Surface and subsurface monitoring of an active landslide in Gresten (Austria)

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INTRODUCTION

Landslides pose a highly underestimated threat to both human life and infrastructure. In the near future, losses attributed to landsliding pose an even bigger threat in some parts of the world, as an increased landslide activity is often listed as an expected impact of human-induced climate change. Without historic information on landsliding, it is difficult to appropriately correlate landslide occurrence and its triggering event with past and potentially future conditions, especially as landslide type, depth and geometry do change with each successive event and modify the initiation dynamics for a given meteorological trigger. However, long term monitoring time series in landslide research are rarely available. Yet, only with long term monitoring results predictions of the impact of variations in the controlling conditions are possible. Consequently, monitoring systems with automated instrumentation have been of great value in the past in terms of predicting and early warning forthcoming landslide dynamics. The aim of this study is to explore current state-of-the-art methods in landslide investigation (such as inclinometers, piezometers and TDR probes) combined with new monitoring methods (permanent TLS and ERT) to assess the structural composition and kinematic patterns of the investigated landslide.

STUDY AREA

First discontinuous monitoring attempts (total station measurements) were carried out between 2007 and 2012. Permanent field instrumentation for the recently established monitoring site started in summer 2014. It is planned to continue this monitoring site for at least a decade. It is located at the active Salcher landslide in the municipality of Gresten (Austria). The landslide extents over approx. 8,000 m² and in the most active part its movement rates on the surface were close to 20 cm per year. The landslide is geologically located in the transition zone between the Rhenodanubian Flyschzone (Penninic) and the Gresten Klippen Zone (Helvetic). Both units strike in a very narrow band from west to east, yet, they contain the highest landslide susceptibility in the whole federal state of Lower Austria (4.6 landslides/km² over an area of ca. 1,400 km²; Petschko et al., 2014). Flysch materials consist of alterations of fine grained layers (clayey shales, silty shales, marls) and sandstones, whereas the Klippenbelt is covered by a sequence of marly beds with intercalated sandy limestones.

INSTRUMENTATION

The monitoring equipment consists of a weather station (measuring rainfall, temperature, air pressure, radiation), TDR probes in different depths for assessing soil water content, one automatic and two manual inclinometers (with a maximum depth of 13 m), and four piezometers to assess ground water levels. All of those measurement devices have been installed along a longitudinal section covering the whole length of the landslide. Next to this longitudinal transect a permanent geoelectrical profile (ERT) has been installed over a length of ca. 160 m with measurements every 3 hours. An autonomously operating permanent terrestrial laserscanning (pTLS) setup was developed that performs a high resolution scan of the entire landslide surface once a day. To further aid in interpreting the subsurface conditions, six core drillings (up to 9 m depth) and 13 dynamic probings have been conducted alongside the longitudinal profile. The data infrastructure consist of constant power supply and broadband internet in order to forward all measurements automatically in near real-time from the field to the data server in Vienna.

RESULTS

Correlating different measurement results clearly reveal a continuous shear plane within the main landslide creeping direction (Fig. 1). The deepest shear plane was detected in approx. 8 m depth.

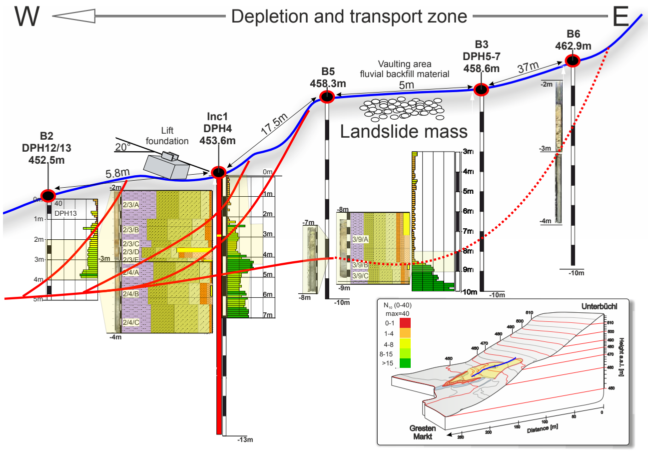

Figure 1. Longitudinal section of the most active part of the Salcher landslide (position of the section on the slope indicated at the bottom right figure). Red lines indicate proposed landslide detachments that converge into a traceable, continuous sliding plane estimated by different investigation techniques (B = borehole, DPH = dynamic probing heavy, Inc = inclinometer). Subsurface borehole and DPH profiles are given in its respective position.

Results from inclination measurements, the geoelectrical profile, dynamic probing, and analyzing drill cores showed good agreement on that. The high activity of the landslide surface can also be shown by the results from repeated terrestrial laserscanning, which clearly identifies the most active parts of the landslide. Discontinuous total station measurements that are performed since 2007 (from previous monitoring efforts) showed highly variable movement rates. The most active part of the landslide revealed movement rates up to almost 4 cm per month between 07/2008 and 12/2009, whereas movement rates between 12/2009 and 11/2012 were lower than 0,5 cm per month. Consequently, total station measurements ceased in 2012, however, the continuation in 01/2015 again revealed movement rates up to 2 cm per month on average.

CONCLUSIONS & OUTLOOK

Although the permanent monitoring site at the Salcher landslide was established only in summer 2014, some interesting observations could have been made so far. Continued total station measurements and recent inclinometer data revealed the high kinematic variability of the landslide surface. The highly disturbed drill cores are evidence for the ongoing dynamic behavior along the detected shear plane. From the daily laser scanning data, which enables very dense and spatially widespread landslide surface movement patterns in an unprecedented temporal resolution, we are able to gain further insights into the dynamic behavior of the landslide as a response to rainfall events. Especially when coupled with the information from the permanent geoelectrical system operated on site covering the whole length of the landslide. The coupling of traditional landslide monitoring methods with new ones (permanent TLS and ERT) are deepening the knowledge on landslide triggering mechanism. More elaborate relations between rainfall and landslide behavior can be drawn with longer soil moisture and piezometric time series from the installed devices (TDR probes and piezometers) in the future. The collected data is further processed for threshold analysis and ultimately for spatio- temporal slope stability analysis.

REFERENCES

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KEYWORDS

landslide monitoring; subsurface investigations, permanent laserscanning

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