29th SCEgeo Conference „Surveying, Civil Engineering and Geoinformation for Sustainable Development”

June 22-24, 2022 – Wrocław (hybrid), Poland

Wrocław University of Science and Technology

Department of Geodesy and Geoinformatics

APPLICATION OF MOBILE LASER SCANNING FOR THE ASSESSMENT OF SLOW-MOVING LANDSLIDE ACTIVITY – A CASE STUDY FROM THE SUDETY MOUNTAINS (SIEDLĘCIN, SW POLAND)



Damian KASZA[1] **Jarosław WAJS**[1] **Aleksander KOWALSKI**[2]

[1] Wrocław University of Science and Technology, Faculty of Geoengineering, Mining and Geology, 27 Wyb. Wyspiańskiego St., 50-370 Wrocław, Poland, damian.kasza@pwr.edu.pl (D.K.), jaroslaw.wajs@pwr.edu.pl (J.W.)

[2] The Polish Geological Institute - National Research Institute, Lower Silesian Branch in Wrocław, 19 Jaworowa Av., 50-122 Wrocław, Poland,

INTRODUCTION

Landslides are one of the main worldwide natural hazards that cause several thousand catastrophic damages to human infrastructure every year. Landslides are predominantly triggered by strong rainfalls or earthquakes, but can also be related to human activity, e.g. deforestation, engineering structures, mining activity, or even interference in slope stability. In the case of the latter, it is often associated with fatal accidents. In the case of Poland, over 90% of landslides identified so far are located in the Carpathian Mts. Area. However, the Sudetes (SW Poland) are also an interesting research area in this respect. In the presented study, two selected examples of landslides were described, triggered both by natural- and human-induced factors. Both landslides are located in the Western Sudetes in the vicinity of Siedlęcin village. The studied landslides occur within unconsolidated Quaternary glacial deposits. Human-induced reactivation of mass movements within the landslide area has been observed since the early 1990ties. One of the studied landslides has repeatedly damaged an asphalt road, posing a genuine threat to traffic. As part of the fieldwork, several laser scanning sessions were performed, with a quarterly interval using the hybrid Riegl VZ-400i scanner, both in stationary and mobile modes. The obtained datasets in the form of a point cloud were classified in the RiSCAN PRO environment in order to extract points representing the terrain surface without elements of the land cover (e.g. vegetation). The final product of the elaboration is a set of differential maps based on LiDAR data of the ISOK project (for the first measurement session) showing the range of mass movements over the years 2011-2019.

RESEARCH AREA

The research area is located in the western part the Sudetes - medium attitude mountain range located in Central Europe, SW Poland (Fig. 1). This area is characterized by a hilly landscapes with heights not exceeding 550 m a.s.l. Investigated landslides have developed in the western slopes of Zadnia hill (442 m a.s.l.).

This area is characterized by complicated geological structure of the bedrock which is capped by a thin, unconsolidated Quaternary deposits. Metamorphic basement of the study area is represented by low- to high-grade metamorphic rocks belonging to two geological units: Izera Metamorphic Complex (IMC) to the south-west and Kaczawa Metamorphic Complex (KMC) to the north-east. Metamorphic rocks are dissected by Upper Carboniferous rhyolites, lamprophyres and minor quartz veins. To the NE the KMC borders the Wleń Graben.

These units are separated by the Intra-Sudetic Fault, which is probably located in investigated landslides. Quaternary deposits cover the substrate, reaching a thickness of up to 20-30 m.

The examined landslides are characterized by poorly diversified relief (Fig. 2).

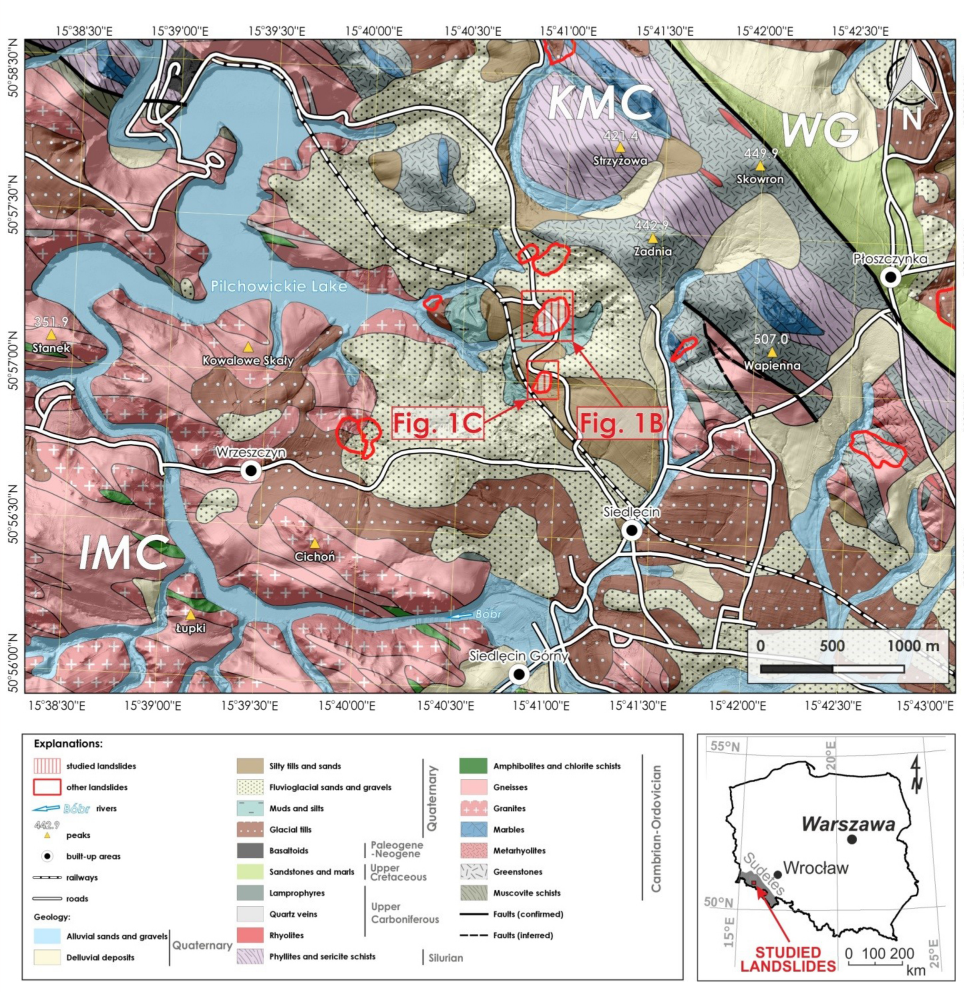


Fig. 1. Location and regional geological sketch map of the study area. Letter symbols: IM – Izera Massif, KMC – Kaczawa Metamorphic complex, WG – Wleń Graben.

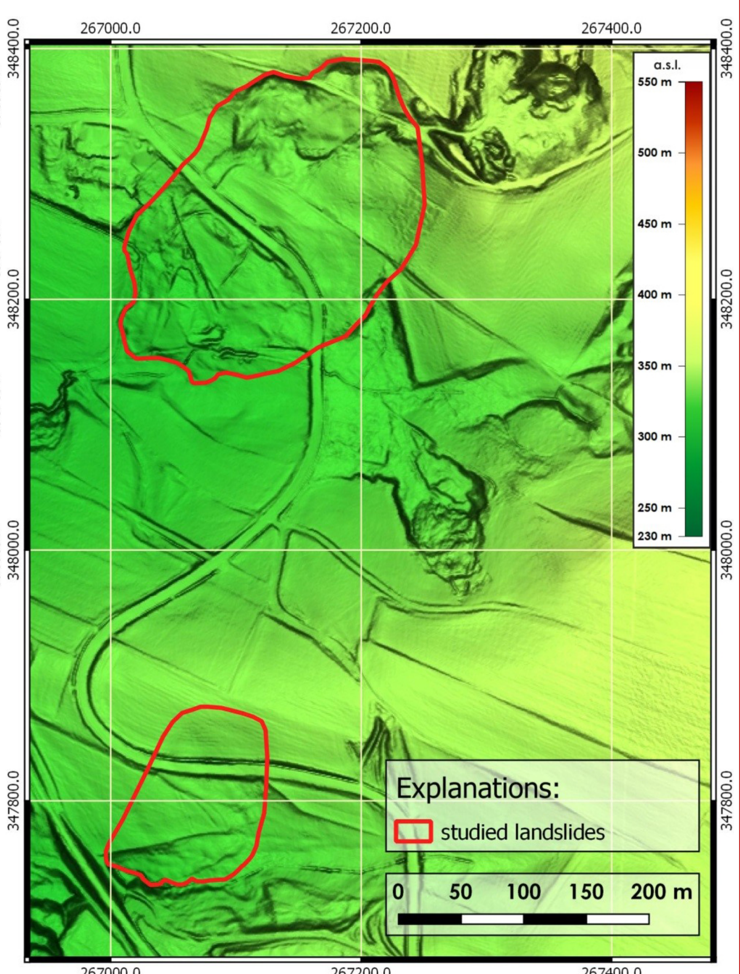


Fig. 2. Field sketch of the measurement area (background from LiDAR data).

MATERIALS AND METHODS (part 1)

Assumptions for the project of monitoring of the area of two landslides in Siedlęcin included mainly geological fieldwork aimed at determining the boundaries of both landslides, stabilization of the points of geodetic control network, points of controlled geodetic network (in the lane of the road) for total station and GNSS measurements, a total of 13 measurement campaigns (in the years 2018 - 2021), as well as the analysis and interpretation of the obtained results. Due to the experience gained during the implementation of quarterly measurement campaigns in 2018-2020, the authors of this study decided to present the key results obtained thanks to the laser scanning technology and their interpretation.

MATERIALS AND METHODS (part 2)

Surface measurements were performed with the use of laser scanning technology. The first measurement campaign was carried out at the turn of November and December 2018 using the Leica ScanStation C10 impulse scanner. As subsequent measurement campaigns were carried out with the use of the Riegl VZ-400i scanner (both stationary and mobile measurements), the authors of this study decided to treat the first measurement campaign with the use of this instrument as the so-called reference measurement (Tab. 1).

Tab. 1. List of completed measurement campaigns.

Number of campaign	Datum	Type of measuring instrument	Operating mode	Duration of data acquisition
#1	Nov/Dec, 2018	Leica ScanStationC10	stationary	~17 hours
#2	Mar, 2019	Riegl VZ-400i	stationary	~8 hours
#3	Jun, 2019	Riegl VZ-400i	mobile	~4 hours
#4	Sep, 2019	Riegl VZ-400i	stationary	~8 hours
#5	Dec, 2019	Riegl VZ-400i	stationary	~8 hours
#6	Mar, 20201	-	-	-
#7	Jun, 2020	Riegl VZ-400i	mobile	~4 hours
#8	Sep, 2020	Riegl VZ-400i	mobile	~4 hours
#9	Dec, 2020	Riegl VZ-400i	mobile	~4 hours

RESULTS

The quarterly analysis of surface changes confirmed the subsidence of a section of the road with the embankment running through the SIEDLĘCIN 1 landslide (especially in the immediate vicinity of the culvert). The discussed vertical changes took the form of small subsidence sub-areas (at the level of a few cm), which were recorded on the road surface (Fig. 3). Changes in vertical values also took place for the minor scarparea near the artificial water reservoir. Morphological changes were also noted, resulting from the construction of the embankment of the access road from the nearby buildings to the artificial water reservoir (south-western part of the landslide; Fig. 4).

The monitored area of the SIEDLĘCIN 2 landslide, both on a quarterly and annual basis, showed no statistically significant values of surface changes that could suggest disturbing activity of the landslide. The changes recorded as a result of the differential analyzes showed only statistically negligible displacement values, most likely related to changes in land cover elements (grass growth and mowing) and agricultural activity.

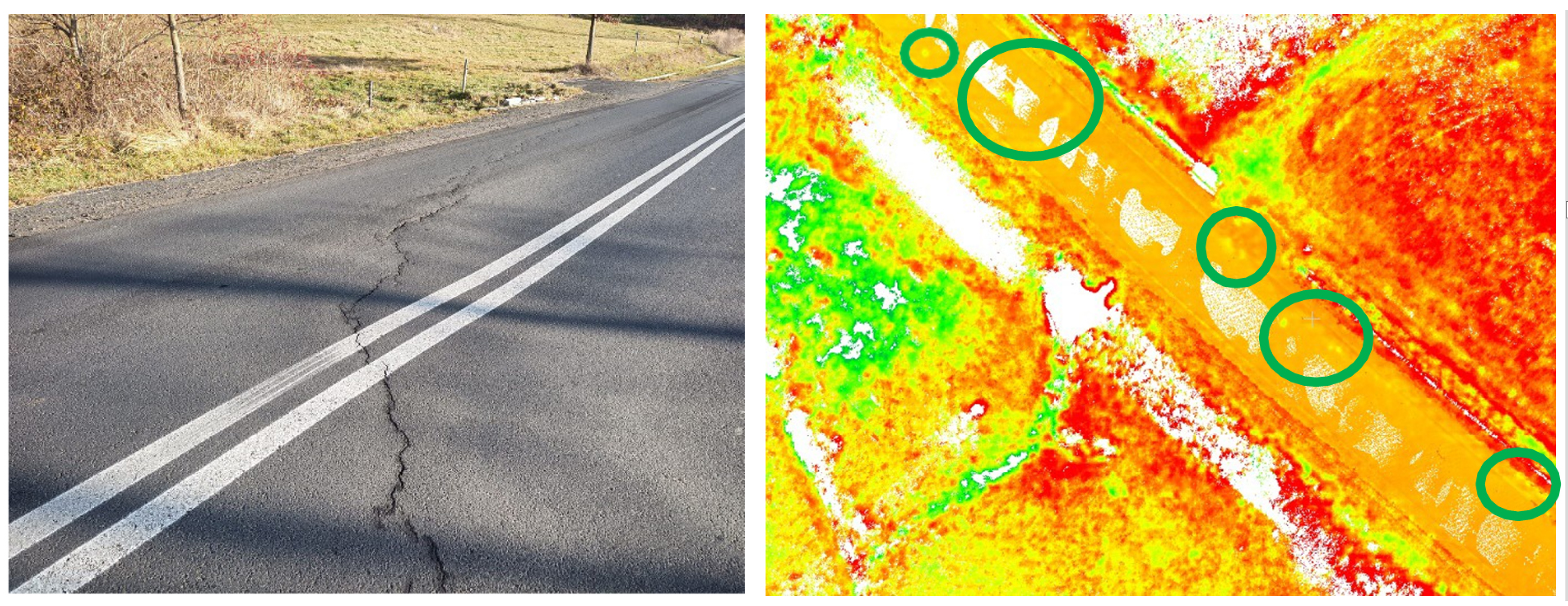
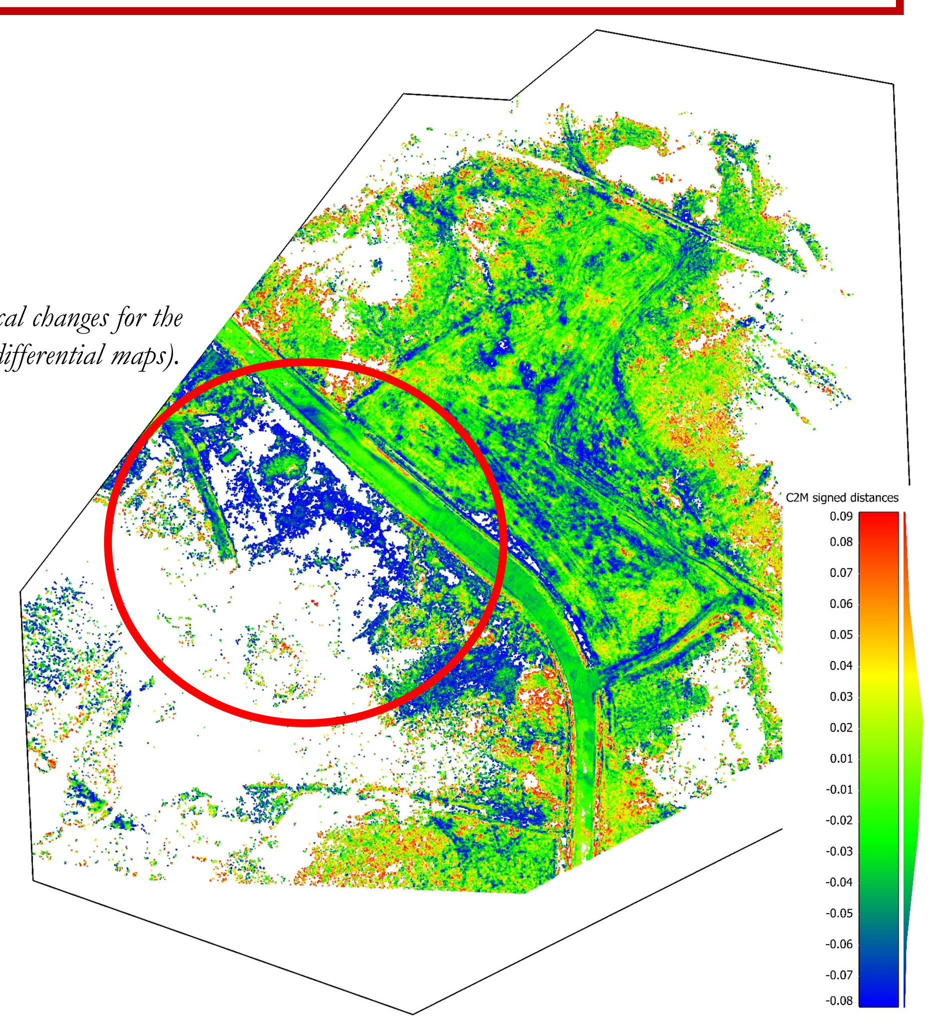


Fig. 3. Photographic documentation of the displacement line directly in the culvert zone under the district road No. 2491D, km 18 + 739.85 - 18 + 836.17 (on the left) and the sub-areas of the asphalt roadway deformation (subsidence troughs visible as light yellow areas).

Fig. 4. View of the minor scarp in the northern part of the water reservoir (blue arrow) and the newly created road embankment (red arrow).

Fig. 5. The extent of the zone of the largest recorded morphological changes for the area of the SIEDLĘCIN 1 landslide (based on the calculated differential maps).



DISCUSSION AND CONCLUSIONS

The series of measurement campaigns carried out in 2018-2020 together with a set of developed measurements of the control and measurement network and surface measurements confirmed the presence of a trend of morphological changes in the area of the SIEDLĘCIN 1 landslide from the road to the artificial water reservoir. The morphological changes are clearly visible in the projection of the numerical terrain model. The values of the changes reach the level of individual centimeters.

The annual compilation of the developed measurement data and the conducted analyzes did not show any statistically significant changes in the area of the SIEDLĘCIN 2 landslide.

Based on the obtained results, monitoring of the area of both landslides was recommended to local government units. This applies in particular to the area within the SIEDLĘCIN 1 landslide marked in Fig. 5, for which morphological changes of several centimeters were recorded. Another danger for this area may be the artificial embankment of the access road weighing down the main body (displaced material) of the landslide. A similar recommendation also applies to the area of the SIEDLĘCIN 2 landslide. Despite the fact that the values of the differential analysis results obtained so far have balanced on the edge of the measurement error, attention should be paid to the fact of active agricultural activity in this area, which may be one of the dangerous factors influencing the start of mass movements.