Climatic and morphologic controls on debris flow initiation and magnitude in Southern Switzerland.

Andrea Salvetti, PhD[1]

INTRODUCTION

In the Alpine region debris flows represent a very destructive natural hazard, affecting settlements on alluvial fans, transport infrastructures, and causing human losses. The triggering mechanisms of a debris flow and the causal-effect relationships of the whole complex process are still partially unknown, as pointed out e.g. by Berti and Simoni (2005).

Consequently, the quantification of the risk from extreme hydrogeomorphic processes is complex as well and requires an integrated approach, including both the analysis of triggering processes and secondary hydrogeomorphic effects. The definition of consistent hazard scenarios is essential for both optimizing hazard mapping procedures, and for prioritisation of constructive measures for risk reduction.

The study area is located in the Southern part of the Ticino Canton, Southern Switzerland, namely the Western slope of the Generoso Peak, where small creeks, characterized by a high altitude range, are regularly affected by debris flow events, triggered by intense rainfall in summer. A set of 15 large and medium size events were recorded from 1992 to 2014, which caused damages to the highway infrastructures on the alluvial fan, transporting several thousand cubic meters of material.

The entire Western slope is characterized by a two steps cascade structure. The drainage network density is extremely high and sudden morphological changes due to intense local erosion increase the uncertainty in the scenario definition, since the impact point of a debris flow can change from one event to the other due to flow path changes on the alluvial fans.

METHODS

Since the source of uncertainty affecting the predictability of hazard pattern are several, a multidisciplinary approach was required for the scenario definition, by considering event documentation, qualitative estimation of experts, numerical models (Mazzorana et al.,2009).

As a first step, a intensity-duration analysis was carried out for rainfall events that lead to debris flows events. A set of five neighboring raingauges was selected and the duration of the rainfall event and the corresponding mean rainfall intensity which triggered the debris flow was identified by solving a simple maximization problem, considering of the maximum intensity and the total amount of precipitation.

The results show that all the calculated „critical“ durations are between 1 and 2 hours and they were further compared with different intensity-duration threshold lines derived for the onset of debris flows for similar geographic areas and with traditional IDF curves of different return periods (Fig. 1).

The threshold line derived from Zimmermann et al. (1997) based on a large set of debris flows occurred on the edge of the Alps (Switzerland randalpin) is also valid for the debris flow events occurring in this region.

The rainfall analysis shows that debris flows can be triggered by events of low return period and the magnitude of the events is not clearly correlated with the mean precipitation intensity. As a second step, a correlation analysis between morphological parameters (basin area, slope, Melton number, …) and documented event magnitude was performed. A modified Melton number, considering the mean slope S of the basin (R_mod „=“ΔH/√(〖S*A〗_eff)), was introduced and two exponential relationship for the median and maximum magnitude were fitted.

A wide range of event magnitudes can be expected (and was also observed) for some few creeks with a basin area of some hectares (Fig. 2, points with modified Melton Number lower than 2); in this basins the morphohydrological processes play a role; on the contrary, in very small basins (high

Rmod values) the observed magnitude of the events is very similar with different rainfall forcing, the fitted relationships converge, probably indicating an hydrological limitation in the triggering mechanism.
Due to the morphological characteristics of the study area, the effects of changing channel morphology and the role of existing and planned mitigation structures have to be explicitly considered in the definition of the scenarios.
Based on such consideration, a set of consistent scenarios was identified by a team of specialists (engineers and geologists) by integrating the quantitative results obtained in the two previous steps with the qualitative knowledge of the experts and historical observations and by considering all the sources of uncertainty with respect to hydrological hazards and torrent processes, as defined e.g. by Fuchs et al. (2008). The selected scenarios allow increasing the robustness of the derived hazard maps and were adopted as basis for the design of different risk reduction measures and for the prioritisation of the activities.

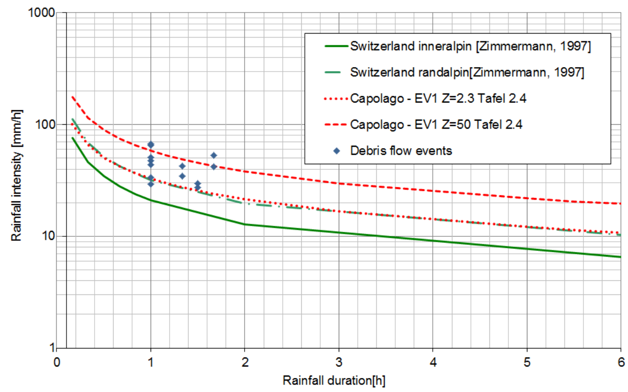

Figure 1. Intensity-Duration analysis and rainfall thresholds

REFERENCES

- Berti M., Simoni A. (2005). Experimental evidences and numerical modelling of debris flow initiated by channel runoff. Landslide, 2: 171-182.
- Fuchs S., Kaitna R. , Scheidl C., Hübl J. (2008). The application oft he risk concept to debris flow hazard. Geomechanics and Tunneling, 1(2), 120-129.
- Mazzorana B., Hübl J., Fuchs S. (2009). Improving risk assessment by defining consistent and reliable system scenarios, Nat. Hazards Earth Syst. Sci. 9, 145-159.
- Zimmermann M., Mani P., Gamma P., Gsteiger P., Heiniger O., Hunziker G. (1997). Murganggefahr und Klimaänderung - ein GIS-basierter Ansatz (Schlussbericht NFP31), vdf Hochschulverlag.

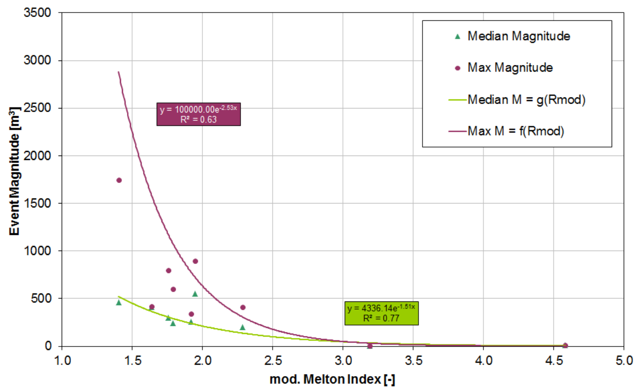

Figure 2. Fitted relationship between modified Melton Number and mean and max event magnitude

KEYWORDS

debris flows; scenario definition; rainfall thresholds; morphology; prioritisation

1 River Management Office, Land Department, Canton Ticino, Bellinzona, SWITZERLAND, andrea.salvetti@ti.ch