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Emerging techniques and impact of human activities in landslide risk management: 3D analysis and human induced landslides

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Nowadays landslide risk management is facing two important challenges. The first is to improve landslide predictability (hazard, early warning systems (EWS)). This is made possible thanks to the recent progresses in geosciences enabled by the new affordable technologies and computing power. The second challenge is to properly address the problem of landslides caused by the increasing impact of human on environment, especially in fast changing countries.

In landslide science, the emergence of high resolution earth surface 3D imaging has played a major role by providing new viewpoints on the slope processes. This technique has improved landslide mapping, enabling to better characterize landslide structures and also to refine numerical modelling. Furthermore, the increasing number of permanent landslide monitoring systems (MS) provide new information about failure mechanisms. These systems can include InSAR, LiDAR, GPS, pore water gauges, rain gauges, inclinometers, etc. These integrated approaches have permitted to demonstrate that most of the mountainous areas are affected by landslides or large slope deformations. As an example, several studies have shown that catastrophic landslides had signs of precursory deformation visible on hi-resolution digital elevation model (HRDEM). Coupling MS and surface deformation analysis enables to characterize the processes that lead to failure, which is fundamental to improve hazard mapping and EWS implementation. With this approach, the mechanisms of failure of several rockslides have been refined (Eiger, Aknes, Randa, Turtle Mountain, etc.), but also of small rock failures (Seychilienne, Catalonia, etc.). Moreover, non-permanent deformations are now identified as potential sources of fatigue of the rock mass. For instance, thermal effect on shallow rock failure starts to be well documented in Yosemite. Another example is the effect of groundwater table fluctuations on a large rock wall in Norway inducing cycles of deformation of a few millimetres of amplitude (demonstrated by InSAR). Similar analyses are also applied successfully to landslides in soils such as earthflows, like Super Sauze in France. Finally, passive seismic monitoring is also a new tool to forecast the reactivation of earthflows by monitoring the decrease of the surface wave velocity.

All these new techniques are promising in order to improve landslide risk management, thanks to a better understanding of dynamic processes from landslide initiation (criterion for mapping) to failure forecast (basics for MS). But that understanding must also include the issues linked to landslides induced by human activities. This is critical considering the fast changes in land uses. In several contexts, anthropic activities are one of the major cause of landslides. Even if the causes are often bad engineering practices, several cases have demonstrated that slope failures can be caused by environmental changes that are not considered to be systematically leading to the modification of the slope profile, water circulations, etc. This means that landslide hazard assessment must clearly include the impact of past, present and future anthropic changes. Based on the work of K. Terzaghi, seven questions must be answered to tackle the potential impact of human on slope environment.
To conclude, the challenges that face the landslide risk management are, in my opinion, linked to the possibility

to develop a deeper understanding of the processes permitting a better detection of landslide prone areas and an improved forecast of failure or reactivation of landslides. In addition, any operation in slopes must take into account the full impact on the neighbouring environment in order to prevent human induced landslides.