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Conditions of landslides development in the Rożnowskie Lake region based on Airborne Laser Scanning (ALS) data analisys.

Abstract:

The aim of this doctoral dissertation was to determine the geological reasons for the activation of landslides in 2010 and later in the area of Rożnowskie Lake. For this purpose, Differential Digital Terrain Models (DDM) generated on the basis of ALS data were used. This paper describes the general usefulness of DDM in the study of landslides, acknowledging the errors that may arise during their analysis. Differences in determining the activity of landslides on the basis of field observations and DDM results were pointed out, emphasizing the importance of the correct assessment of activity in the study of the exisiting causes of landslide development. The reasons for the activation of mass movements were investigated mainly on the basis of the elements of the landform and geological settings, which, according to the author's assumptions, has the greatest impact on the development of landslides among the passive factors. Study area is characterized by a complicated geological structure, represented by four tectonic units (Silesian Nappe, Grybów Nappe, Michalczowa Nappe, Magura Nappe) with different lithologic setting.

Data used in this study descends from four airborne laser scannings carried out in the area of research in the period 2010 – 2019. In the first stage, the ranges of landslides were determined on the basis of archival materials, field observations and Digital Terrain Model (DTM. The processed ALS data enabled generating DDM's on the basis of which active zones were determined. The accuracy of the obtained DDM's was determined by comparing them with the results of instrumental monitoring on selected landslides. It also allowed to determine the impact of depth displacements on deformation of the terrain surface. The determination of the actual activity of landslides was the basis for the statistical determination of the causes of their development in the area of Rożnowskie Lake. For this purpose, the results of DDM analyzes were used, together with calculations of the percentage share of landslides in a given lithological unit, calculation of the displacement index and calculation of landslide susceptibility using the WoE (Weight of Evidence). In this work the Global Mapper 21, ILWIS 3.4 and Las Tools software were used, which enabled DTM processing, DDM calculation, preparation of passive factors maps and calculation of landslide susceptibility.

The state of diagnosis of landslides in the area of Rożnów Lake in the literature begins with a study prepared in 1935 for the construction of a water dam in Rożnów and several post-war works. In the last decade, in the study area, the registration of landslides was carried out under the SOPO project and a number of geological documentations. In recent years, there has been a significant increase in the number of identified landslides in the vicinity of Rożnowskie Lake. As a result of field research and analyzes, 1275 of them were designated for this dissertation. The largerst lanslide form covers an area of more than 100 ha, but most of the landslides in the study area do not exceed 1 ha. The most recorded landslides are compound slides, much fewer landslides were classified as rotational and translational slides. Single rockfalls and earthflow slides or debrisflow slides occure in th area of research. The average slope of the land surface affected by mass movements is nearly 20°, while landslides with an area of more than 2 ha are usually characterized by a much lower slope of 8-14°.

The results of DDM analyzes from 2010 – 2019 indicated that after the heavy rains that occurred in 2010, about 790 landslides could have been activated in the area of Rożnowskie Lake. Most of them were activations within older landslide forms, only in 5.5% of cases the expansion of borders was recorded. Newly formed landslides composed 1.6% of the total number of landslides

and were logged only on DDM from period immediately after the catastrophic precipitation in 2010. As a result of the analysis, a large impact of thin-bedded formations on the development of landslides and an increased role of thick-bedded formations (especially the Ciężkowice Sandstones) in the period of long-term rainfall, which occurred in 2010, was noticed. Tectonics plays an important role in the development of landslides. This is confirmed by the fact that most of the landslides, within which in the period 2010 – 2019 there were at least two activation times, were developed in tectonically disturbed zones. Many of them are located in the area of the Przydonica overlap and the overlap of the Magura Nappe onto the Silesian and Grybow Nappe. DDM also made it possible to calculate the displacement index that was defined for the purposes of the study as the ratio of the volume of surface deformations on landslides in given litology unit into surface a given litology unit. The highest index for all the performed DDMs was obtained for the hierogliphic beds of the Silesian Nappe. The high position of the Ciężkowice sandstones also deserves attention, but only in the period right after the catastrophic precipitation in 2010.

Comparison of the results of DDM analysis with the results of instrumental monitoring of selected landslides allowed to determine the accuracy of DDM at the level of 25-35 cm. When comparing the results of inclinometric measurements with DDM, it was noticed that the displacements that occurred below 8.5 m below the surface point are not reflected on the ground surface.

It was assumed in this study that to determine the causes of the current development of landslides, an objective assessment of their activity is important, and the data resulting from archival and field (often subjective) evaluation may turn out to be insufficient. The compliance of the ALS raids periods with the landslide mapping period in the south-eastern part of the study area, as part of the SOPO project, made it possible to compare the existing data with the results of DDM analyses. The results were confirmed in 67% of cases. Errors that may arise from DTM and DDM analyses are also listed. In this study are presented the examples of landslides where anthropogenic activity led to changes visible on DDM, which could lead to an incorrect assessment of their activity.

In the final part of the study, the landslide susceptibility was calculated using the WoE method. The following passive factors were taken into account in the calculations: lithology, distance from major tectonic dislocations, landuse, hillside exposure, slope, absolute height, distance from watercourses and the presence of lithological units borders. Statistical reasons for activating landslides were calculated in three variants: taking into account all activated landslides in the period 2010 - 2019, landslides activated at least twice and zones of surface deformation. The results indicate the highest probability of new movements in the area of Bilsko, Tęgoborze, Znamirowice, Gródek nad Dunajcem, Bartkowa-Posadowa, Przydonica, Zbyszyce, Kurów and the eastern areas of Roztoka-Brzeziny.

The research showed a strong relationship between the activation of landslides and lithology, the presence of boundaries of lithological units and tectonics. Landuse, hillside exposure, slope, absolute height or distance from watercourses are much less important. The most susceptible to landslides are the compositions of Hierogliphic beds of the Silesian Nappe, Inoceramic beds of the Magura Nappe and areas where there is contact of variegated shale with the Ciężkowice Sandstones or compositions of Hieroglyphic beds. The conditions for the development of landslides vary depending on the amount of precipitation. In less rainy periods, thin-bedded forms are of significant importance. In the event of catastrophic precipitation, the greatest deformations may occur within the Ciężkowice Sandstones. The analyses confirmed the usefulness of the ALS data, in particular DDM in the study of the current causes of the development of mass movements. Despite the accuracy of RMT with an error of 25-35 cm, correctly analyzed allow to determine the main trends in the development of landslides in large areas.