The application of GIS tools (ILWIS) for landslides susceptibility analyse in the Polish Outer Carpathians – a case study of the Mszana Dolna area.

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The Outer Carpathians area constitutes part of Poland with the biggest landslide hazard. The Carpathians occupy only 6% of the Polish area, but 95% of all landslides in the country, which amount is about 23 000, occur here (pgi.gov.pl).

The landslide development in this area is favoured by the geological structure of basement - flysch deposits, usually with a large percentage of shale and sandstone-shale beds, as well as character of the relief – high relative altitudes and slope gradients (e.g., Poprawa & Rączkowski, 2003). The structure of the Carpathians: tectonic anisotropy of rock massifs and their fragmentation is also an important factor (Margielewski, 2001). The Outer Carpathians are characterised by the complicated tectonics with domination of forms connected with folding accompanied by longitudinal forms of discontinuous tectonics (overthrusting) and faulting of all massif.

The analysed Mszana Dolna area has complicated geological setting. From the south-east to the north-west it is crossed by the boundary of the two biggest units of the Outer Carpathians: overthrusting of the Magura Nappe onto the Silesian Nappe. In the northern part of the field deposits of the Sub-Silesian Nappe outcrop as tectonic windows of the overthrusting of the Silesian Nappe. A fragment of one of the biggest tectonic window in the Polish Outer Carpathians – Mszana Dolna tectonic window – occurs in the southern part of the field, where deposits of the Dukla Unit crop out. The lithology of this area is typical for the Outer Carpathians: layers of sandstone, shale, mudstone and marl occur in different proportions. The southern part of the area (Magura Nappe) is built of more resistant to weathering rocks, with a bigger amount of sandstone, than the northern part (Silesian and Sub-Silesian Units), which is visible in the morphology – all highest elevations are situated in the southern part of the area.

Creation of the map of landscape susceptibility as far as geological structures is concerned and connected with its morphology and hydrogeology, was the aim of the presented analysis. On the basis of the literature (Zabuski *et al*., 1999; Długosz, 2011) the six factors which have the main influence on the landslide development in the Carpathians were selected for the analysis: 1) lithology (shale to sandstone ratio); 2) morphology (slope angle in degrees); 3) depositional dips of bedding; 4) tectonics (occurrence of overthrustings and scales); 5) hydrogeological conditions (underground water level); 6) distance from the geological formations boundaries.

The Mszana Dolna sheet of the Detailed Geological Map of Poland 1: 50 000 (Burtan, 1974), explanations (Burtan, 1978), tectonic sketch, and hydrological sketch to this map, as well as digital elevation model (DEM) of this area were used. Digitalization of maps and analysis, both vector and raster processing, were realized in ILWIS 3.4 (Integrated Land and Water Information System) software.

Maps of landslide hazard with regard to conditions occurring in the field were created for all of the six factors. Afterwards, all maps were summarized, taking the coefficients of relevance for individual factors into consideration (coefficients on the basis of: Zabuski *et al*., 1999). The resultant map was reclassified: received results were grouped to 4 classes, where the first class constitutes slopes not susceptible to landsliding and where the fourth class is comprised of slopes with high and very high landslide hazard (after: Zabuski *et al*., 1999).

The presented analysis showed that a large part of the studied area belongs to the class with the lowest hazard with regard to natural factors, like geology, morphology, tectonics, and hydrogeology. However, landsliding could develop even there if conditions of slopes load were worsened, as a result of following factors: construction projects, embankments, road cutting, seismic tremors, and blasting works. Areas with higher landslide hazard also occur in the studied field, and there landslides may be developed even as a result of medium or small loading of slopes.

Comparison of the analysed results and the available data about the existing landslides (Burtan, 1974; maps of the System of the Landslides Protection of the Polish Geological Institute – geoportal.pgi.gov.pl) showed general accordance between localisation of the present landslides and occurrence of the areas of the highest landslide susceptibility on the resultant map of the presented analysis. Nevertheless, it must be noticed that the resultant map shows only potentially endangered areas, whereas development of landslides usually depends on occurring or not occurring of direct, active factors, like precipitation, seismic tremors or anthropogenic activity (Zabuski *et al*., 1999). Moreover, the comparison also showed the occurrence of some existing landslides in areas which display reduced susceptibility to landsliding according to this analysis. This can be explained by intensive anthropopression or influence of some factors which are not considered in the analysis.

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