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Environmental aspects of relief transformation (Silesian Upland, Southern Poland)

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ABSTRACT

The geological structure and the occurrence of mineral resources in the Silesian Upland in a significant way influenced the development of industry and caused transformation of every landscape element, among others changes in relief and therefore the formation of anthropogenic landforms. The paper focuses on environmental aspects of relief transformation in the Silesian Upland. The author described aesthetic, geomorphological, hydrological, climatological, pedological and biological aspects on the base of representatives of two groups of landforms– consciously created by human being and being an unintentional effect of human activity (of secondary character). All analysed landforms are new elements in relief, in majority of cases being in disharmony with their neighbourhood. They are alien to the landscape and disturb the equilibrium in the nature. It was proved that they strongly influence water and climatological conditions and soil cover. But sometimes the anthropogenic landforms can be perceived as advantageous for the nature, especially in case of subsidence depressions because of development of aquatic and hydrophilous species and in case of spoil tips due to spontaneous development of vegetation cover. The nature easily adapts to new environmental conditions (process of natural succession and independent introduction of species for new habitats). In these terrains the increase in biodiversity was observed.

KEY WORDS: sandpit, spoil tip, subsidence depression, relief, Silesian Upland

1. Introduction

The Silesian Upland is known to be an area of ecological disaster, because of huge changes in the environment caused by long-lasting period of industry development, most of all coal-mining and iron metallurgy. From many changes, the transformation of relief seems to be the most important, because man-made landforms refer to large area, are very visible in the landscape and influence other elements of the environment. They also vary in time and area. The anthropogenic landforms are intentionally created by man (direct impact) or they are an unintentional effect of his activity (indirect impact) – in cooperation with economic and natural processes (e.g. ŻMUDA, 1973; HAIGH, 1978; HARNISCHMACHER, 2007). PODGÓRSKI (2001) classifies anthropogenic landforms as an effect of direct influence of human being of constructive, destructive and modifying character and as an effect of morphological processes induced or directed by human being, whereas MIGOŃ (2006) divides man-made landforms into intentional and of secondary character (they are inseparable, not necessarily intentional consequence of human activity). To the first group belong among others: spoil tips, sandpits, embankments, whereas to the second one e.g. subsidence depressions.

The purpose of this paper is to analyse the environmental aspects of relief transformation in the Silesian Upland, from aesthetic, geomorphological, hydrological, climatological, pedological and biological points of view. In this respect, the following representatives of anthropogenic landforms in the Silesian Upland were identified: – consciously created by human being – convex: spoil tips, concave – sandpits, and landforms being the unintentional effect of human activity – subsidence depressions.

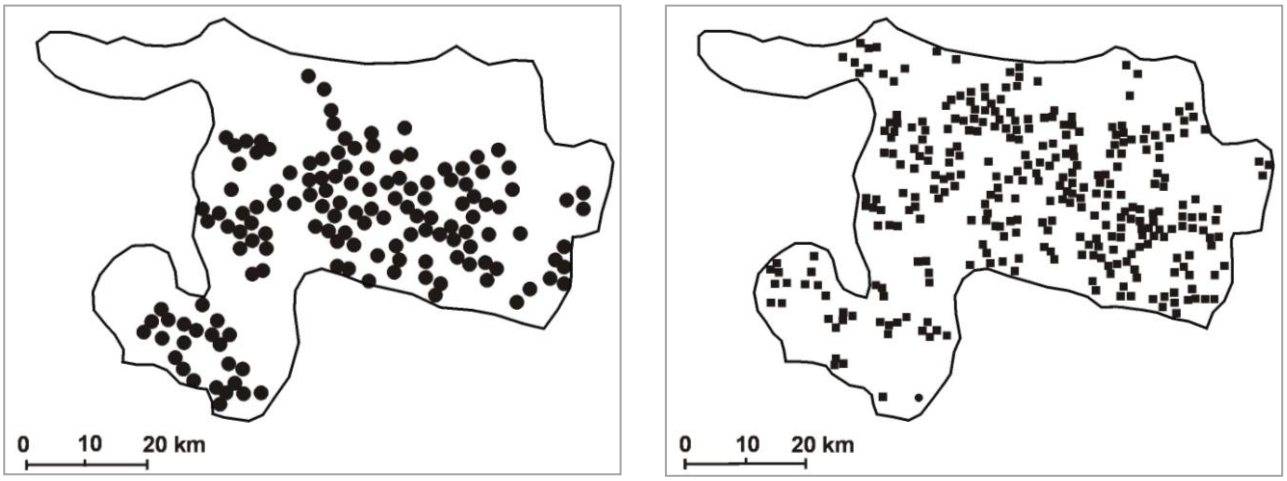
2. Study area

The macroregion of the Silesian Upland is located in southern Poland (KONDRACKI, 2002) (Fig. 1).

Fig. 1. Location of the study area

The geographical environment of this area during some last hundred years has been transformed significantly. But the largest changes refer to terrain relief. The underground mining of black coal and surface exploitation of mineral resources were of decided importance in relief transformation.

Mining activity has caused the formation of many new concave (negative) and convex (positive) landforms. Due to underground exploitation of black coal by means of "fall of roof" method, depressions of different sizes and shapes originated. Surface exploitation of mineral resources also caused the formation of widespread depressions (Fig. 2A). The largest sizes are typical for excavations after exploitation of stowing sand. The development of mining also caused the formation of many spoil tips. They occupy significant areas (Fig. 2B), especially in the central part of Silesian Upland, and the largest of them reach the height of more than 100 metres.



A B

Fig. 2. Distribution of excavations (A) and spoil tips (B) in the Silesian Upland (made by the author on the base of aerial photos and topographic maps)

3. Methods

Investigations were aimed to determine the influence of artificial landforms on selected elements of the environment. They required interdisciplinary researches: of field (observation) and study character. The author used various sources of information to receive a clear picture of changes in relief. The field work and literature collecting was conducted in the years 2010-2014. Within study works the visual evaluation of aerial photos and topographic maps from different time periods was made. Documenting source materials and literature were also analysed. So, this work has a character of review of hitherto written and available literature supported by case studies from the Silesian Upland.

4. Environmental aspects of relief transformation

The human impact into the relief has been widely described for the last 150 years (e.g. MARSH, 1865; FISCHER, 1915; SHERLOCK, 1922; SPENCER & HALE, 1961; ZAPLETAL, 1968; HAIGH, 1978; KLIMASZEWSKI, 1978; NIR, 1983; PODGÓRSKI, 2001; MIGOŃ, 2006; SZABÓ ET AL., 2010; CHARTIN, 2011; MANEA ET AL., 2011; GOUDIE, 2004' 2013). In the Silesian Upland researches on anthropogenic landforms began in the mid-20th century and have being continued till now (e.g. HORNIG, 1955; ŻMUDA, 1973; JANIA, 1983; SZCZYPEK, 1995; JANKOWSKI & HAVRLANT, 1999; JANKOWSKI, 2000; PELKA-GOSCINIAK, 2007; PELKA-GOSCINIAK ET AL., 2008; DULIAS, 2013). They mainly consisted in classification of landforms and qualitative mapping. Some works referred to

quantitative and temporal changes in distribution of man-made landforms (e.g. DULIAS & JANKOWSKI, 1990; SZYPUŁA, 2011, 2014). In this paper the author focuses on environmental aspects of relief transformation on the example of sandpit, subsidence depression and spoil tip.

4.1. Sandpits

The most known deposits of sands are located in eastern part of the Silesian Upland (SZCZYPEK, 1995; DULIAS, 2010, 2013). They occupy large area within Basin of Biskupi Bór. In period of exploitation sandpits had geometrical shapes, steep slopes and flat bottoms. They were about 15-20 m deep (DULIAS, 2013).

The beginning of sandpit in Bukowno dates from 1954 but its intensive development took part till the beginning of the current century. In 2004 the area of active and inactive excavations amounted to about 31 km^2 and the main depth of excavations exceeded 20 m (DULIAS, 2010). The sandpit exploited the Quaternary sand, used as stowing material to fill empty places in coal mines. In the last years this area underwent land reclamation in forest and partly water direction (DULIAS, 2010). The active exploitation caused the transformation of every component of the landscape – relief, surface and underground waters, soil and vegetation cover and local climate (WÓJCIK, 2006).

Aesthetic and geomorphological aspect. The sandpit is a new artificial landform, being in clear disharmony with its surroundings (Fig. 3). In consequence of human activity sandy bottom and slopes were uncovered and were subject to natural morphogenetic processes, mainly aeolian ones. Wind modelled the bottom and slopes of excavation and created a lot of different accumulation and deflation forms. The most interesting was the modern scarp dune, which existed on eastern slope of sandpit. Another aeolian landform- sandy cover was created due to introduction of trees and shrub. It was developed on northern slope of sandpit. Vegetation introduced by man increased sand accumulation and limited the spatial development of this form. Initial dunes of different shape and size were also developed. They were created with contribution of willow *Salix acutifolia* introduced by man. The northern part of bottom in the eastern fragment of the sandpit was covered with small accumulative forms. They were "sand shadows" creating themselves behind clumps of the herbaceous plants, most of all – *Calamagrostis epigeios, Elymus arenarius* and *Corynephorus canescens*. There were also extensive deflation planes and pavement, created in cooperation with gravel (PEŁKA-GOŚCINIAK & SZCZYPEK, 2014). Indirectly anthropogenic character also have relatively weakly marked processes of rill – and sheetwash. Their results were visible at the sandpit bottom west of aeolian landforms. Within sandpits happened landslides within steep and weakly stabile slopes located above the zone of exploitation (PEŁKA-GOŚCINIAK & WAGA, 2004; PEŁKA-GOŚCINIAK, 2006).

Hydrological aspect. Exploitation of sand on a large industrial scale forces the man to drain underground water to reach the deeper located strata. Due to this activity in the lower part of the sandpit many drainage channels have been formed. River beds were taken into the system of artificial canals or even liquidated, sometimes their direction was also changed. Draining of water from sandy beds caused the lowering of underground water horizon in the nearby area. The extensive cone of depression has been created. It caused the impoverishment of water resources and made the development of already devastated forest more difficult. It also caused dryness of soil cover and undergrowth.

Climatologic aspect. The climatic changes, observed in the neighbourhood of sandpit, are as follows – change in albedo, change of wind directions (canalised wind direction), increase in wind velocities, increase in temperature, large 24 hours' temperature fluctuation, occurrence of cold air masses and sand storms.

Pedological aspect. To prepare place for stowing sand exploitation it was necessary to cut forest and remove soil cover (RADOSZ, 1991). In the case of sandpit at Bukowno the soil cover was accumulated in the determined place to use it in the further process of reclamation. The soil cover was overdried and polluted.

Biological aspect. Abandoning of land reclamations caused the spontaneous introduction of vegetation. It is clearly visible in the oldest parts of sandpits. In the majority of excavations the early stages of natural vegetation succession run in the similar way. At initial stages loosely distributed psammophylous grasses with *Thymus pulegioides, Hieracium pilosella, Corynephorus canescens, Festuca rubra, Koeleria glauca, Poa compressa, Bromus secalinus. Erigeron acer, Erigeron canadensis, Rumex acetosella, Sedum acre* are observed. At reclaimed areas grasses are compact and built of one- or two species. Later the vegetation origins from self-seeding and neighbouring areas. Along draining ditches natural succession is also visible. There characteristic zonal arrangement of vegetation is observed (associations with rushes

Magnocaricion, peatland associations *Caricetalia fuscae*, wetland alder forests and willow bushes (SZWEDO ET AL., 1995) (Fig. 4).

Owing to intentional reclamation works, especially in water direction and thanks to natural vegetation succession the gradual landscape restoring follows. It is considered to be very advantageous for the natural environment because aquatic, wetland and peatland vegetation developing at artificial habitats do not differ in its composition and character from analogous occurring in natural ones (SZWEDO ET AL., 1995). In sandpits the occurrence of rare and protected species *Myricaria germanica, Centaurium umbellatum, Parnasia palustris, Equisetum variegatum* and *Epipactis palustris* is also observed (in the outflow of ground water of spring character or at wet sands) (e.g. CZYLOK & RAHMONOV, 1998).

Fig. 3. Active sandpit in Biskupi Bór near Bukowno (*J. Pełka-Gościniak, June 2010*)

Fig. 4. Vegetation at the bottom of sandpit in Bukowno – near draining canal (*J. Pełka-Gościniak, June 2010*)

4.2. Subsidence depressions

They originate as a result of gradual lowering of terrain surface over mined-out coal beds, which are not filled by stowing material. They appeared in the relief probably at the beginning of the 20th century, but period of the largest lowering of terrain surface happened in the 1960s.-1980s. In the Silesian Upland the predicted depth of subsidence basins had to reach even 35 m – in Rybnik Coalfield (Fig. 5). But at present the deepest subsidence depression is located in Bytom–Miechowice and it is 30 m deep (DULIAS, 2013).

Aesthetic and geomorphological aspect. Process of subsiding causes the big transformation of relief. It causes gradual lowering of terrain surface and creates depressions, which are new element in the landscape. When they are filled with water they can be positively perceived by neighbouring population, especially in case of the Silesian Upland, which is characterised by deficit of surface waters (PELKA-GOSCINIAK, 2007). From geomorphological point of view one should also mention of change in longitudinal profile of rivers.

Hydrological aspect. Subsidence cause change in course and parameters of channels in result of translocation of watersheds, including the remodelling of channels of lost streams and formation of channels of new streams. There are also changes in catchment area, river flow and runoff (JANKOWSKI, 1986). Depressions, originated in result of terrain subsiding, under advantageous conditions automatically fill with water, thus increasing the retention. Accumulation of precipitation-snowmelt waters in subsidence basins without drainage causes the formation of pseudo- drenched areas and formation of water reservoirs (JANKOWSKI ET AL., 2001) (Fig. 6). Water escapes to lower-located water-bearing horizons due to cutting of horizons insulating water-bearing horizons. The following effect can be a change in hydrochemical properties of underground waters in result of mixing of waters from different water-bearing horizons. In places, where rivers flow through subsidence depression, it is necessary to build protection embankments and hanging channels.

Climatologic aspect. When depressions are filled with water then of changes in topoclimate follow: formation of basins of the thermal inversion and increase in humidity.

Pedological aspect. Subsidence depressions cause changes in water conditions of soil: swamping, gleying, accumulation of silt and increased rise in biomass and next in humus.

Biological aspect. Wet subsidence depressions fulfil the special role for the animated nature. Their formation causes the largest species richness.

There was observed the increase in biodiversity of biotopes and formation of new floristic-faunistic complexes. He main community covering shores of water reservoirs in subsidence depressions is *Typhetum latifoliae*. Such areas make potential habitat for aquatic-marshy birds and amphibians (CEMPULIK ET AL., 2002; PEŁKA-GOŚCINIAK & WAGA, 2004; PEŁKA-GOŚCINIAK, 2006, PELKA-GOSCINIAK ET AL., 2008).

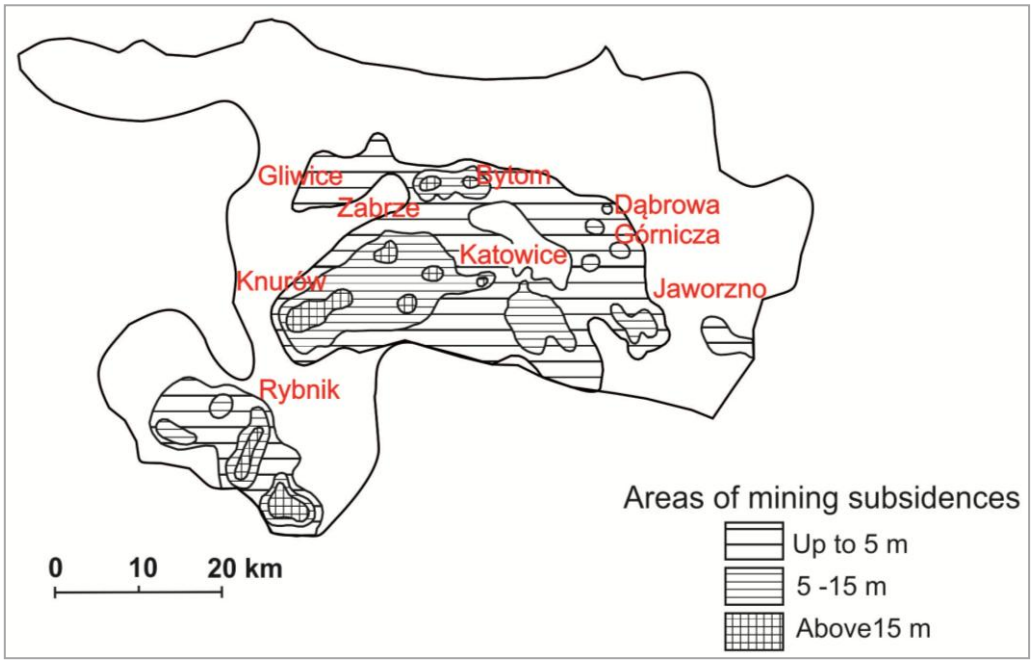


Fig. 5. Range of mining subsidences within the zone of black coal exploitation in the Silesian Upland (after Dwucet et al., 1992, changed)

Fig. 6. Subsidence depression in Jastrzębie Zdrój (*J. Pełka-Gościniak, June 2010*)

4.3. Spoil tips

They are the most popular anthropogenic landform in the Silesian Upland and have different size, height, area and shape. They are mainly connected with black coal mining. The highest spoil tip is 101 m high ("Charlotte" in Rybnik Coalfield) whereas to the largest belong spoil tips of mine "Knurów"(1,7 km^2) and "Sośnica" (1,5 km^2). The last one is also the largest in respect of capacity (25 million m^3) (DULIAS, 2013).

Aesthetic aspect. In majority of cases spoil tips are in clear disharmony with the nearby area and they are negatively perceived by the population. They disfigure landscape and are very hazardous for people health. Sometimes they decide that the landscape has a "lunar character".

Geomorphological aspect. Spoil tips are new elements in the relief. They cause geomechanical changes in earth surface. At spoil tips it is possible to observe natural geomorphological processes, among others rill wash (Fig. 7), sliding and wind activity (KOZYREVA ET AL., 2004).

Hydrological aspect. Waste accumulated on spoil tips and leaching of toxic substances are large hazard for the quality of surface and underground waters. They can cause the increased salinity and acidification (MOLENDA, 2006, 2013).

Climatological aspect. Spoil tips are the source of secondary atmospheric air pollution (blowing out of dusty elements). They can change wind direction because they make the barrier.

Pedological aspect. Spoil tips are also the source of soil contamination. Soils are very often characterised by acidification (PATRZAŁEK, 2010). The degradation of upper soil horizons under the influence of drying, impoverishment in biomass and slowing down of matter decomposition processes are also observed. The soil of spoil tip is much poorer than the common soil. It is characterised by a lack of nitrogen and phosphorus, which are necessary for vegetation growth. Due to specific albedo (dark surfaces) and high temperature plants die out.

Biological aspect. Spoil tips disturbs the ecological equilibrium. But sometimes they create a new chance for the nature. Sometimes anthropogenic habitats originate. They are the place where halophilous, xerothermic and hydrophilous species can create. It was stated that on spoil tips about 600 plant species can occur, including 300 species of vascular plants, 45 species of capped mushrooms, 13 species of Bryophyta. Investigations on vegetation at spoil tips showed that the most popular communities are as follows: *Tussilago farfara*, *Calamagrosis epigeios*, *Solidago serotina*, *Artemisia vulgaris*. Flora and vegetation on tips is unique and to a small degree similar to flora and vegetation of the neighbourhood (przyroda.katowice.pl/pl/czowiek-i-przyroda/.../haldy/45-haldy; ROSTAŃSKI, 2006) (Fig. 8).

Fig. 7. Processes of rill wash at spoil tip of mine "Murcki-Staszic" in Katowice Kostuchna (*J. Pełka-Gosciniak, November 2014*)

Fig. 8. Vegetation covering the spoil tip of mine "Murcki-Staszic" in Katowice Kostuchna (*J. Pełka-Gościniak, November 2014*)

5. Conclusions

All analysed landforms are new elements in relief, being in clear disharmony with surrounding areas. They are alien to the landscape and disturb the equilibrium in the nature. It was proved that they strongly influenced water and climatological conditions and soil cover.

But sometimes the development of new landforms can be perceived as advantageous for the nature, especially in case of subsidence depressions (development of aquatic and hydrophilous species) and spoil tips (spontaneous succession of vegetation). The nature easily adapts to new environmental conditions through the process of succession and independent introduction of species for new habitats. In general, within three analysed landforms the enrichment of species was observed. Climatological and hydrological aspects also seem to be advantageous, especially nearby water reservoirs in subsidence depressions or sandpits reclaimed in water directions.

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