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Monitoring dedicated to the set up of an alert system for landslide triggered debris flows: the Valloire case study (Savoie, France)

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Introduction

The Rieu Benoît is a debris-flow-prone catchment located in Valloire (Savoie, France). In 2011, a lateral landslide was detected about 600 m upstream of the fan apex where houses are present. This landslide has evolved slowly but is likely, in case of rapid collapse, to provide up to 200,000 m³ of material to the channel and generate intense debris flows thus threatening human settlements on the fan and in the Valloire ski resort. We present the definition of a protection strategy based on the principle that a catastrophic evolution of the landslide can be detected sufficiently in advance to set up an effective alert procedure.

Methods

Before setting an effective early warning, we need to better understand and quantify all factors potentially contributing to the debris-flow triggering. In the case of a landslide triggering, it is critical to unravel the various cascading effects that can lead to increased risk to the population. We focus on the methodology and monitoring techniques used to address these questions about the physical processes at work. This is achieved by considering the following points:

- Debris flows initiate in the upper part of the catchment independently of the landslide. Their study is based on a Lidar survey covering the whole catchment, which is used to characterize the areas of active erosion and to analyse their

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connectivity with the hydrographic network. We supplement this analysis with information on past events from historical archives.

- We need to characterize the landslide and, in particular, its volume and conditions of collapse, which was carried out using seismic and electrical tomography; and monitor it to be able to anticipate its evolution, which is carried out using photogrammetry, seismic and RFID sensors (Colombero et al., 2017)
- We need to analyse precisely the processes at the contact between the landslide and the stream channel which could be a key-point of debris-flow triggering. The monitoring combines two techniques: permanent observation using a camera and quantitative evaluation by comparison of Lidar surveys carried out with a drone, each time some substantial activity is detected by the camera.
- Because of the complexity of cascading processes, one can hardly deduce the flow characteristics (depth, velocity,...) immediately upstream of the areas at stake only from consideration of the triggering conditions. Thus, we installed a flow monitoring station at the apex of the stream fan (Fontaine et al., 2017)
- It is only after better understanding the potential impact on urbanized areas that we can set up efficient alert procedures. In practice, the impacts for a series of scenarios of future evolution of the landslide are assessed with the help of the 2D numerical model dedicated to the computation of debris-flow spreading.

Results and discussion

Several landslide scenarios ranging from 5,000 to 200,000 m³ have been deduced from the initial landslide study based on seismic and electrical tomography, and preliminary simulations of the subsequent debris-flow have been carried out. The permanent monitoring system has fully been deployed with location of the devices given in Figure 1.

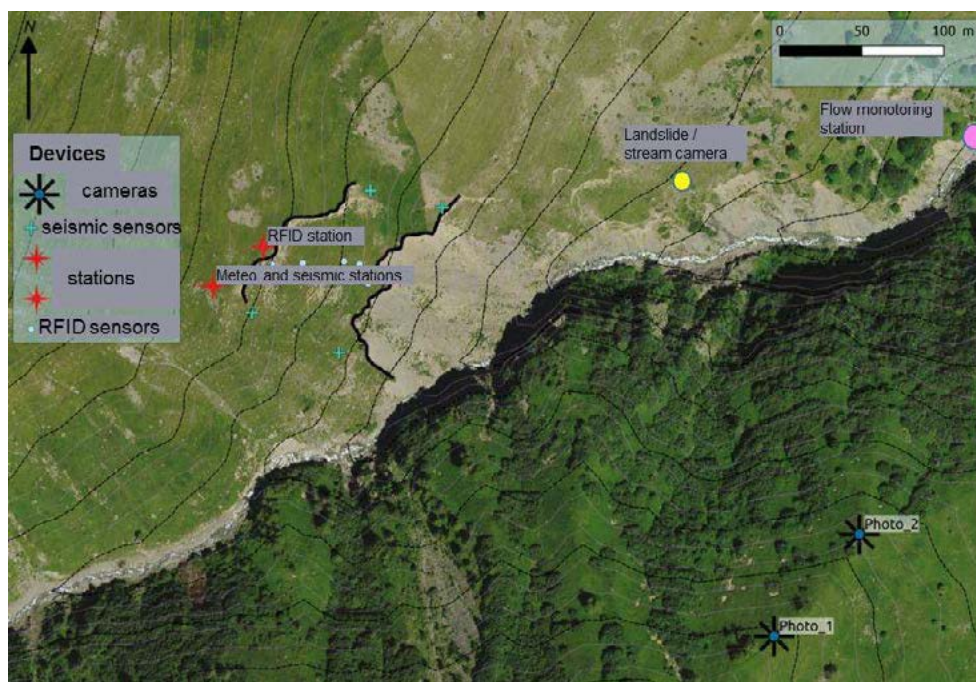


Figure 1: Location of the landslide, stream channel, and monitoring devices

Conclusions

We have presented the monitoring activity developed to improve understanding of the cascading effects, which, from a landslide collapse, may lead to debris-flow spreading in the urbanized areas of the Valloire ski resort. This study helped defining event scenarios, and assessing the corresponding hazards more accurately, and contributed to define the features of a permanent alert system. The next step will consist in collaborating with the local municipality to transfer the system and define a crisis management plan (information, warning, evacuation...).

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