IN-SITU MONITORING OF SLOPE MASS-WASTING. EXAMPLES FROM THE PYRENEES

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Slope mass-wasting triggered by rainfall is a complex phenomenon and represents an important hazard in most mountainous regions. In-situ monitoring of the involved processes is difficult due to harsh environmental conditions and the fact of remote monitoring sites. The present work shows examples of monitoring data gathered in two test sites, where shallow landslides and torrential processes produce slope mass-wasting.

Keywords: slope-mass-wasting, in-situ monitoring, Pyrenees

INTRODUCTION

Mass wasting due to shallow slope failures represents the most important erosional process in many mountainous regions and may also be the most dangerous (Hovius et al., 1997). Slope mass-wasting induced by rainfall and associated downslope/downstream sediment transfer due to debris flows and debris floods can have manifold direct and indirect consequences such as damages of infrastructure and buildings, injured persons and fatalities, soil degradation due to loss of agriculture or forested areas and volume reduction of water reservoirs.

The in-situ monitoring of rainfall-triggered mass movements is generally focusing on the hydrologic response of the natural slopes (e.g. Fannin et al., 2000; Huang et al., 2008). Very few studies have combined a sensor network recording (pre-)failure and post-failure behavior. Most of them have only been installed temporally and the failure has been triggered by artificial rainfall (e.g. Ng et al., 2008). In contrast, an interesting and exceptional case is described in Godt et al. (2009), who could monitor a rainfall-induced shallow slope failure for the first time under natural conditions.

The in-situ monitoring of slope mass-wasting in natural slopes and catchments, which will be presented in the following, is incorporated in a multidisciplinary Spanish research project called "SMuCPhy" (http://smucphy.upc.edu). This project focuses on the analysis of slope mass-wasting at three different scales: regional, catchment and individual slope. A main goal of the project is the investigation of future global changes (temperature, precipitation, vegetation etc.) on the rate of slope mass-wasting.

DESCRIPTION OF IN-SITU MONITORING

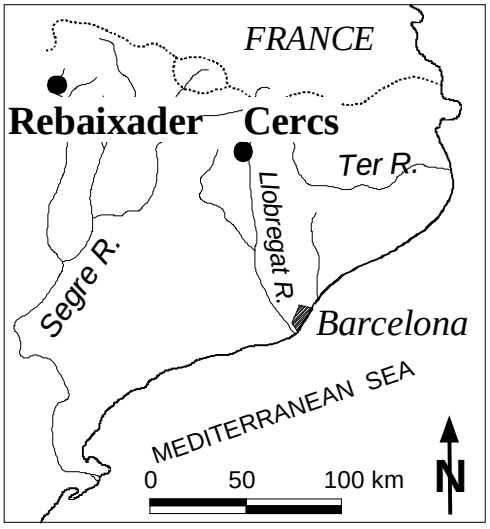
The two monitoring sites selected in this work are Rebaixader and Cercs, both located in the Catalan Pyrenees (Fig. 1a). The Rebaixader catchment is a typical old high-mountain glacial basin, in which slope and torrential processes are nowadays dominant. The drainage area covers 0.7 km^2 with altitudes between 1425 and 2475 m a.s.l. The slope mass-wasting under consideration at this site include different torrential processes like shallow slides, debris flows, debris floods, surficial sediment erosion, rockfalls etc. The in-situ monitoring was started in 2009 and consists nowadays of different wired and wireless stations (Tab. 1), which analyze the rainfall infiltration in the soil layer inside the headwater and detect the torrential processes in the downstream channel reach. Details on the monitoring system and preliminary results can be found in Hürlimann et al. (2014).

The Cercs monitoring system is installed in a shallow slope failure developed in weathered claystones of the Garumnian Facies (Upper Cretaceous-Paleocene), located in the Pre-Pyrenees (Fig 1a). The wireless monitoring consists of a set-up, which includes a meteorological station, different sensors to register the rainfall infiltration and also a wire extensometer (Tab. 1). The sensors are installed both in the weathered claystone and in the overlaying clayey colluvium.

Tab. 1 List of the sensors installed at Rebaixader and Cercs, which focus on the rainfall infiltration.

Sensor	Rebaixader	Cercs
rain gauge	1	1
air temperature sensor	2	1
relative air humidity sensor	1	1
snow height sensor	1	0
soil moisture sensor	10	3
water potential sensor	4	2
soil temperature sensor	4	2
piezometer	2	1

a)



b)

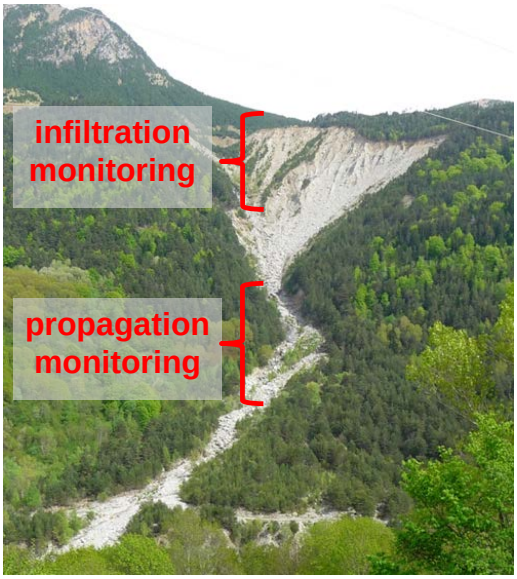


Fig. 1 a) Location of the two monitoring sites. b) General view of the Rebaixader monitoring site indicating the two principal areas of monitoring.

RESULTS

Some results on the response of the unsaturated soils in relation with precipitation are presented. Fig. 2 shows the data recorded on the rainfall infiltration in Cercs slide during 2015. The daily precipitation measurements are compared with the water potential and volumetric water content at two different depths. The data show a clear correlation between the rainfall intensity and the hydrologic regime in the unsaturated soil layer.

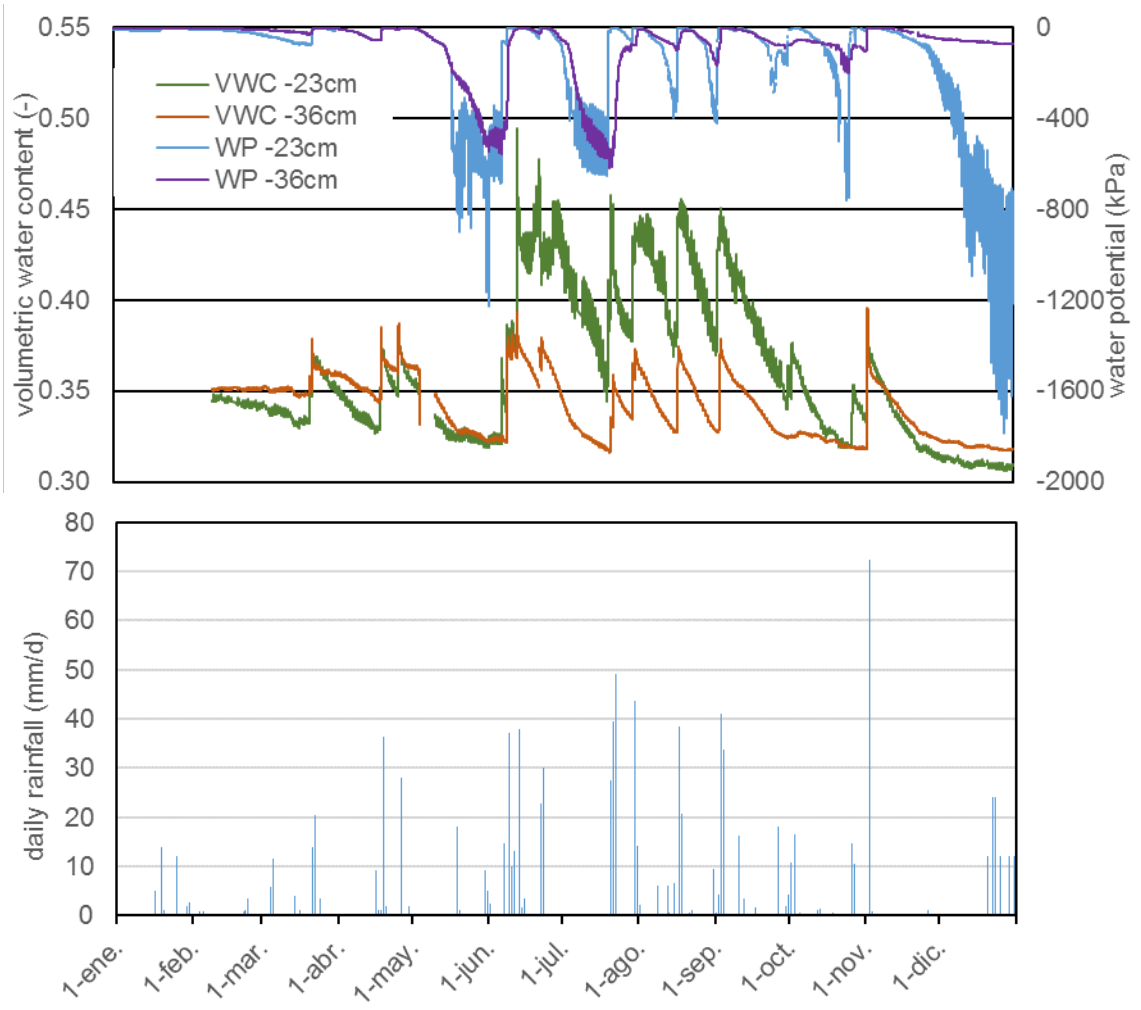


Fig. 2 Data of in-situ monitoring in Cercs gathered during 2015. The daily rainfall (below) and the response of the soil by volumetric water content and water potential (above).

The second example shows interesting data gathered at Rebaixader test site during a rainstorm on July 7th 2013. This typical summer rainstorm triggered an important debris flow in the catchment. The monitoring data reveal a clear relationship between the timing of the rainfall, the infiltration of water in the soil and the subsequent torrential process (Fig. 3). Due to the characteristics of the soil, which is formed by a glacial deposit mainly consisting of gravel and sand, the increase of water content is almost immediately.

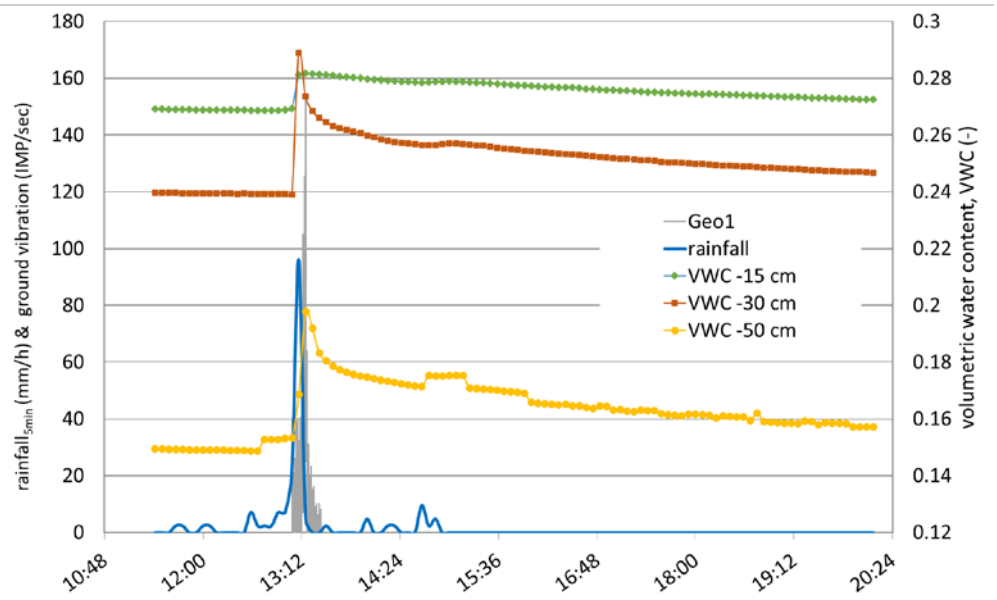


Fig. 3 Data registered at Rebaixader during a rainfall episode in July 2013 that triggered a debris flow in the catchment. The rainfall and volumetric water content are compared with the ground vibration measured at geophone Geo1.

CONCLUDING REMARKS

In-situ monitoring provides essential data for the understanding of mechanisms related to rainfall infiltration into unsaturated soils. In addition, the registered data offer necessary inputs for numerical models. Our experience shows that monitoring of slope mass-wasting is a difficult task due to harsh environmental conditions and associated technical issues. Moreover, the registered data strongly depend on the adequate installation and maintenance of the sensor system. Special focus should be taken on the accurate lithological and geotechnical understanding of the soil layer, where sensors are installed, in order to correctly interpret the gathered data.

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