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THE SOZOLOGICAL AND HYGROGRAPHIC MAPS OF POLAND AS A BASIS FOR THE ANALYSIS OF ENVIRONMENTAL CHANGES IN MINING AREAS

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Summary: In the forthcoming decades large resources of lignite are going to play a role of energy security stabiliser in Poland. This proves the significance of the problems of mining areas in geographical space and entails an increased demand for data on their structure and functioning. This paper shows the informative potential of the sozological and hydrographic database and the numerical Sozological and Hydrographical Maps of Poland, scale 1:50,000, which were created based on the data. The maps are a designed, implemented and functioning system of spatial information, fulfilling all tasks of GIS. The paper proposes a method of adapting and developing the system to a degree of detail which permits to employ it in comprehensive geoenvironmental and landscape studies in the mining and post-mining areas of the Middle Odra Region. The properly structured information system is a unique tool for diagnosing changes in the natural environment of mining areas in the aspects of quantifying, systematising and forecasting and constitutes an auxiliary element in making spatial planning decisions.

Key words: thematic databases, geographic information system, mining and post-mining areas

1. INTRODUCTION

In reference to the thesis of Antrop [2006], saying that landscape can be sustainable regardless of the degree to which it is natural, a still topical research problem in lignite mining is the observation of landscape change sequences related to subsequent stages of extraction which aims to consider the problem of recovering post-mining landscapes to new (secondary) balance states. Observation of land reclamation processes in Poland and Western Europe shows that after the stage of intensive extraction and reclamation in which economic purposes were considered most important **(the transformation stage)** was followed by the **stage of managing and planning** post-mining areas, which incorporated the sustainable development paradigm. The landscape oriented trend in adapting post-mining areas, known as ecovention *(ecology + invention)*, is based upon the principle of treating those areas as a national and European cultural heritage documenting one of the periods of civilisation development. Those areas are adapted as recreational areas (sports, picnic, cycling, parks, water reservoirs) or educational areas (didactic paths, heritage parks).

The implementation of this approach should be based on cooperation of specialists in landscape ecology, landscape architecture, spatial planning and environment management and should employ comprehensive geoenvironmental studies and studies on scenic post-mining areas. The studies should be founded on a database characterising the structure and functioning of those areas as well as trends and dynamics of change.

This paper underlines the possibility to make use of the informative potential of the sozological and hydrographic database in the development of a spatial information system which could be applied in mining area research. Information systems which employ the GIS technology are at present an indispensable tool in diagnosing the natural environment and an auxiliary element in making spatial planning decisions.

2. THE SOZOLOGICAL AND HYDROGRAPHIC MAPS AS A FOUNDATION FOR CREATING A SPATIAL INFORMATION SYSTEM FOR THE NATURAL ENVIRONMENT OF THE MINING AREAS OF THE MIDDLE ODRA REGION

Geographic Information Systems (GIS), unlike other information systems, relate the data to a specific location in space. The spatial attribute of the data is identified as the principal feature enabling it to assist in making decisions connected with spatial data processing, and a wide range of analytical functions makes GIS a unique research tool.

The need and necessity to create spatial information systems for the purpose of a coherent European environmental policy is pointed out in the INSPIRE directive. Out of the thematic databases made in Poland, only two comply with the directive, which prescribes creating thematic databases based on an official system of topographic references. These are the sozological and hydrographic databases, based on which the Sozological Map of Poland and Hydrographic Map of Poland, scale 1:50,000 [Graf, 2005] were created.

The Sozological Map of Poland contains a wide range of information on the condition of the natural environment. The contents of the map are divided into five information levels consistent thematically with GIS-4 Technical Guidelines [2005]: forms of natural environment protection, degradation of natural environment components, counteracting degradation of the natural environment, reclamation of the natural environment, wasteland. The Hydrographic Map integrates the information on water objects and phenomena: topographic watersheds, surface water, groundwater outflows, first-level groundwater, ground permeability, phenomena and objects in water management, hydrometric points in stationary measurements [GIS-3 Technical Guidelines, 2005].

The most significant feature of the maps described above stems from the fact that they are not a mere collection of information but constitute a designed, implemented and functioning spatial information system, which performs all GIS tasks. What is worthy of a special note in the rich set of functions they provide is the possibility to transform the maps from the sheet layout into any reference system chosen (drainage area, geocomplex, commune, mining area), and the possibility to enter, store and update data. The layer-based structure permits a free configuration of the map content and selection of a combination of layers that interest the user at the moment, which makes it possible to assess phenomena from an analytical perspective (e.g. spatial distribution of excavations and dumping grounds – 1 layer) or synthetic perspective (e.g. land changes within a mining area – 7 layers: excavations, dumping grounds, post-extraction deformations, mining area range, anthropogenic land, and raw material, fuel and waste storage sites). Those attributes permit to adopt and develop the structure of the databases used for the sozological and hydrographic maps, which were defined on a regional level (scale 1:50,000), to create a comprehensive and efficient local (1:10,000) geographic information system for mining areas. Such a system is an indispensable tool for managing nature resources in mining areas. It is estimated that 75-90% of the information used in local-level management involves spatial location [Bartkowska, 1992]. Therefore the significance of the system to optimising mining area management and planning is indisputable.

An answer to the demand is the geographic information system developed currently based on the sozological and hydrographic databases for areas transformed by underground and surface lignite mining in the Middle Odra Region. The first stage of the process consisted in verification and transformation of the sheet representation of the sozological and hydrographic maps into an object-oriented representation relating to typological units identified in a detailed physiogeographic regional classification of the Middle Odra Region carried out based on Żynda's classification [1978]. The transformed maps became a framework for constructing a database for the information system on mining areas. The source of data were the existing resources of the sozological and hydrographic databases. Information selected from all thematic layers were saved in a separate database created for every physiogeographic unit analysed and complemented mainly through cartometric measurements. Automatic calculation for surface areas (e.g. of land use forms), lines (e.g. length of roads, power lines, water-courses) and point objects (e.g. waste dumping grounds) was performed, and statistics were made, mainly for the amount of emission and sewage discharge. Next, the resulting quantitative attribute of geographic objects was included in the database. The system was also complemented with information from the following:

- Remote sensing sources – satellite and aerial pictures, Corine Land Cover 2000, 2006 database and other cartographic sources (hydrogeological and geoenvironmental maps; VMapL2, scale 1:50,000; detailed cartographic studies, scale 1:10,000: topographic map, soil and agricultural map, map of forest habitat types)
- State environment monitoring, expert's reports and archives of mines
- Direct registration of phenomena and processes in the field

This stage of the information system development involved also final determination of the database structure, whose shape depends on the purposes of the system being created. The main purpose of the system is to integrate data which will enable the user to establish the specificity of the functioning of mining areas within the system of natural spatial units. Furthermore is aims to discover the qualitative and quantitative relations and links between diverse elements of the primary (characteristic of the pre-extraction period) and secondary (post-mining) structure of complex landscape systems subjected to strong anthropogenic pressure related to underground and surface lignite mining which has been present in those areas since 1870s.

The data was arranged in order by referring it to specific components of the natural environment (lithosphere, pedosphere, surface water and groundwater, fitosphere, atmosphere) and the 'anthroposphere' (this category groups data on the burdening of the natural environment by technical infrastructure). Referring the data structure to individual components of the natural environment is the first stage of data processing aimed at collecting information on the condition of the entire environmental system or its elements. At the subsequent stage the data was divided into two groups. The first group encompassed information for diagnosing dangers, changes and the condition of the natural environment in the analysed units. The second group included data on resources, protected areas, valuable nature areas or assets of the areas. As a result, each of the spatial units studied integrates a set of around 100 diagnostic features, which – in different configurations – permit to analyse the functioning of the natural environment.

3. THE GEOGRAPHIC INFORMATION SYSTEM IN STABILITY ASSESSMENT IN THE POST-MINING AREAS OF THE MIDDLE ODRA REGION

The spatial information system being developed is going to enable the performance of the initial stage of the stability assessment procedure, namely the diagnosis of the natural environment of the units studied and the post-mining areas within them. It is based on a sequential consideration of transformed components of the natural environment observed in the perspective of the causative force – pressure – condition – reaction and focuses on cause and effect relationships in the assessment of the current functioning of the post-mining areas of the Middle Odra Region. The medium of reference for the diagnosis made is the comprehensive study by Kozacki [1980] evaluating the impact of lignite mining on the transformation of the natural environment of the area, and in particular the role of underground mining. Underground lignite mining is a phenomenon that is little known and specific to north-western Poland, and because of different geological conditions and extraction depth, totally incomparable with underground hard coal mining in southern Poland. It results from the fact that a characteristic feature of the geomorphology and geology of the Middle Odra Region are glaciotectonic aberrations [Kozacki 1980, according to Dyjor] and a low-depth location of lignite in glaciotectonic structures (folds and slices).

Kozacki [1980] catalogued and analysed 179 mining fields situated in the Middle Odra Region (fig. 1). The location of each was expressed in physiogeographic units determined by Żynda [1978]. This substantiates the adoption of the spatial division and the physiogeographic units as the basic fields of reference for the sozological and hydrographic databases in the spatial information system for post-mining areas being constructed.

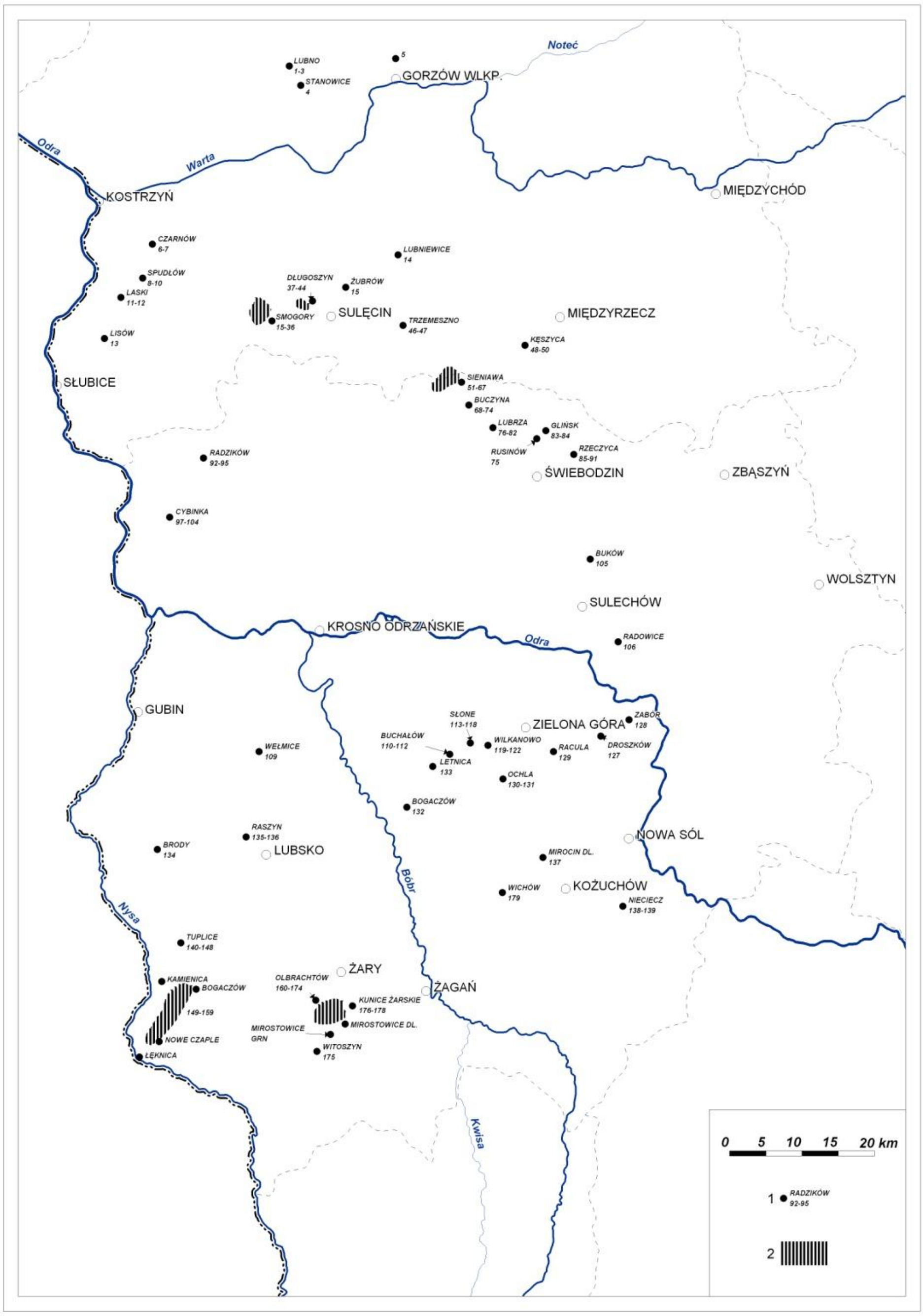
Mining fields were characterised by identifying the following: dimensions (length, mean width, surface area), size and character of deformations, form within which the field is located, land use and surface of the excluded area. A vast majority of the fields are situated in a zone of pushed end moraines which are characterised by varied hypsometric features (large drops and descents) and domination of forests in the land cover. The remaining fields are situated within older sandur levels, mostly afforested but with a flatter relief (tab. 1). Those characteristic features will condition the relations between the components of the natural environment.

Table 1. Mining areas of the Middle Odra Region according to geomorphologic units [Kozacki 1980]

Morphologic unit	**Amount (pcs)**	**%**
Pushed end moraines	140	78
Sandur levels	37	21
Morainic plateau	2	1

Each of the catalogued fields was classified in respect of:

- Topographic location: plain-flat, plain, plain-undulated, slope, valley, non-runoff, peak
- Type of surface deformation: troughs, troughs with small edges or clefts, straight subsidences, subsidences with spurs, symmetrical terrace subsidences, asymmetrical terrace subsidences, subsidences with overdepth, scattered subsidence craters, in-line subsidence craters



1 – names of localities, and field numbers, 2 – large transformed areas

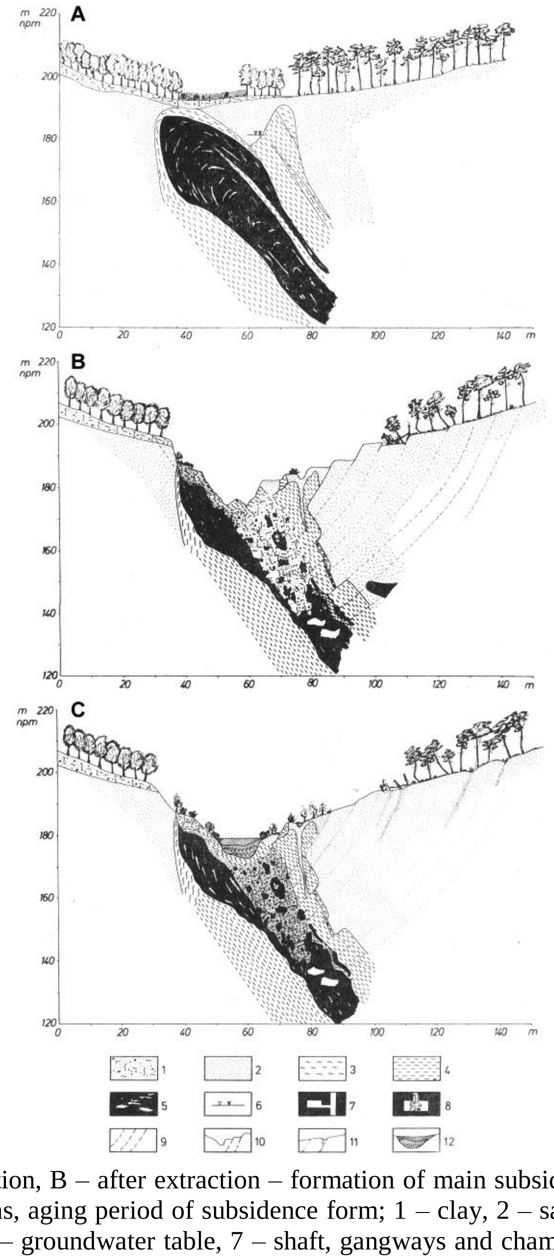
Fig. 1. Distribution of mining fields in the area of the Middle Oder Region [Kozacki 1980]

As written above, the sozological and hydrographic database required adaptation and further complementation, particularly with information which would permit to take into account the description and classification criteria adopted by Kozacki [1980] in the assessment of the **current** condition and functioning of the mining areas of the Middle Odra Region. What is especially important in the construction of this part of the system is the remote sensing methods and field research, which supported by the GPS technology will permit to determine the current geometry of subsidences, excavations and dumping grounds, their surface area, depth or height, condition of landslides, scarps, places subjected to inundation and land cover structure. The information system prepared this way will make it possible to carry out research tasks which in reference to the existing mining areas will consist in verifying the model of environment transformation during the developing underground lignite extraction [Kozacki 1980] based on updated data. The model shows all phases and the related extraction processes in a dynamic manner. Figure 2 presents three selected phases. The first one shows an area before mining operations. The second one permits to observe the consequences of underground mining, which are manifested on the surface by subsidences, subsidence craters and clefts. A characteristic element here is the cut surface formed as a result of relieved tension on the orogen containing a post-extraction hollow. The contact between the cut surface and the land surface starts geomechanical processes which result in the formation of landslides, horsts and clefts. The boundary of the new post-mining form tends to expand and as a consequence creates an active boundary zone stretching beyond the mining area.

The last phase presents the processes of accumulating formations in subsidence depressions and spreading vegetation onto scarps which aims to create a new balance in the geocomplex formed.

Detailed data on the functioning of post-mining areas will make it possible to identify which of the processes have been completed and which are still active. The premises will permit to answer the question whether the evolution in post-mining areas following previous abrupt processes (linked with underground extraction) stopped, which of the post-mining forms achieved the secondary balance and whether they can be deemed stable.

The results of the research can become an important argument in a discussion on whether post-mining areas of the Middle Odra Region should be included in planned reclamation or whether it is more beneficial when shaping sustainable landscapes to let the natural processes operating at the point of contact of anthropogenic geocomplexes (primary and secondary) work.



A – before extraction, B – after extraction – formation of main subsidence, C – secondary transformations, aging period of subsidence form; 1 – clay, 2 – sand , 3 – loam, 4 – silt, 5 – lignite, 6 – groundwater table, 7 – shaft, gangways and chambers, 8 – filling of chambers and gangways, 9- tension and cleft lines, 10 – terrace transformation of slopes, 11 – subsidence craters and scouring places, 12 – accumulation of formations in substinence depressions

Fig. 2. Diagram of environment transformation during the development of underground lignite mining [Kozacki 1980]

Analyses will focus on large areas transformed by mining (fig. 1) situated near Sieniawa, Smogóry, Łęknica (Łuk Mużakowski) and Mirostowice. The surroundings of Sieniawa are a very special research object as this is an area where the influences of underground and surface lignite mining meet. Using data on the functioning of this mining area in the spatial information system being developed will permit to apply it to forecast environmental changes in potential mining areas.

4. FORECASTING CHANGES IN THE NATURAL ENVIRONMENT IN THE PLANNED LIGNITE MINING AREAS (GUBIN – MOSTY DEPOSIT) – APPLICATION OF THE SPATIAL INFORMATION SYSTEM FOR POST-MINING AREAS

The structure of the spatial information system described above permits to identify the relations, mutual influence between elements of the environment, which condition the manner in which a particular fragment of geographical space (geoecosystem) functions. Simultaneously, is shows a system of relatively uniform geoecosystems, called landscape, which determines the specificity (qualities, features) of an area. Such structure of the database constitutes a ready-made tool for comprehensive geoenvironmental and landscape research in the currently existing and future mining areas of the Middle Odra Region in the following research aspects:

- quantitative, through:
  - employing methods of a quantitative description of the structure (composition and configuration) of the mining landscape, primarily landscape metrics, to document landscape changes, its geodiversity assessment, consistence of the composing elements which form primary and secondary landscapes and identify those landscape metrics which are best indicators of the landscape system stability
  - employing in the functional analysis of mining areas the synthetic index of ecological efficiency as an indicator of balance in the mining landscape. The informative potential of the system permits to develop around 90 diagnostic **indices of functional features and disturbances** which restrict the functioning of the analysed geosystem. Diagnostic indices represented in the form of a synthetic index constitute a measure of effectiveness (efficiency) taking into account the resources of the ecosystem and the degree of their transformation. The measure defines the degree of balance between the processes which were disturbed by anthropogenic pressure.
- systematising: permits to classify the analysed geosystems according to the ecological efficiency criterion [Fagiewicz 2007] and identify areas subjected

to the strongest anthropogenic pressure as well as reference areas with the best assets

- forecasting, through:
  - **employing studies on structural and functional transformations of geosystems connected with surface lignite mining to forecast changes in areas with lignite deposits, which are a potential source of resources (Gubin-Mosty deposits). The contents of the geographic information system combined with the aforementioned studies constitute a tool for making *environmental impact reports for enterprises* both at the stage of geological licensing and extraction.**
  - **employing methods of anthropogenic geosystem assessment to optimise the structure of newly created post-mining landscapes through identification of reclamation criteria and trends, determining how to shape the landscapes so as to minimise the influence from lignite mining.**

5. SUMMARY

The idea to adapt the spatial information system in a form of numerical sozological and hydrographic maps, scale 1:50,000 and create based on its structure a uniform system supplied and updated on a local level (1:10,000) seems well-grounded. The implementation of an extended form of an existing and functioning system is far easier than seeking new solutions. The system registers spatial changes that are most significant to landscape ecology, is a source of current data on the functioning of the natural environment and permits to prepare measures quantifying the strength of anthropogenic pressure, which is important in research of an application nature. It is a database that is made accessible for the purpose of various planning studies. A wide spectrum of research problems presented in this paper which can be solved using the proposed spatial information system proves it to be a unique tool supporting the process of environment management in mining and post-mining areas.

6. ACKNOWLEDGEMENTS

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SOZOLOGICZNE I HYDROGRAFICZNE MAPY POLSKI JAKO PODSTAWA DO ANALIZY ZMIAN ŚRODOWISKA NA TERENACH GÓRNICZYCH

Streszczenie

W nadchodzących dziesięcioleciach znaczne zasoby własne węgla brunatnego stanowić będą rolę stabilizatora bezpieczeństwa energetycznego naszego kraju. Fakt ten świadczy o znaczeniu problematyki obszarów górniczych w przestrzeni geograficznej oraz wiąże się ze wzrostem zapotrzebowaniu na dane dotyczące ich struktury i funkcjonowania. W opracowaniu zwrócono uwagę na potencjał informacyjny bazy danych sozologicznych i hydrograficznych oraz utworzonej na ich podstawie numerycznej Mapy sozologicznej i Mapy hydrograficznej Polski w skali 1:50000. Stanowią one opracowany, wdrożony i funkcjonujący system informacji przestrzennej, realizujący wszystkie zadania GIS. Zaproponowano adaptacje i rozwinięcie tego systemu do poziomu szczegółowości umożliwiającego jego aplikację w kompleksowych studiach geośrodowiskowych i krajobrazowych na terenach górniczych i pogórniczych Środkowego Nadodrza. Odpowiednio ukształtowana struktura systemu informacji stanowi unikatowe narzędzie diagnozowania zmian środowiska przyrodniczego obszarów górniczych w aspekcie ilościowym, systematyzującym i prognostycznym oraz element wspomagający podejmowanie decyzji w zakresie planowania przestrzennego.