Recognition of the ecological structure of mining areas as a premise for landscape shaping

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Zusammenfassung

Im polnischen Flachland (NIZ Polski) findet man Bergbaufolgelandschaften in verschiedenen Stadien der Entwicklung (Öffnung, Extraktion und Rückgewinnung). Diese sind geprägt vom offenen Braunkohletagebau, der seit über 50 Jahren in Betrieb ist. In diesen Gebieten wurde die ökologische Struktur der Landschaft untersucht und dabei ein besonderes Augenmerk auf ihre Verbindungen mit den angrenzenden Geosystemen gelegt. Dadurch können Veränderungen in den Geosystemen durch Bergbautätigkeiten identifiziert werden und die ökologischen Vernetzungen in der Landschaft zwischen Geosystemen und überdurchschnittlich natürlichen Merkmalen beurteilt werden.

Die Identifizierung der Bereiche, die regeneriert und zurückgewonnen werden sollen, um die strukturelle Konnektivität der natürlichen Systeme in den Prä- und Post-Bergbaugebieten zu erhalten, ist von entscheidender Bedeutung für die Festlegung von Richtungen der Landrückgewinnung und der Beurteilung der Wirksamkeit von durchgeführten Rekultivierungsmaßnahmen. Die Ergebnisse der Untersuchungen können verwendet werden, um laufende Rekultivierungsmaßnahmen anzupassen sowie zukünftige zu planen.

Abstract

There are mining landscapes in various stages of development (opening up, extraction and reclamation) in the Polish Lowlands (Niż Polski), shaped by open-pit lignite mine that has been operating there for over 50 years. The landscape ecological structure was examined in those areas and a particular attention was paid to their connections with adjacent geosystems. This allowed for determining the changes caused by mining activity in geosystems and to assess the landscape ecological connectivity between geosystems with natural features above average. Identifying the areas which needed to be reshaped and reclaimed in order to maintain structure connectivity of the natural system in the pre- and post-mining terrains is vital for defining directions of reclamation and assessing effectiveness of the conducted reclamation works. The conclusions may be used to adjust the reclamation activities in progress, as well as to plan future actions.

1. Introduction

In the Polish Lowlands (Niż Polski), there are mining landscapes in various stages of development (opening up, extraction and reclamation) shaped by open-pit lignite mining, which has been going on there for over 50 years. In the past, the process of shaping the structure of new post-mining landscapes used to focus mainly on the technical and biological aspects of reclamation, which did not account for natural determinants nor principles of landscape ecology.

In landscape ecology, it is assumed, that the spatial structure of landscape and spatial configuration of ecosystems, play an essential role in the conservation and management of biodiversity. The possibilities of survival and spread of particular species depend, not only on the size and shape of ecosystems, but also on the distances between them, the existence of the corridors and ecological barriers (SOLON 2004; FORMAN & GORDON 1986; DOERR 2010 et al.). All these factors are of great significance for for landscape connectivity. Landscape connectivity is the degree to which the landscape facilitates or impedes movement among the resource patches (TAYLOR 1993 et al.). The analysis and assessment of landscape connectivity takes two aspects into consideration:

- structural connectivity, which defines the physical characteristics of the landscape between patches of occupied habitat (HILTY 2006 et al.)
- functional connectivity, which defines the functional relationship among habitat patches, owing to the spatial contagion of habitat and the movement responses of organisms to landscape structure (WITH 1997 et al.)

Connectivity is therefore a feature of a whole landscape, where the scale of the landscape is determined by the habitat use and movement scales of the organism in question (TISCHENDORF & FAHRING 2000; GOODWIN & FAHRING 1998). In this study, a special attention was paid to the issues of structural connectivity of the post-mining landscapes, and particularly connectivity between the post-mining ecosystems and natural ecosystems (not transformed by the open-pit mining), which are in their surroundings.

The main purpose of this study was the recognition of the ecological structure of mining areas (identification of ecosystems and their spatial distribution) and assessment of the character of the ecological relationships (connectivities and non-connectivities) between the ecosystems as a premise for shaping post-mining landscapes in reclamation process.

Reclamation of the post-mining areas, preceded by the analysis of the landscape structure and taking into consideration the necessity of reconstruction of the spatial connectivity in the post-mining area, should become an essential and permanent element of spatial planning in the areas degraded by open-pit mining.

2. Methods

Diagnostic studies included identification of the ecological structure of the landscape and its analysis. The ecological structure of the landcape is treated as the mosaic of the basic soils, which were

determined according to the category of land use. Analysis was conducted on the basis of the patch-corridor-matrix model, according to which the landscape is created by different combinations of patches and corridors situated within the matrix.

Topographical maps and thematic maps (sozological and hydrographical) in 1:50 000 scale were the source material. The detailed analysis (1:10 000) of the layout of the landscape structure and the relations between the post-mining geosystems and the original ones was conducted on the basis of the teledetective materials: ortophotomaps, aerial pictures and the works in the terrain. Results were presented as a case study of the area which is within the scope of influence of the Brown Coal Mine Adamów, which, along with presently exploited deposits Adamów, Koźmin and Władysławów, consists of municipalities Brudzew, Turek, Przykona and Władysławów, which are part of the Turek District (Wielkopolska Voivodeship).

3. Diagnosis of the ecological structure of the post-mining area of Adamów

3.1 Identification and evaluation of the spatial layout

Identification and evaluation of the spatial layout of the basic forms of land use, especially essential for keeping ecological balance and biological variety: forests, meadows, pastures, river valleys, reservoirs. Within these areas one can also find lands which are exceptionally valuable and environmentally protected by law. There are two areas of landscape conservation which were listed within the researched area. The first one is Złotogórski Obszar Chronionego Krajobrazu (The Area of Złotogórski Lanscape Conservation) and Uniejowski Obszar Chronionego Krajobrazu (The Area of Uniejowski Lanscape Conservation); both of which are part of Great Spatial Network of the Protected Areas. The second one is the area Nature 2000 "The Valley of the Middle Warta River" – with a bird colony of European value. The spatial layout of the anthropogenic geosystems, which were created as a result of the mining activities, was presented against a background of recognized ecological network (fig.1).

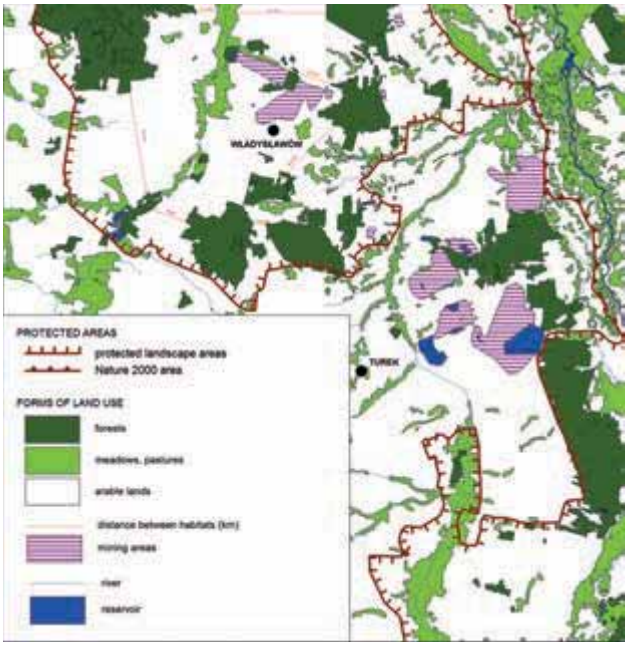

Fig. 1: Ecological structure of the mining area Adamów

3.2 The analysis of the ecological structure

The valley of Warta and Teleszyna Rivers as well as the valleys of the smaller water courses – Struga Janiszewska, Kiełbaska, Topiec, are predominant elements within the layout of the ecological structure of The Liginite Mine Adamów. The valleys of the longitudinal course determine the main axes of the structure. They create the ecological corridors which are greatly significant (both at the regional and local levels) for realization of the ecological connections. That is because they make up the path for migration of substance, energy and organisms in the landscape. In the great majority they are the meadow-moss paths, which are afforested at the small sections (fig.2).

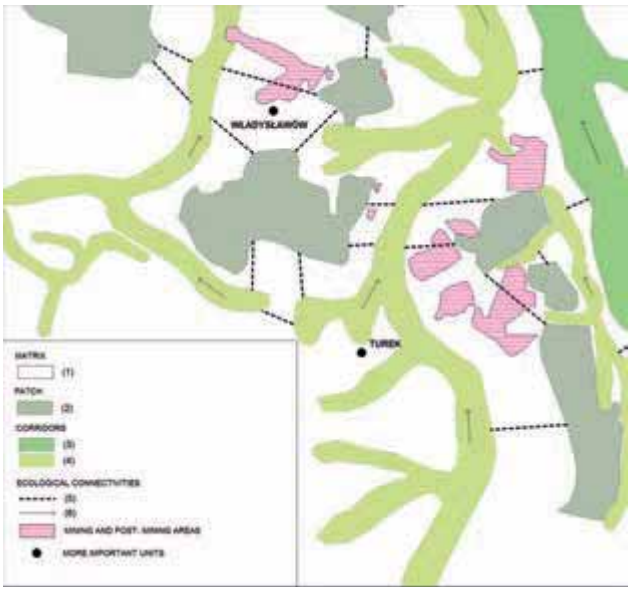

Fig. 2: Analysis of the ecological structure of the mining area Adamów
1 – arable and fallow lands, 2 – height and valley forest , 3 – the main ecological axis – the valley of Warta River, 4 – stream continuity and river corridors, 5 – ecological connectivities realized by forests areas, continuity of trees and shrubs, which require shaping, 6 – ecological connectivities realized by the river valleys and smaller watercourses

The breakage in the continuity of the ecological corridors as well as in the continuity of the nature, resulting from the mining activities, is a characteristic phenomenon for post-mining areas, which can also be observed in the researched terrain (fig.3).

The structure is replenished by forest areas. South of Władysławów there are three forest complexes covering an area over 2300 ha. A forest covering an area of 4073 ha extends between the areas of open-cast mine in Koźmin and Adamów and further towards South. Within the whole researched land, the total area covered by both the natural and reclaimed forest ecosystems amounts to 12700 ha, while the ecosystems of meadows and pastures cover 14350 ha. The natural resources of the analyzed area, on the basis of the area size index, can be considered as abounding and stable, creating good conditions for existence and species development. The problem, however, is the isolation of the habitats, which limits the possibilities of migration and exchange of species. The distances between the habitats are wide apart, which shows a high level of

their isolation. For instance, the forest complexes south of Władysławów are separated by 500, 800 and 1200 m, whereas to keep the ecological connections this distance should not go beyond 500 m.

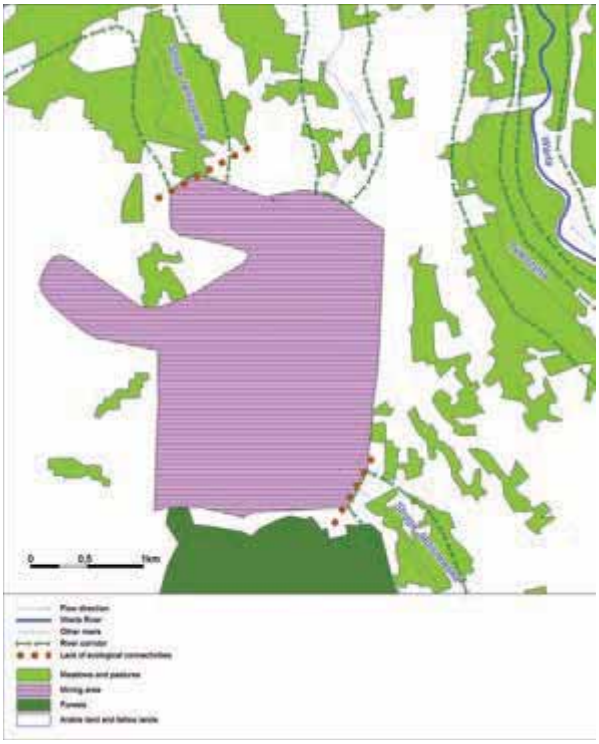

Fig. 3: Breakage of the continuity of the ecological corridor of the valley of Struga Janiszewska as a result of lignite exploitation in the open-cast mine Koźmin

3.3 Analysis of the diversity of the ecological structure on the basis of Shannon's diversity

Analysis of the diversity of the ecological structure on the basis of Shannon's diversity index reflects a degree of heterogeneity and variety of landscape structure.

In this analysis the index was used to evaluate the diversity of changes of ecological structures on the mining area of Adamów in reference to the condition before brown coal exploitation in this area. Low values of the index in the pre-exploitation period are connected with the domination of the agricultural way of spatial utilization.

$SHDI = -\sum_{i=1}^{n} (Pi * \ln Pi)$	SHDI – Shanon's diversity index
	Pi – proportion of I category
	n – number of categories

Tab. 1: Shannon's diversity index (MC GARIGAL & MARKS 1995)

	Pre-mining period (year 1944)	Presently (year 2011)
Shanon's diversity index SHDI	0,52	1,94

Tab. 2: Values of Shannon's diversity index on the post-mining area of Adamów before the mining activities and present

There were also vast, dense forest areas in the landscape. The increase of the index within the period of mining activities is connected with the increase of the mosaic which is a result of the fragmentation of the vast, homogeneous habitat patches (both forest and meadows), simplification of the shape of patches' boundaries, especially those, which were formed as a result of the reclamation works.

4. Ecological-landscape principles for shaping the structure of post-mining areas

On the basis of conclusions on the diagnosis and having taken into consideration the principles of landscape ecology, the main principles of shaping the structure of post-mining areas have been formulated.

1. According to the rule of the continuity of a particular habitat, one can consider the possibility of re-creating the habitats which were existing in the particular area before the exploitation took place; this rule refers particularly to the forest habitats.

2. One should harmoniously connect the elements of natural structures of the post-mining areas with the ones which are local to them – the natural areas ("in agreement with the boundaries").

3. One should create vast habitats, which are more stable and more conducive for keeping and enlarging the number of plant and animal populations inhabiting theses areas. At the local level (municipality) one should strive for creating at least one forest stronghold covering an area not bigger than 500 ha and other stable transitional strongholds. Adopting the method of forest reclamation one should design possibly vast forest areas consisting of a great number of species and enlarge the already existing habitats or connect the smaller forest complexes.

4. One should shape the boundaries of the anthropogenic geosystems. The boundaries of the natural geosystems are developed (winding) and mild. The anthropogenic forms cut themselves off from the environment by straight and sharp lines. The winding boundaries with bights and peninsulas create a greater variety of habitats, which favor species diversity and have positive influence on limiting the processes of denudation. Boundary-shaping refers also to their spatial development, which means the creation of a transitional zone between anthropogenic and natural geosystems by thickening them with permanent vegetation. It refers mainly to the boundaries between forests and other forms of utilization. The well developed vegetation of the border zone of forests enables faster formation of the conditions, which are characteristic for the interior of forests (e.g. microclimate) and it creates a barrier protecting the interior of forests from the penetration of unfamiliar species.

5. One should sustain and restore the ecological connectivity and continuity between the geoecosystems by creating a network of ecological chains and corridors as structures which are the most essential for the migration of substance, energy and organisms within the landscape. Planning and creating the ecological corridors on post-mining areas is the most essential for the optimization of the ecological structure. Ecological corridors enable the connection of the isolated spatial structures, which were separated as a result of mining exploitation. With reference to the evaluation of the degree of habitat isolation depending on their distribution, we talk about a low degree of isolation between similar habitats when the distance between them is not greater than 200 m and there is no barrier influences from roads, for instance. If the distance between the habitats is great than 500 m we can say that the degree of isolation is

high.Thus, one needs to create strip-like structures between the scattered patches of land in the landscape (forest, meadow habitats), and spatially connect the forest areas with valleys and river troughs with a system of corridors.

6. One should strengthen the ecological microstructure by introducing and replenishing midfield forests on the reclaimed areas for agriculture, along the small watercourses and waterways, around water basins and depressions with no outlet (ANDRZEJEWSKI 1986; CHMIELEWSKI 2005; GACKA-GRZESIKIEWICZ & CICHOCKI 2001; ŻARSKA 2006)

The essence of the idea of landscape shaping based on ecological premises can best be presented by the "3m rule": magnification of the number of nature strongholds, magnification of the number of ecological corridors and magnification of the hierarchical strongholds and ecological corridors (ŻARSKA 2006). Implementation of this idea for planning the directions of reclamation will enable the achievement of a new balance in geosystems which were transformed by the open-cast mining.

5. The concept of shaping the ecological structure of post-mining areas (a case study of open-cast mine Władysławów)

The open-cast mine Władysławów is situated in the north-west part of The Liginite Mine "Adamów". It spans from the north-west to the south-east, taking the elongated shape tipped with two arms in the south-west and south directions. The exploitation of deposits is presently realized in the eastern part of the mine, while the remaining part is the post-mining area. The western part of the mine is an outer waste bank covering the area of 40 ha and the relative height is 20-28 m and is situated in the bottom of the river Topiec. This unfamiliar form, clearly separated from the environment, constitutes the barrier, which limits the proper functioning of the right bank of the ecological corridor of the Topiec valley. In the immediate neighborhood of the waste bank there is a fragment of an opening pit, which is presently, simply collects dirty water. Towards the eastern arm and further on to the south-western and southern arms, there is the outer waste bank zone, reclaimed mostly for agricultural purposes. There is just a small part of the land, mostly advanced towards the East which underwent forest reclamation. The main elements of the ecological structure of the open-cast mine Władysławów are the valley of the River Topiec, which has the longitudinal course and the vast forest strongholds situated on the eastern bank. There are three vast forest complexes in the South (1043 ha, 1140 ha, 257 ha), two dense forest areas in the north-eastern part and also the north-western part of the analyzed area afforested. All the forest areas cover vast areas; are dense and can be called natural strongholds. Within them there are conditions, which are good for sustaining the continuity of the existence of both flora and fauna species. However, the distance between the strongholds (8.2 km, 7.3 km, 7.8 km) does not allow for keeping the connectivity between the ecosystems. The mining and post-mining area of O/Władysławów is the characteristic element of the landscape. It forms an elongated structure, perpendicular to the axis of the valley, which in the East adjoins the forest complex (fig.4). Thus, with such layout of the structure, shaping the landscape should be based mainly on:

• protection of the valley of River Topiec as the main natural structure and its consolidation by introducing trees and bush planting, especially in the upper reaches of the river

• creating, in a form of network, connectivities between the already existing stable forest nodes and between the node areas and the valley of River Topiec; forming the spatial continuity should be realized mainly by forestations and filling-up with the elements of ecological microstructure (introduction of the system of forest and midfield bush planting)

• correcting the shape of the forest areas and shaping the marginal zones of forests

• shaping the ecological continuity, within the post-mining area of O/Władysławów, which would connect the forest stronghold (739 ha) with the valley of River Topiec. The realization of this task means correcting the established directions of reclamation and requires forestation of the northern part of the open-cast mine on ca. 3 km length and a width of 200 m, between the forested outer waste bank and eastern part of the mine reclaimed for the forest; in the plans of reclamation of presently exploited deposit, one expects to create a water basin in the ending cavity. It is proposed to plant forest around the area in order to create a node which would be a basis for building ecological continuity along the arms of the open-cast mine for forest complexes situated in the South of the analyzed area.

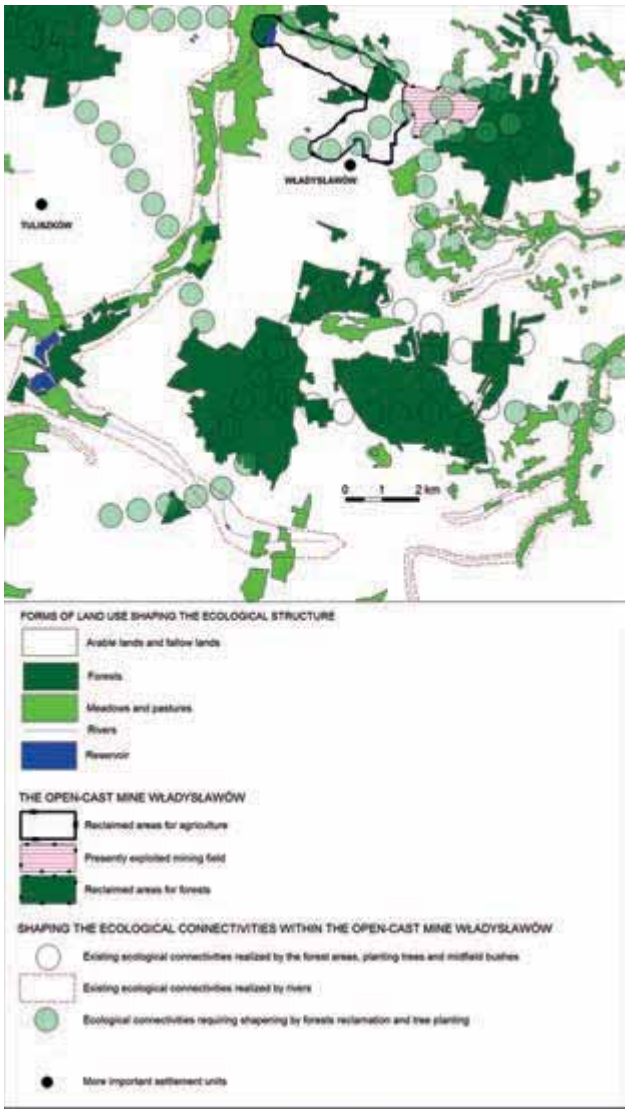

Fig. 4: Concept of shaping the ecological structure within the area of the open-cast mine Władysławów

The concept of shaping the ecological structure within the O/Władysławów and in the immediate environment is presented in figure 4.

6. Summary

The rules of shaping the ecological structure of post-mining areas presented above as well as the examples of their application within the area of Adamowskie Zagłębie Węgla Brunatnego (Adamowski Brown Coal Basin) show interchangeably, that the planning of reclamation works cannot be limited to the areas degraded by the process of exploitation. One must take into consideration its relations with the environment. We can, therefore, conclude that it is a diagnosis of the ecological structure which has main significance when determining the direction of reclamation and evaluation of the effectiveness of the covered works. The conclusions reached from this analysis can become the basis for corrections of reclamation activities as well as planning for reclamation works according to the rules of environmental protection in the future.

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