Non-productive principles of landscape rehabilitation after long-term opencast mining in north-west Bohemia

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Synopsis

Remediation of the environmental (and social) disturbances caused by opencast brown coal mining in the past in north-west Bohemia is a priority for state environmental policy.

In order to provide a concept for full restoration of land following disturbance by opencast mining, a special interdisciplinary project supported by a grant from the Czech Ministry of Environment was started in 2000. The initial stage of the project was intended to summarize and evaluate the findings and the works carried out in connection with various reclamation activities in the afflicted area over a period of more than 50 years. The main aims of the three-year project are to make use of the best available landscape environmental management knowledge in order to harmonize the ecological, aesthetic, productive and social functions of new valuable landscape, including the recovery of historical continuity and an understanding of 'landscape memory'.

The basic landscape functions were assessed on two different scale levels. On a large scale, the relevant attributes were investigated over the whole area of the Sokolov brown coal basin (220 km^2). The data and experience acquired were used to define large-scale guiding principles for the rehabilitation of a post-mining landscape. On a small scale, the basic characteristics and functions of the landscape were analysed in the Litov-Chlum model area (2 km^2). The information derived from this analysis was used to formulate a small-scale approach for the rehabilitation of the model area and also to define general methodological principles.

Keywords: rehabilitation, post-mining landscape, degraded landscape, non-productive priorities

Introduction

Landscape disturbed by opencast mining is a subcategory of cultural landscape with a highly productive accent. The most evident productive attribute contrasts sharply with the natural essence of the landscape. During active mining, this landscape type is labelled a destroyed landscape. Opencast mining affects all landscape components and functions. After initiation of mining, the ongoing landscape development is disrupted, the original ecosystems are removed, the original topography is significantly changed, the fundamental ecological relations are irreversibly disturbed, and biodiversity is rapidly reduced. These consequences are compounded into total ecological destabilization and into elimination of the aesthetic values and the recreational potential of the landscape. Post-mining landscapes have been called 'landscapes without a memory'[1].

Recultivation has a long tradition in the Sokolov and north Bohemian brown coal basins (Czech Republic). Before the middle of the 20th century there was some general recultivation of small areas after intensive mining, without any cohesive strategy. The next stage (1970s and 1980s) is typified by a clear preference for productive functions (forest and agricultural recultivation) rather than ecological, aesthetic and social functions[2].

By 2001, an area of more than 100 km^2 had been recultivated. An area of about 75 km^2 is in the development planning stage. The total rehabilitation of the brown coal basins will cover about 205 km^2, including areas that will be disturbed in the future. This shows that there is a large area that can still be positively affected by appropriate rehabilitation approaches that take into account the multifunctional character of the landscape. Although non-productive functions of recultivation are not sufficiently applied, and are not sufficiently provided for in the legislation[3], many specialists recognize the urgent need to implement forms of rehabilitation that increase ecological stability and have high aesthetic values. Approaches that combine restoration of ecological and aesthetic values with the social needs of the regions are sought[4].

In 2000, the Ministry of the Environment of the Czech Republic supported a research project on Rehabilitation of Post-Mining Landscapes (RPML). The objectives of the project are to evaluate the landscapes in the Sokolov and north Bohemian brown coal basins, taking into account existing recultivation approaches, and to propose an overall strategy for sustainable post-mining landscapes.

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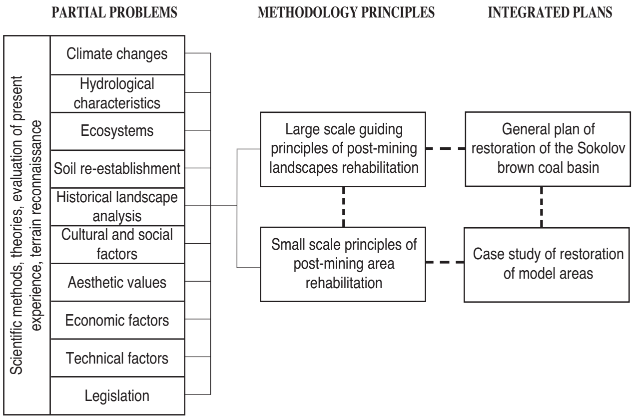

Figure 1—Scheme of the RPML project

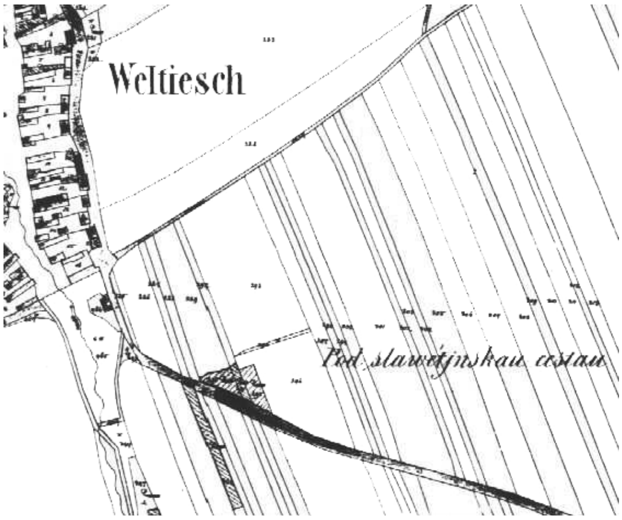

Figure 2—Illustration of the Stable cadaster map (1842)

Implementation of the RPML project

The RPML project analyses the consequences of existing recultivation methods and formulates some new priorities and principles. It also proposes a methodology that specifies these new approaches (Figure 1). The project is based on a holistic perception of the problems by Stinner[5], Bastian[6] and Naveh[7]. The key stage in the RPML project is the definition of new objectives, priorities and criteria for post-mining landscape rehabilitation that have not been sufficiently applied in existing approaches. The new principles have been verified in several case studies, and the findings have been used for feedback correction of the methodology. The methodology is to be a tool for implementing new principles in practical applications. Generally, the project and also the methodology take into account two levels: large-scale and small-scale approaches, and emphasize their reciprocal interconnections.

Large-scale principles

The large-scale principles define the general objectives, limits and techniques for rehabilitating whole areas of brown coal basins. They specify the role of each post-mining site in the landscape of the given brown coal basin, its land use, connections between the sites and the surrounding areas, relations to territorial planning, etc. The large-scale approach has recently been implemented in the General Recultivation Plan. The reference scale is usually 1 : 50 000.

In addition to the overall principles (see Conclusions), some generally applicable basic ideas have been elaborated. These can be exploited in further studies and projects in these regions. We present these three basic ideas, which illustrate some new principles in the rehabilitation of post-mining landscapes.

Reconstruction and interpretation of Stable cadaster maps

Stable cadaster maps (1817-1861) are available for the whole area of the Czech Republic on a 1 : 2 880 scale (Figure 2). They depict the conditions in the country before the industrial revolution[8]. The maps are relatively easy to compare with more recent maps and with other historical sources. This comparability is used in making an evaluation of the landscape evolution.

The Stable cadaster maps were scanned as raster images, transformed and digitized as polygon boundaries and labels using GIS tools (Topol for Windows version. 5.5) for the whole area of the Sokolov brown coal basin (220 km^2) and also for several study areas in the north Bohemian brown coal basin. The results of interpretations of this source were implemented in a retrogressive analysis of the changes in landscape microstructure, for reconstructing the relevant landscape attributes in the areas of rest holes and spoil banks, for making geobotanical reconstruction maps, and for other purposes. The RPML project recognized the Stable cadaster maps as a source of very useful information on landscape conditions from the period before it started to be intensively exploited. The methodology recommends these maps as a major historical source for post-mining landscape rehabilitation planning. Digitized maps now form a generally applicable basis for landscape planning in the regions.

Visibility analysis

This landscape classification provides a tool that reflects not only the internal aesthetic attributes of the landscape units but also the external negative visual characteristics of the neighbouring mined areas. The recent situation (in 2001) was analysed, and the future state (in 2025) was predicted for the whole area of the Sokolov brown coal basin. This prediction is based on the official plan for ongoing rehabilitation of the post-mining landscape provided by the Sokolovska uhelna mining company. This method is based on the idea that the rehabilitated post-mining areas should not have a negative visual effect on the surrounding landscapes.

A visibility analysis is very useful for land-use or physical planning. In particular, a prediction of the exposure of the landscape to negative visual impacts is a very significant tool for urban development planning and for a prognosis of the recreation potential of a region. Visual improvements brought about by the reclamation changes have been simulated and presented by calculating the

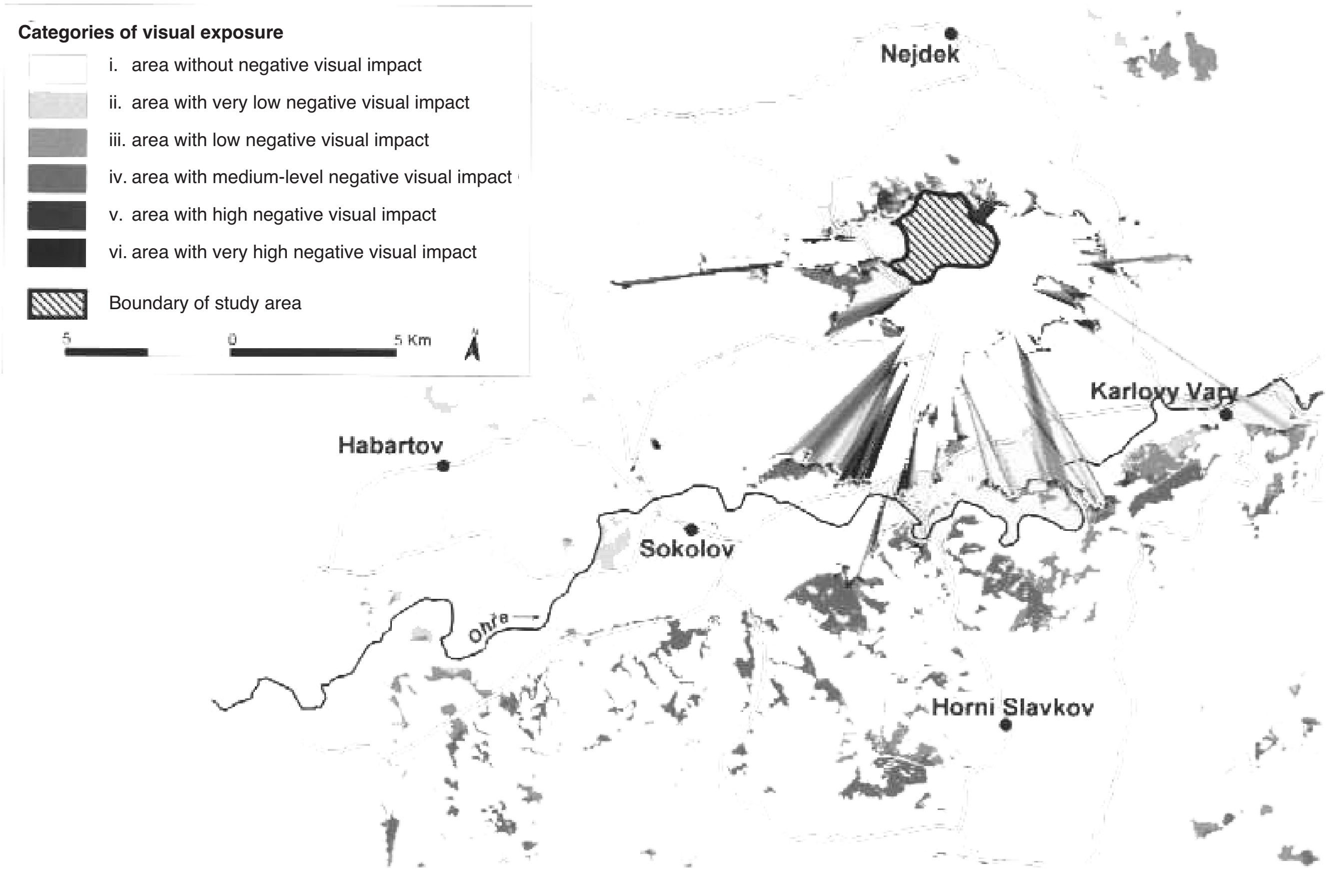

Figure 3—Visibility analysis of the surrounding area of a mining site in the Sokolov brown coal basin—an example

visibility of the recovered landscape structures. The visibility map shows how much of the visually degraded territory will vanish from the viewshed. The process of simulating visual improvements uses ArcView 3.1 tools and its Spatial Analyst extension. We classified the landscape into six categories according to the intensity of negative visual impacts. The visibility analysis of a mining site is shown in Figure 3.

Stand continuity analysis of permanent landscape structures

Permanent landscape structures are landscape components that remain in the same place for a relatively long time. They are characterized by relatively high ecological value and ecological stability. The most important land-use types that can be counted among the permanent landscape structures are: woodland, grassland, water areas, wetlands, fluvial plains, orchards, gardens, and woody dispersed vegetation (small woody biotopes). Stand continuity is a relevant attribute of permanent landscape structures. It is a major factor supporting the species diversity and ecological stability of landscape elements, and of the surrounding landscape[9, 10].

The stand continuity evaluation method is based on an overlay analysis of the land-use pattern in three periods: 1842, 1952, and 2000, using GIS tools. Landscape elements that have been dislocated for a long time (*ca.* 160 years) were compared with the proposed ecological network. In the Czech Republic, this ecological network is known as Territorial Systems of Ecological Stability (TSES). Following the comparison, proposals were made for some spatial (dislocation) changes of the component elements of TSES—ecological centres and corridors (Figure 4). Stand continuity is considered to be a key criterion for TSES proposals[11].

Small scale principles

The small-scale principles were verified in a number of case studies. One illustration was selected for presentation in this paper—the Litov-Chlum study area (2 km^2), which is situated in the Sokolov brown coal basin. This study area is a finalized part of a spoil bank, shaped like an amphitheatre with a water reservoir in its centre. Many research projects have been carried out in this study area, analysing zoological and botanical characteristics, hydrobiological attributes of the water reservoir, the qualities of the soil substrate, hydrological and mesoclimatic characteristics, aesthetic values of the landscape, and its historical evolution. The dynamic changes in relevant attributes of the land-use pattern have been analysed in the study area. The results show a dramatic decrease in landscape heterogeneity (-53.2 %) between 1842 and 2000[12]. The role of the study area in the TSES was defined, together with detailed principles for supporting ecological connectivity.

The study area is adjacent to the monastery of St. Mary (Church of the Assumption of the Virgin at Chlum), which is

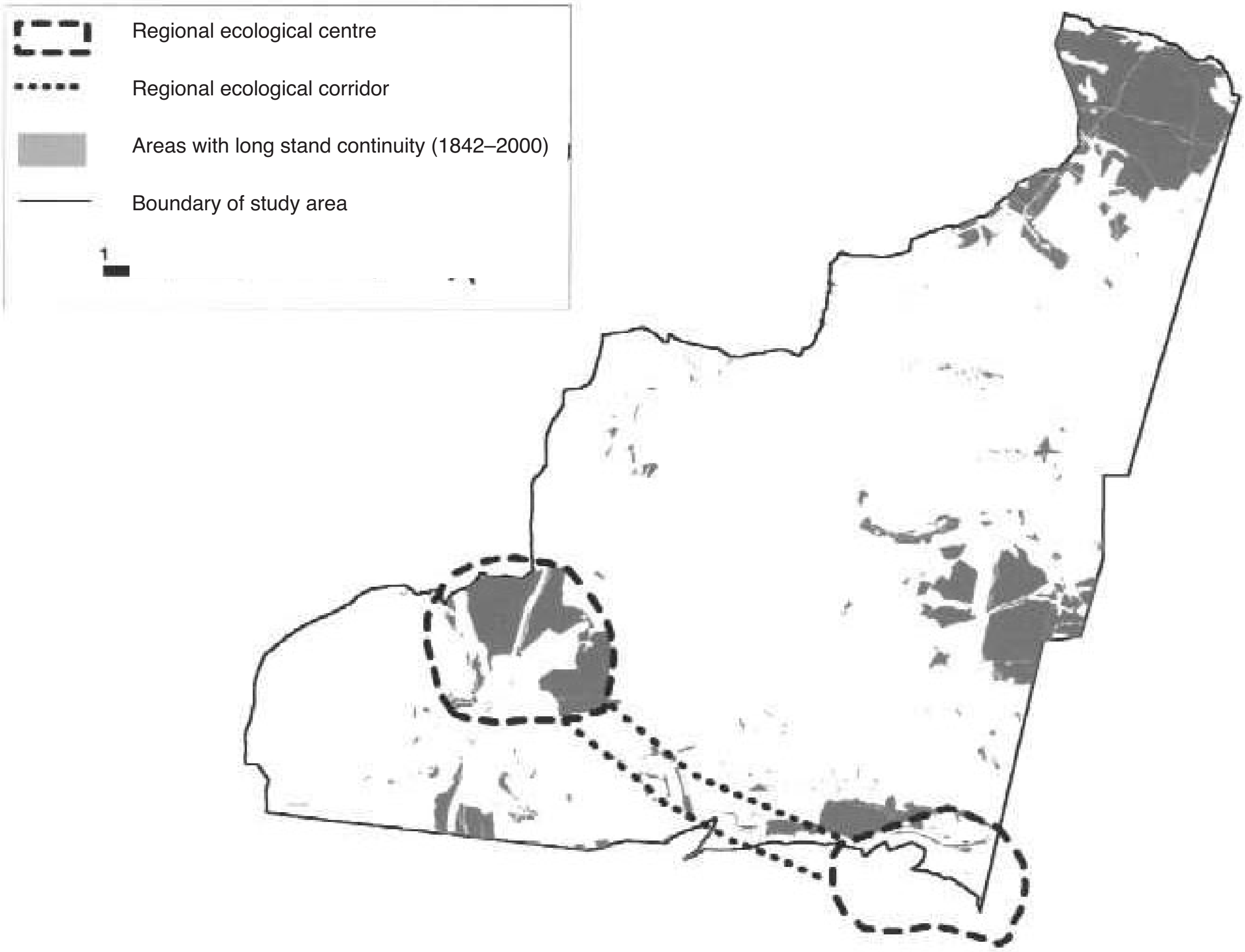

Figure 4—Comparison of TSES with stand continuity analysis

a historical monument. This positive landscape feature of regional importance is a very significant place of pilgrimage for Czechs and Germans. The monastery is the main contributor to the very powerful *genius loci,* and for this reason the restoration work was important. We therefore constructed a visual diagram centred round this positive dominant feature of the landscape.

Based on the results of initial studies, a method for study site rehabilitation was defined. Due to the great importance of the monastery, a recreational function was deemed to be most appropriate. The final design of the study area was proposed on the basis of the RPML integrated approach. This is determined mainly by the following factors: visibility analysis, geo-botanical restoration principles, erosion control measures, revitalization of the pit, raising the heterogeneity of the landscape microstructure, and the economic feasibility of the proposed variant. A 3D visualization of the final design (Figure 5) was made in order to be able to present the project clearly to specialists and to the general public.

Conclusions

The RPML project defines guiding principles that have not been sufficiently applied in recent approaches. These principles involve non-productive priorities for post-mining landscape rehabilitation. The basic principles of this holistic approach were inspired by general methods of landscape assessment[13], of landscape ecological planning[14, 15], by the process scheme of Schulz and Wiegleb[16], and also by the Visual Impact Analysis method[17] for analysing the landscape impacts of policy scenarios and for presenting them in visual terms. These particular approaches were integrated in the process of rehabilitation of post-mining areas, and were implemented in the study areas on a regional and also on a local scale. The principles were amended in the process not only by the research team but also by specialists from the mining company, taking into account comments from the public. The visibility studies were considered very useful for further planning activities mainly by the local authorities and urban planners.

The RPML project involves some new principles and procedures that can help landscape planners to redesign a landscape after its evolution has been interrupted for a long time. This requires information about the historic state of the landscape before it was disturbed by opencast mining. Knowledge about the historic landscape structure and its development can support the design of design a new concept

Figure 5—3D visualization of the final design of the study area

of roads, land-use patterns, streams, ecological networks, etc. Our project presents a suitable basis for this purpose, and puts forward specific approaches that are still not a part of normal practice in the Czech Republic. The proposal for the new landscape structure can be adjusted by a spatio-temporal analysis of some landscape pattern attributes. In particular, landscape heterogeneity attributes can be used as quantitative criteria for landscape reconstruction.

Overall principles

- Respect for the historical evolution of the landscape.
- Restoration of the connections between directly impacted areas, indirectly impacted areas, and areas unimpacted by opencast mining.
- Interconnection of small-scale forms with large-scale forms of rehabilitation.
- Interconnection of the plans for post-mining landscape rehabilitation with other forms of landscape planning (territorial planning, land-use planning, forestry planning, etc.).

Ecological principles

- We assert that biological diversity (at all levels) and speed (success) of revitalization are the two key criteria for post-mining landscape rehabilitation.
- Creation of long-term functional ecosystems in the post-mining areas (rest holes, spoil banks) and enhancement of the surrounding ecosystems.
- Support for landscape connectivity and population dispersal (migration) for successful colonization of post-mining sites and the establishment of equilibrium diversity. Prevention of further landscape fragmentation and elimination of recent dispersal barriers. In the Czech Republic, TSES deals with this issue by means of conservation and complementarity.
- Permanent landscape elements with long standing continuity constitute fundamental features of the ecological network of the landscape.
- Restoration of small (closed) hydrological cycles[18] in the post-mining landscape. Support for higher water retention and accumulation, on the basis of revitalization of streams and their fluvial plains, creation of new water reservoirs, wetlands and their relatively regular distribution in the landscape.
- Prognosis of the climate is an important consideration when defining the qualitative parameters of new ecosystems (especially species composition). Pre-adaptation of ecosystems to anticipated climate evolution also requires terrain modification leading to the formation of thermal areas capable of sustaining thermophytes.
- An increase in the heterogeneity of post-mining landscapes, mainly heterogeneity of the landscape microstructure. Variety of relief is a key factor.
- Natural succession is taken to be an ordinary form of post-mining landscape rehabilitation. It should be enabled in areas where it provides outcomes that are at least comparable with the results of landscape management.

Landscape-architectural principles

- The fundamental principle of post-mining landscape rehabilitation is the conservation and restoration of the original cultural and aesthetic values and the creation of new values[19].

- New landscape should be characterized by high aesthetic value.
- The new approaches should take into account or, rather, emphasize recent positive landscape features, and eliminate (or at least visually mask) recent negative landscape features. New roads, bikeways and hiking trails should fit in with this approach.
- The rehabilitation of each post-mining site should have a clearly defined landscape-architectural motive (e.g., landscape composition, dominant feature, religious, etc.)
- The rehabilitation of post-mining landscapes offers a unique opportunity for landscape architects to design a quite new landscape. There should be adequate participation of the general public, specialists and the responsible authorities in the process of planning and decision making. A competition is a suitable way to select the best proposal.
- A visualization of the proposed design is an integral part of the planning process. Clear visualization helps to formulate more design variants, and also facilitates participation of the general public in the decision-making process[20].

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