and alder than birch. Tree species also affected the redistribution of Cstock between the organic and mineral soil horizons. Compared to the other tree species, pine was characterized by a higher Cstock in the Oi + Oe horizons at the post-mining and undisturbed sites. In the 0–5-cm horizons, a higher Cstock was detected under alder at the post-mining site and under birch and alder at the undisturbed site. The C:N ratios of the Oi + Oe horizons increased in the following order at all studied sites: alder < birch < pine. This trend only transferred directly into the 0–5-cm horizons of the undisturbed sites. The highest C:P and N:P ratio values were detected in the 0–5-cm horizons of the post-fire site, which indicates a P deficiency. Moreover, alder adversely affected the C:P and N:P ratios in the regenerated and undisturbed soils. The stoichiometric ratios indicate that alder may have had a stronger effect on P immobilization than pine and birch—especially at the post-fire site. However, this phenomenon was not observed in undisturbed soils. This suggests that the influence on soil C and N accumulation, as well as the stoichiometric ratio values of elements, should be considered when introducing N fixers to disturbed sites as phytomelioration species.

Humus layer development under various tree monocultures on a post-mining spoil heap

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Postindustrial lands occupy many local areas, however, in total their area achieves a significant extent. Their biological restoration is extremely difficult due to the initially soilless substrates. Thus, the reclamation activities aim at soil substrate enrichment, to create biological *perpetuum mobile*. After all, soil is the crucial element of newly established ecosystems on degraded landscapes. We aimed to compare the humus layer development under canopies of various forest monocultures on a reclaimed spoil heap of the Bełchatów Lignite Mine (Central Poland), with reference stands on adjacent forest sites. We investigated a set of physicochemical properties of the A horizon. A set of 43 soil pits were excavated in five different tree species stands. All tree stands were divided into three groups according to their ecological properties: Pinus sylvestris, nitrogen-fixing – *Alnus glutinosa* and *Robinia pseudoacacia*, and other deciduous – *Betula pendula* and *Quercus robur*. We found that soil characteristics connected with fertility were higher in forest compared to postindustrial sites. However, the differences were clearly visible mostly in Scots pine stands. There was no such distinct trend under N-fixers and other deciduous. Soil properties linked with soil structure and water capacity reflected a similar lack of specificity to habitat type in these two ecological groups. Again, the significant differences between habitat types (without unequivocal trend) were noted in Scots pine stands. The A horizon thickness was generally greater in forest than postindustrial sites and also in N-fixers than in other groups in both habitats, however, the differences were statistically insignificant. Moreover, A horizon depth was not significantly correlated with other features studied. The differences in A horizon physiochemical properties between habitat types were the lowest for N-fixers, followed by other deciduous and Scots pine stands. It indicates that deciduous species stands, especially N-fixers, are the best fertilizers in reclaimed areas.

Landscape dynamics in two regions under influence of the bauxite mining in Minas Gerais – Brazil

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The landscape analysis is an important tool used to manage, monitoring, conservation and to take decisions, mainly when related with degraded areas, which are more propitious to effects or external pressure agents that cause disturbances. In this sense, this study evaluated the dynamic of the soil use and coverage in two regions under influence of mining activities. These regions are located in Minas Gerais state, more specifically in the municipalities of São Sebastião da Vargem Alegre and Miraí (R1) and Descoberto (R2), both located in Zona da Mata Mineira. The image classification was done using ArcGis 10.2® which used satellite images from TM/LANDSAT 5 for the years 1985, 1995, 2005 and from MSI/SENTINEL-2 for 2016. As results, was verified the dominance of pasture areas in both regions and years evaluated, besides a trend to increase the forest areas and decrease the livestock areas mainly in the last years. Thus, we can conclude that, taking into account the landscape scale, the mined areas not affect the process of forestal advance in both evaluated regions. On the contrary, the mining results in the increase in the forest cover in both regions due environmental compensation with planting of regional native species as well as creation of one Private Natural Heritage Reserve (PNHR): ″Boa Esperança Farm″, located in region 2.

From spoil to soil: utilizing waste material to create soils for mine rehabilitation

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The Latrobe valley in Victoria, south-east Australia, is home of three large open-cast brown coal mines. Due to the nature of the mining operations, there is lack of topsoil to cover the whole area that is to be progressively rehabilitated. This has led to development of artificial topsoil via industrial symbiosis, utilizing waste products from 3 industries, located in the Latrobe valley: mining (overburden, subsoil, waste brown coal and fly ash from the power plant), paper milling and recycling (effluent sewage recovery and recycling waste) and municipal green waste collection (compost). These waste products have been mixed at different ratios and tested in laboratory, greenhouse and field conditions to establish the best type of artificial soil, that has properties suitable for plant growth, is safe for the environment and stable in the long term. If proven suitable, this new concept will not only aid in rehabilitation of large post-mining areas, but will also help in waste reduction. Initial lysimeter experiments revealed that the mixture of overburden and fly ash can mitigate acid mine drainage and immobilize heavy metals. An addition of paper mill waste compost and brown coal increased the content of essential macronutrients which enabled plant growth, however in an initial field trial the plant growth was suboptimal due to high salinity, alkalinity and low rainfall in the months following trial establishment. Replacement of paper mill compost with green waste compost and reduction of fly ash content in the soils has significantly improved the soil chemical properties and supplied additional nutrients which boosted plant growth. Preliminary results from a current field trial are showing that plant growth in artificial soil is better than in natural topsoil.

Waiting is not enough. Prospect and a safe path can make post-mining forests more attractive

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The goal of this research is to explain why forests growing on post-mining sites differ in their attractiveness and to use this knowledge for a proposition of forest management which can mitigate some of the negative consequences of coal mining. Attractiveness of forests growing on sites of previous mining activity is seriously affected compared to forests that people like to visit. Nevertheless, some of the post-mining forests are in their attractiveness approaching recreational forests; sometimes growing spontaneously on coal mine spoil heaps, sometimes have been planted with conifers on landscaped terrain, but being rather older than younger. In order to explain this variability and to find a pattern we conducted a mediation analysis to test whether the attractiveness of post-mining forests is affected by general visual characteristics that have been found in literature to explain environmental preferences. To do so we conducted an on-line experiment (N = 869) with a within-subject design and photographs of post-mining forests. A sample of the adult population from a post-mining and a control region was invited to participate in the study. We found that different levels of permeability, stewardship, safety, familiarity and perceived naturalness explain the varying attractiveness of individual types of post-mining forests. While some of these visual characteristics change by themselves with the increasing age of the forest (e.g. permeability and perceived safety), others do not and require targeted after-care (e.g. perceived stewardship). In any case our results are promising in that they imply that the recreational value of post-mining forests may further increase. In conclusion, the attractiveness of post-mining forest is in principle governed by the same rules as the attractiveness of other natural environments (e.g. Gatersleben & Andrews, 2013) and the prospect-refuge theory (Appleton, 1975) still provides a powerful theoretical framework.

The Chicken Creek Catchment: a landscape scale approach on minesite restoration

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The Chicken Creek catchment was constructed in the Lusatian mining area as a research platform to study initial ecosystem development at the landscape scale. The 6 ha site was formed as a hillslope with 2 to 3.5 % inclination. Up to 3.5 m of Pleistocene sands were dumped as an aquifer on top of a 1-2 m clay layer. The construction process using large-scale mining machinery resulted in slight differences in substrate properties in different parts of the catchment reflecting the natural variation in overburden material that was used for aquifer construction. After completion of the construction in 2005, a cross-disciplinary long-term monitoring program was initiated to record major environmental parameters adapted to the development of the site. No amelioration, fertilization or planting was carried out to allow for primary succession. Especially during initial stages of young ecosystems, the geodiversity of a site or landscape may have a lasting impact on dominating abiotic feedback mechanisms that set the stage for further ecological development. During its first 15 years, the Chicken Creek experimental catchment showed a very dynamic development. Whereas the abiotic geosystem of the first 2-3 years was characterized by heavy erosion and sediment transport, primary succession by invading vegetation and the unexpected formation of soil crusts within only a few years resulted in biotic-abiotic feedbacks that controlled catchment hydrology. Time series of environmental data recorded since 2005 revealed that the geodiversity of the initial site affected a number of both abiotic and biotic processes (e.g. surface runoff, erosion intensity, top soil development, colonization by plant functional traits, soil moisture, groundwater patterns, formation of biological soil crusts). Our data indicate that even minor variations in initial substrate characteristics (e.g. texture) and stochastic single events like thunderstorms can have lasting impacts on the geomorphological, hydrological and biological development of the catchment.

Tree and shrub species grown on post-mining sites as source of biomass for bio-based industry

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Reclamation sites in East-Germany are characterized by very sandy substrates being almost free of organic matter, with extremely low nutrient contents and an annual precipitation of only 570 mm and lower. To enhance the value of such marginal lands for a future regionally based bioeconomy the EU funded BeonNAT project plans the plantation of regional tree and shrub species. The obtained forest biomass will be used for the production of biodegradable bio-based products and bioactive compounds that will play an important role to replace fossil-based competing substitute products. Field trials in different European countries will be established to test the benefit of intercropping/mixed-forest in marginal cultural land versus the natural growing/monoculture. In Germany, one test site is located in the post-mining sites of Lusatia. In this field trial the biomass development, the impact on soil fertility and biodiversity will be investigated after planting Robinia pseudoacacia and Rubus fructicosus.

Herbaceous vegetation development under planted woody species contribute to ecosystem recovery in tropical coal mined spoil, India: A case study

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Opencast mining for the extraction of coal and minerals replace the existing vegetation with vast deposits of mine waste known as overburden dumps and cause a significant loss biologically and pedologically. Natural recuperation of mined ecosystems is a time-consuming process; therefore, ecosystem recovery on mined spoils is often triggered through artificial succession. Herbaceous vegetation acts as an indicator of site conditions and contributes to ecosystem development on derelict mined spoils through organic matter enrichment. However, the role of herbaceous species in ecosystem recovery on these degraded sites is less explored yet compared to their woody counterparts. In this case study, we investigated the structure and function of herbaceous vegetation beneath four planted woody species, i.e. Albizia lebbeck, Albizia procera, Tectona grandis, and Dendrocalamus strictus of ages 5 and 17. A total of 44 species of herbaceous plants belonging to 14 families were recorded across all ages of all plantation stands through phytosociological study. Canopy cover of all planted woody species of both ages exerts a strong exponential relationship with species richness and evenness. Total biomass of herbaceous layer amongst plantation stand of all species decreased from 980.67-1487.33 g m-2 at 5th-year age to 273.00-1283.33 g m-2 at 17th-year age of plantation stand. They indicated a negative effect of increasing canopy development of the all planted woody species with age that substantially affected herbaceous biomass and their reconstruction. Woody species with open canopy architecture tend to yield higher herbaceous biomass as compared to closed-canopy species. Further studies are more warranted to get an in-depth understanding of the roles of herbaceous vegetation in reclamation improvement of degraded mined sites.

Ecological restoration of degraded mined habitats: Opportunities and challenges in 21st century

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Significant areas of land worldwide have been degraded due to unprecedented mining operations for extracting natural resources such as coal and minerals. The situation is quite alarming in the tropical areas where coal and minerals are shallowly deposited and host a vast level of biodiversity. Coal resources might be a part of energy generation and power the economics of many countries worldwide but a vital source for India. Therefore, excessive mining to meet the rising energy demand has resulted in deforestation, loss of biodiversity, and ecosystem degradation. Establishing the natural vegetation on mined spoil through the natural process may take a long time due to hostile soil conditions for microbial and plant growth, low soil seed bank and rootstocks, and soil profile disturbance. However, the ecosystem recovery on degraded mined spoils can be hastened by planting desirable woody species and herbaceous development. The selection of tree species is equally essential for reclamation efforts as all woody plants cannot withstand the hostile environment. Vegetation development may contribute to faster ecosystem recovery by improving soil physical and chemical environment. Further, vegetation has an excellent ability to ameliorate microclimatic understory conditions for developing litter and humus layers. Many efforts have been undertaken to understand the carbon sequestration potential of planted degraded lands since they can play an essential role in offset CO2 emission. In the present case study, an effort has been made to summarize the available information on ecological restoration of coal mine spoiled lands. Furthermore, we envisaged in light of the existing research gaps, management options, and development priorities to restore degraded mined habitats to gain all new ecosystem services in a dry tropical region of India where it was before mining.

Evaluation of the phytostabilization potential of tree species occurring on the Copper Tailings Dams of the Copperbelt Province in Zambia

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Mine tailings dams present major environmental problems globally. Restoration of these metalliferous sites via phytostabilization presents a cost effective and efficient way of restoring the sites. Screening native tree species occurring on copper (Cu) tailings dams of the Copperbelt province in Zambia is vital for their restoration. The current study evaluated the potential of 32 native tree species from 13 families occurring on the tailings dams for phytostabilization potential of Cu, Co, Zn, Al, S, B, Cd, Cr, Ni, Mn and Mo. The study employed the use of the bioconcentration factor (BF) and translocation factor (TF) to evaluate the heavy metal accumulation strategy of tree species growing on Copperbelt tailings dams. Six of the 32 species showed dominance in the following sequence, Rhus longipes (IVI) (15.985 ± 3.428) > Syzygium guineense (13.316 ± 5.093) > Senegalia polyacantha (8.642 ± 3.822) > Ficus craterostoma (8.201 ± 2.069) > Albizia adianthifolia (6.477 ± 0.925) > Bauhinia thonningii (6.451 ± 3.032) > Combretum molle (5.106 ± 2.334). Heavy metal concentrations as well as the BF and TF varied from species to species with most species having BF and TF < 1 for various heavy metals. Significant differences were observed in heavy metal accumulation by roots and shoots. Out of the 32 studied species, the results suggest that 25 species (Albizia adianthifolia, Albizia antunesiana, Albizia versicolor, Azanza garckeana, Bauhinia petersiana, Bauhinia thonningii, Brysocarpus orientalis, Combretum apiculatum, Combretum molle, Combretum microphyllum, Dichrostachys cinerea, Diospyros mespiliformis, Dodonaea viscosa, Ficus capensis, Ficus craterostoma, Ficus sycomorus, Peltophorum africanum, Phyllanthus guineensis, Rhus longipes, Senegalia polyacantha, Senna singueana, Syzygium guineense, Terminalia mollis, Terminalia stenostachya and Vachelia sieberiana) have potential for phytostabilizing Cu contaminated sites.

Development of Comprehensive Soil Quality Index (CSQI) for suitability ranking of plant species used for reclamation in coal mine degraded land

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Research highlights: (1) Evaluation of reclamation success is not only influenced by the type of plant species used for revegetation approach but also their ameliorative effect on mine spoil. (2) A comprehensive soil quality index (CSQI) is developed for screening the suitable plant species to achieve sustainable reclamation. Background and Objectives: Screening of appropriate plant species is mandatory for sustainable and successful restoration of post-mining derelict landscape. The degree of recuperation of rhizospheric mine soil quality by mixed plantation approach acts as an important pioneer for selecting most suitable plant species amongst them. The objective of this lab-scale experiment was to evaluate efficiency of revegetation towards Technosol development. Materials and Methods: A field study was carried out in the 25-years old afforested post-mining site to collect rhizospheric soil samples from four different plant species growing on the reclaimed overburden (OB) dump of Singrauli coalfield, India. The physico-chemical and biological properties of collected soil samples were assessed and based on these soil characteristics, principal component analysis (PCA) was employed to develop CSQI for estimating suitability ranking of species. Results: The most significant properties derived from PCA that control the health and quality of reclaimed mine soil (RMS) are soil organic carbon (SOC), moisture content, nutrient content (N, P, K), coarse fraction, dehydrogenase activity (DHA) and available nitrogen. The CSQI values were validated with vegetation characteristics (canopy cover, diameter at breast height, tree height, reletive density) for each species. Plant species having highest CSQI values could be suggested for sustainable reclamation of mine derelict ecosystem. Based on the CSQI values, leguminous plant species like Cassia siamea, Dalbergia sissoo seems in present study to be most suitable for effective biological reclamation. Conclusions: Screening of suitable plant species for revegetation, thus had diverse impacts on rhizospheric soil quality which could determine trajectory towards self-sustainable and successful reclamation.

Verification of the suitability of woody plants for forest reclamation in the area of the Sokolov coal basin

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In the 1970´s, no information was available on the suitability of individual tree species for successful forest reclamation in the Sokolov brown coal district, and therefore it was decided to establish a large research area to verify the suitability of tree species for reclamation purposes at the internal dump of the Antonín mine located in the Sokolov coal basin. Overburden deposition on the inner dump of the Antonín quarry was completed in 1969. The technical reclamation of the dump was completed in 1972 and, subsequently, forest reclamation was carried out, and completed in 1974. The total reclaimed area of the dump is approximately 165 ha. By 1974, according to historical records, a total of 98 taxa and cultivars of woody plants and shrubs were planted at the Antonín dump, of which 27 were taxa of coniferous trees and 71 taxa of deciduous trees. Planting of trees was carried out in the form of monocultural or mixed stands, or individually mixed tree species in these stands. Part of the reclaimed areas (13 %) was left to spontaneous natural succession. In the years 2017 to 2019, a comprehensive inventory of woody plants and their stands was carried out in the area of the Antonín dump in order to evaluate the suitability of individual woody plants for forest reclamation in the Sokolov region. The inventory defined a total of 473 invidual monocultural or mixed areas of forest stands. The inventory documented the presence of 19 taxa of coniferous trees (70.3 % of the declared taxa planted between 1972 and 1974) and 41 taxa of deciduous trees and shrubs (57.7 % of the declared planted species). The inventory also included an evaluation of the health status of surviving tree taxa and an evaluation of their suitability for forest reclamation in the Sokolov coal basin

Monitoring of restored sites using airborne LiDAR and hyperspectral data

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Monitoring of restored sites is required to gather ecologically meaningful data that can provide objective and quantitative measures of the restoration success. This in practice includes monitoring of particular habitats (e.g. water bodies) or species diversity of various taxa. Many studies evaluated the effect of habitat heterogeneity on the diversity of species on restored sites, however, the environment in such studies is usually represented by semiquantitative or categorical measures only (e.g. by rough subjective estimates of vegetation cover). Moreover, these measures are usually spatially and temporarily limited as monitoring of habitats and their attributes is extremely time demanding. Although a direct field survey can provide valuable information, it is unsuitable for repeated monitoring due to both labour intensiveness and limited informative value of subjective estimates, especially where exact habitat location and detailed characteristics are needed. Airborne remote sensing data represent efficient and cost-effective sources for developing indicators relevant to the large-scale decision making and developing effective management tools that will maintain high biodiversity of species and habitats on restored sites. Here, we examined (1) how the vegetation structure and old senescent vegetation derived from LiDAR and hyperspectral data predict species richness and rarity of bird communities colonizing restored habitats; and (2) the possibility to integrate LiDAR and hyperspectral data to classify open surface water bodies. Our findings demonstrate that indicators derived from LiDAR and hyperspectral data play an important role in bird species diversity on restored sites and can be also used for identification of small water bodies. Airborne remote sensing, particularly laser scanning, should constitute an integral part of restoration success assessment and should be acquired with reasonable repetition rate (e.g. 5–10 years), as the information derived from such data can be more easily implemented in management actions than subjective measures collected during intensive fieldwork.

On The Role of Redox-Promote Dissolution Processes in Reforested Surface Mine Soil

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Ubiquitous to the source material used as soil in reclamation of surface coal mine sites in the Appalachian region, acid-generating materials such as sulfur-bearing minerals (e.g. pyrite) dominant weathering and initial soil chemical and soil development processes. In this study we point to the, sometimes overlooked, role of redox-promote dissolution processes in the development of surface mine soil and their impact on soil water chemistry and composition. Reforested research plots (each ca. 2 acre in size) were constructed using weathered ('Brown') and non-weathered ('Gray') sandstone rock fragments as topsoil replacement material, with/out compaction. The plots were instrumented with shallow (30 – 80cm) soil water sampling devices and solution composition was monitored for three years, 15 years after reclamation. The research site is located in the Appalachian southern coalfields in West Virginia USA, and results of soil water chemistry from the 3-year monitoring study are discussed. High levels of total dissolved solids (up to 1700 µS/cm) were inversely related to redox potential, peaking as solution pH shifted towards circumneutral values. Period of extreme dry conditions led to a sharp decrease in soil moisture and pH (from 5.85 to 4.26), subsequently increasing solubility of elements of environmental concern (e.g. Al, Co, Fe, Mn, Ni, Zn). Results are discussed with respect to potential inherent vulnerability of the redox-ladder's terminal electron acceptors (TEA) pools and fluxes (e.g. NO3, Fe/Mn oxides) in such soils, and amid availability of others TEA pools and fluxes (i.e. SO4), poor soil moisture buffering, as well as the increase in frequency and intensity of extreme weather events.

Pure or mixed stands? Response of soil Gamasina and Uropodina mites to habitat type and litter decomposition on reclaimed post-mining land and adjacent forest sites

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Soil, or rather a soil substrate, on post-mining areas, e.g. external spoil heaps, differs from forest soil by many physical, chemical, and biological properties and characteristics. However, these disturbed sites may be a potential habitat for many soil animal species, including mites, which are important for soil-forming processes. One of the most numerous soil mite group is Mesostigmata, particularly from Gamasina and Uropodina. Mites from these suborders differ in terms of morphology, habitat requirements, and life strategy, including feeding and reproduction. Our aim was to recognize the relationship between Gamasina and Uropodina mites in relation to litter of various tree species within the stands growing on two contrasting habitat types, i.e. on a reclaimed post-mining area and adjacent forests. The litterbag experiment was conducted on the external spoil heap of the "Bełchatów" lignite mine and adjacent stands growing on forest habitats. The litter decomposition experiment was conducted for five years. We found that mean abundance of Gamasina mites differed between the habitat types and 14 tree litter types studied. Interestingly, Uropodina mites differed significantly between habitat types, but not between the litter types. Abundance of mites from both suborders differed between the collection days during the ongoing decomposition. Among 14 litter types studied, the highest mean Uropodina abundance was found in Prunus serotina (575.7 ± 668.7; mean ± SD), while Gamasina mites in Ulmus laevis (445.7 ± 279.5) litter. Moreover, the highest mean abundance of Gamasina and Uropodina mites were recorded in birch stands growing on the forest area (653.5 ± 690.3 and 290.0 ± 380.9, respectively), whereas Uropodina mites had an equally high mean abundance in mixed stands on a spoil heap (264.0 ± 406.7). Results of the study supported our assumption that mixed stands on a spoil heap create suitable conditions for Uropodina mites. Their high abundance indicated on a spoil heap may prove the forming stability of the habitats studied.

3D observation and assessment of restored ecosystems on post-mining sites

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There are more and more post-mining sites on the earth. The restoration of the ecosystem and landscape of post-mining sites has received extensive attention. In the past few decades, people have worked hard to carry out ecological engineering on post-mining sites, including terrain remodeling, soil reconstruction, and vegetation reconstruction, but there is a lack of post-investigation and research on the structure and function of the restoration ecosystem. Traditional ground surveys and coarse-resolution remote sensing technologies are difficult to fully reveal the internal structure and functions of the ecosystem. In this research, we try to introduce drones, LiDAR and Hyperspectrometer to realize the three-dimensional observation and assessment of the restored ecosystem on post-mining sites. We tested this idea at an open-pit coal dump in China. Studies have shown that remote sensing technology based on drones can quickly obtain large-scale ecosystem data, and extract a large amount of ecosystem structure and function information, including digital elevation models, vegetation observation models, and digital surface models. Three-dimensional ecological observation can reveal the spatial heterogeneity of the reconstructed vegetation in the horizontal and vertical directions, and can also reflect the functional characteristics such as vegetation photosynthesis and nitrogen fixation. At the same time, we found that different initial vegetation combination patterns affected the succession process of ecosystem structure and function. Based on three-dimensional ecological observation, we have developed a spatially explicit vegetation structure optimization method. In general, three-dimensional ecological observation can help people better plan, manage, assess, and optimize the restored ecosystems on post-mining sites.

Overcoming arrested succession on reclaimed surface mines of the eastern USA

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Coal mines in the eastern USA that were reclaimed between 1977 and 2010 were commonly compacted tailings planted with non-native grasses and legumes. Natural succession on these sites is greatly delayed with limited tree and shrub establishment even after 30 years, in contrast to other disturbance types on which forest naturally establishes and closes canopy in 10-15 years. Tree planting efforts generally fail due to compacted soils, competitive herbaceous vegetation, and browsing by wildlife. We reduced soil compaction on 10 ha in 2015 and another 9 ha in 2017 by using a subsoiler to loosen soils to a depth of 1.2 m. A variety of native trees and shrubs were planted on a 2.4 by 3 m spacing. To re-establish native herbaceous species we tested two seed mixtures along with unseeded control plots in 2015. In 2017 we tested 9 fast-growing annual species for their ability to replace persistent invasive grasses. On all sites, including unseeded controls, the cover of invasive species decreased to less than 50 % in the first year, and herbaceous vegetation was quickly dominated by native perennials. Planted annual species performed poorly, but many planted perennial species established well and increased the diversity of the site. The probability of browsing damage to planted tree seedlings ranged from low of 6 % for Pinus strobus to high of 64 % for Quercus rubra, and was influenced by herbaceous cover. It appears that the disturbance alone was sufficient to overcome the dominance of invasive species and speed succession on these sites.

Over 40 years of creating novel ecosytems on a smelter-impacted landscape of Sudbury, Ontario, Canada

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Sudbury houses major nickel mining and smelter complexes. The impacts of sulphur gases from roast yards before 1928 through to the more modern smelter operations emitting sulphur gases and metal particulates created a barren landscape of ca 17000 ha and an additional 64000 ha of stunted forest. The accumulation of bioavailable and potentially toxic metal levels in the acid surface soils, accompanied by soil erosion, lack of organic matter and soil nutrient depletion, impeded natural vegetation recovery. The requirement for reduction of emissions (now 97 %) set the stage for an assisted landscape recovery program. Over the past forty plus years the Sudbury Regreening Story, based on effective interaction between community, government, academia and industry, describes the regional transformational program now recognized globally. The Sudbury Method for barren landscape restoration has evolved from regreening activities that involved application of dolomitic limestone, fertilizer, seeding of agricultural grasses, legumes and planting of tree seedling to a more complete biodiverse restoration strategy. By 2020, 3490 ha had received soil amelioration and over 10 million trees and shrubs had been planted for approximately $33.5 million while employing over 4800 individuals over the 40 years. Recently, a chronosequence investigation showed that restoration efforts increased mean total ecosystem carbon at the study sites by 54.4 ± 10.2 Mg C ha-1 or a C sequestration rate of 1.7 ± 0.3 Mg C ha-1 y-1. The continuance of the Regreening Program will help the Sudbury through a Community Energy and Emissions plan to be carbon neutral by 2050. At present VETAC (City Regreening Advisory Panel) is contemplating success or completion criteria for the numerous watershed management units across the City. The outcome of the Regreening Program is a new image for the City of Greater Sudbury that has helped to attract new business enterprises, tourists and encouraged an increased respect for the environment.

Do different tree species have different effects on infiltration and preferential flow? A case study from clayey spoil heap

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Restoration of soil hydrological functions at spoil heaps is important step for the whole ecosystem recovery. This study analyzes effects of different tree species on key infiltration parameter - field saturated hydraulic conductivity (K_s), preferential flow and related soil properties (size and origin of pores, number of earthworms and others). The study was performed in Velká podkrušnohorská spoil heap (near Sokolov, Czech Republic) at reclaimed sites after lignite mining. Examined soils in these sites are developing under three distinctly different tree monocultures (alder, oak, and spruce). For alder topsoil, value of K_s was significantly higher than for oak and spruce sites. For spruce topsoil, the lowest value of K_s was observed. For subsoil, no significant differences in Ks were observed between tree species. For alder site, infiltration tests with dyed water (brilliant blue solution) showed the greatest lateral flow in topsoil, the highest infiltration rate and the highest vertical range of the dyed soil patterns. For subsoil at alder site, dye-stained patches indicated that dominant part of the preferential flow was concentrated in channels around roots and in earthworm burrows. These two biostructures were often connected. Thin soil sections of alder soil show that worm-created structures (namely burrows and casts) significantly contribute to the porosity around the roots (59 % of dyed worm-created structures in root microsite). For oak site, preferential flow along roots started nearly from the surface. Horizontal ranges of dye-stained patches in oak topsoil were smaller than in alder soil. For spruce site, the lowest overall range of preferential flow and the lowest infiltration rate were observed. The largest occurrence of macropores (>300 μm) was observed in alder topsoil. This correspond with the highest number of earthworms at alder site. Soils developing under tested tree species exhibited different infiltration and preferential flow characteristics due to the different effects of trees on pore size distribution and pore connectivity. These effects were caused by their specific root systems and litter qualities. Earthworm activity (determined by character of the litter) strongly influenced pore connectivity and macroporosity.

Impact of Pheidole fallax (Hymenoptera: Formicidae) as ecosystem engineer in rehabilitated coal mine areas

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Pheidole fallax is one the most abundant ants in sites where coal mines have undergone rehabilitation and in forests without mine intervention. The impact that this species may have as ecosystem engineer needs to be assessed. We aimed to test whether P. fallax nests have an effect on soil chemical properties, characterize the organic debris found in the refuse piles, and describe nest architecture as proxy of bioturbation effect. The study was carried out in a coal mine in Colombia, in areas with 16 and 20 years of rehabilitation. Samples were taken from inside the nests, from the external refuse pile, and from a control area one meter away from the nest. The three sample types were subjected to chemical analysis and near infrared spectra (NIRS). Results showed that P. fallax use food resources of different trophic levels, being arthropods and seeds the main items in their diet. The NIRS analysis enabled distinguishing the origin of the sample: refuse pile, interior of nest, or control soil. Samples from the refuse piles of P. fallax had a lower pH and accumulated high contents of Ca + 2, Mg + 2, K + 1, and organic matter, when compared with samples from the other two sites. Nest molds presented an asymmetric architecture, with mean volume ranging from 30 to 105.7 cm3 and an average of 11.8 chambers per nest. The construction and maintenance of nests may play an important role in the reestablishment of ecological processes, such as bioturbation and fertilization in mine restoration scenarios as they may act as “fertility islands”.

Genetic variability and selection pressure influence phenotypic responses to stressful environment as well as bacterial and fungal assemblages in the rhizosphere of balsam poplar

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In a previous study, Populus balsamifera was deemed suitable for mine waste revegetation by initiating a community of microorganisms closer to a functional vegetated ecosystem, increasing soil nutrient content, and improving pH. Even though substrate type was the main driver of rhizosphere microbial community composition, it was shown that plant genotype can act as a selective pressure in structuring rhizosphere microbial communities. In the present study, we assess the effect of genetic variability between Populus balsamifera genotypes on the tree's suitability for mine waste revegetation, by comparing the effect of genetic variability induced by selection pressure and genetic variability in neutral population structure. The distribution of Populus balsamifera across Canada has resulted in three levels of genetic clusters: Western, Central and Eastern. Similarly, the selection pressure occurring on two mine waste storage facilities located in Abitibi (Quebec, Canada) induced genetic variability within the Central cluster, resulting in two new clusters named after the mine sites: Westwood and La Corne Mine. During a greenhouse experiment, at least three genotypes of each genetic cluster were grown in non-amended waste rock (NAWR) from the Westwood site, amended waste rock (AWR) and a control (CTRL) substrate, to assess both the effects of tree genotype, and its belonging to a genetic cluster, on the structure and composition of the rhizosphere microbiome, physicochemical properties of bulk soil and plant growth. Our results show that genotypes originating from the Westwood site were the least impacted by waste rock regarding tree growth. Additionally, tree genotype and genotype's origin have an impact on bacterial and fungal community structure. These results suggest that genotypes selected by the mine site environmental conditions could be better suited for revegetation purposes than genotypes origination from natural settings. A longer-term field study would be needed to validate the results of our short-term greenhouse study.

Evaluation of reclamation success of coal mine sites through soil quality index

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Coal mining has a devastating effect on land and soil quality. The overburden materials possess adverse physico-chemical characteristics and are biologically inactive. The chronosequence approach helps to study the temporal dynamics of pedological characteristics. From the management point of view, it is important to know the time required to develop a self - sustaining forest cover in the post-mining sites. So to evaluate the progress and success of reclamation of the different aged dumps, it is necessary to assess the changes in physico-chemical and biological characteristics of the chronosequence sites. Soil organic carbon, and biological parameters like enzymes, microbial biomass, and respiration were more sensitive to reclamation than other variables. Based on 'soil quality indicator parameters' an integrated 'mine soil reclamation index' (MSRI) was developed to determine the status of ecosystem recovery and mine soil quality. Integrated soil quality indices based on a combination of mine soil characteristics better reveal the stage of recovery of the degraded land than discrete properties and also helpful in comparing soil properties from different chronosequence sites. The calculated MSRI ranged from 0.2 to 0.7 in the chronosequence sites (2-17 years old). The greater the index value, the better is the reclamation status. So it is proposed that reclaimed sites with MSRI > 0.5 may be considered as ecologically sustainable with superior soil functions. Age of reclamation plays a pivotal role in the establishment of plant biomass, aggradation of soil nutrients, and enhancement of microbial properties. In this study, reclamation status of 17-year mine site is similar to a nearby natural forest. This indexing approach can also be used for the selection of plant species and amendments for mine site reclamation.

Spatial heterogeneity of woody vegetation during primary succession in post mining heaps

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The Sokolov brown coalfield is one of the most affected areas in the Czech Republic. Opencast mining has had a negative impact on vegetation cover, biota and landscape character. Most of the heaps have been reclaimed by planting trees but some of them were left to spontaneous colonization. Previous studies show that in ungraded overburden the establishment of woody vegetation consisting from willows, birch and aspen trees is quite fast resulting in closed canopy in c 20year old sites. Here we studied spatial heterogeneity of spontaneously developing woody vegetation at 12, 25, 32, 60 and 100years old heaps. Trees have initially clustered distribution, which gradually changes to random distribution. Oak supplemented by beech and spruce the most important trees climax trees that establish after the pioneer trees (birches, willows and poplars) on 100 years old heaps. It is also important to leave unflatten terrain of heaps. Because of these typical waves helps the initial attachment of vegetation. Specifically, the leeward side of the terrain waves. Eventually the other parts of the wave may become more advantageous due to competitive reasons and environmental development. This relationship between terrains appear not only in pioneer trees but also in climax ones.

Ecology and protection of post-industrial habitats from the point of view of invertebrates

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Coal is currently mined in 41 regions of EU countries. Due to the vulnerable economy, these regions must prepare for the reduction and phasing out of mining. After the end of mining activities, large areas of post-mining landscape will remain to be restored. This situation is a unique opportunity to preserve individual habitats and rare species of invertebrates. The aim of the research is to compare the effects of stinging bees and moths on the area of reclaimed and ongoing primary and secondary succession in these localities.

Falcon catchment whole ecosystem scale approach on minesite restoration

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Understanding how natural processes arise from complex interactions between particular processes at small spatiotemporal scales and in turn how these processes form patterns at large spatiotemporal scales is one of the current principal questions in environmental science. The problem is very complicated, as in many cases, key processes are often studied by researchers in separate disciplines such as ecology, soil science or hydrology. One of the major obstacles is that the processes at a landscape scale are difficult to manipulate and, in many cases, even measure. In particular, the belowground processes are in many cases overlooked or at least understudied. Here we briefly describe a methodological solution used to cope with this problem and describe artificial catchments designed for experimental manipulation at the level of a landscape, called FALCON. This array has two treatments: one mimics a site reclaimed using an alder plantation and the other was left to unassisted primary succession. For each treatment, there were two replicates in four similar catchments. Individual catchments are hydrologically isolated from the environment and equipped with instruments, so that all the main processes and all significant flows of substances and energy in the ecosystem can be monitored, including the cycling of water, nutrients and gas between the ecosystem and the atmosphere. In addition, in each catchment there are sets of lysimeters, which allow the study of small-scale processes and how these can be extrapolated to the catchment scale. In addition, two lysimetric fields exist alongside the catchments for monitoring the effects of the experimental manipulation.

Do soil trasfer speed development of sil fauna in post mining soils?

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Three compact blocks of topsoil (10 × 0.4 m) from a well-developed meadow were transplanted into bare substrate of post-mining spoil heaps to investigate the effect/s of soil transplantation on survival and colonization of soil fauna near Sokolov (Czechia). The samples of soil micro- (nematodes), meso- (mites and springtails) and macrofauna were taken in the "Initial" period (1995–1997) right after transplantation and then in the "Follow-up" period in 2015–2016. We sampled transplanted blocks (Transported), spoil heap at a 2-m distance from the transplanted blocks (Adjacent), and spoil heap at a 30-m distance from the blocks (Control). In the beginning of the experiment, nematodes were slightly higher in Transported plot than in the Adjacent, whereas on follow-up period, the numbers in the Adjacent plot overgrew the total abundances in the Transported plot. In both periods, Control plots had the lowest number of nematodes. The number of mites was highest in the Transported in the initial period, whereas 20 years later, the number was highest in the Control plot. Lumbricidae and most of the miscellaneous macrofauna were favoured in the Transported plot throughout the time. The high macroarthropod densities in the Transported plot even after 20 years, and the low microarthropod densities in the Adjacent plot suggest a limited role of transplanted soil blocks in the colonization of the spoil overburden. This together supports the findings by other authors that soil development of the spoil overburden might be even more critical for establishment of soil fauna than the migration barrier.

Use of chronoseqence method on post mining sites

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To describe the changes of the ecosystem properties in time at postmining sites, researchers typically use a chronosequence approach. The uniqueness of post mining environment enable us to precisely date the origin and history of research sites. This means that we can choose and compare similar sites of various ages at one time. Although this method is useful, this approach has an important limitation, which is site variability.
To overcome this obstacle at first study we amended the chronosequence approach by repeated measurements of sites after extended periods of time (11 years) to strengthen data and allowing us to assess real-time changes in accumulation of soil organic matter and associated changes in individual plots. The study was carried out at post-mining sites near Sokolov where the soil C stock and soil chemistry variables had been measured in 1999. In 2010, we used the same methods to repeat these measurements at the same sites. All sites had been reclaimed by planting of alder in the graded overburden without topsoil application; the overburden consisted of alkaline clay shales. Sites were 4–45 years old in 1999 and 15–56 years old in 2010.
With age of site soil pH gradually deceased; this decrease was more pronounced in the upper soil layer. Changes in pH between 1999 and 2010 were negatively correlated with the initial pH; as a consequence, pH decreased in alkaline sites and increased in acidic sites. Soil carbon (C) increased with site age but the rate of increase declined with site age. The average increases in C stock were similar as determined by the chronosequence and real-time approaches. Trends in soil nitrogen contents were similar to changes in soil C content. Phosphorus content did not differ significantly among sites but tended to be less at older than at younger sites.

Chronoseqences method was, as well, used to distinguish microbial community at the level of microhabitats during pedogenesis at reclaimed and unreclaimed sites at intermediate and late successional stages.

Microbial community in bulk soil and POC fractions were studied using phospholipid fatty acid analysis. Soil C content increased and pH decreased with plot age, these trends being more pronounced at reclaimed sites. The light and bound POC fractions increased with age, higher values and a larger increase being found at reclaimed sites. In both chronosequences, the light fraction was an order of magnitude higher than the bound fraction. We discovered that microbial communities were more affected by the POC fraction than plot age. The bulk soil of reclaimed sites was more similar to bound POC, while the bulk soil of unreclaimed soils was similar to the light POC fraction. Observed differences were positivly correlated with a higher level of bioturbation at the reclaimed sites, which promotes faster accumulation of bound POC and drives bulk soil microbial communities closer to those of bound POC.

The effect overburden grading on spontaneous development of woody vegetation

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Here we used manipulation experiment and chornosequence comparison to test effect of overburden grading on woody vegetation establishment. In Sokolov we prepare experimentally three pairs of sites one of them leveled after heaping the other left in wave like appearance. Significantly higher woody vegetation coverage dominated by Salix caprea, Betula pentula and Populus tremola developer on wave like sites. On leveled sites grasses dominate an establishment of woody vegetation is very limited.

To explore long term effect of ungraded and graded surface have studied two chronosequences of post mining sites after opencast lignite mining near the town of Most (Czechia). Both chronosequences were without any tree planting, the first one was on sites where no leveling or any other technical measures was done after heaping and sites keep their wave like appearance created by dumping process. The second chronosequence was formed by sites, which were levelled by earthmoving machinery, and some shallow topsoil layer was spread in most sites. Both chronosequences were about 30 years old and consist from 8 and11 sites. In addition, birch site outside of heaps was sampled as a control. Results show differences in the development of tree and herb layers in both chronosequences. In levelled sites herb and tree cover increase after levelling, woody cover develop much slower, in ungraded site woody cover develop faster and herb layer slower. Soil chemistry however show similar pattern over time characterized by decrease in pH and Na content. Study suggests that site levelling alter long term ecosystem development in post mining sites, wave like sites tend to develop towards pioneer forest while leveled sites being covered by grass and herb vegetation.