LATE HOLOCENE DEBRIS-FLOW ACTIVITY ON A FORESTED CONE IN THE SWISS ALPS

LESSONS LEARNED FROM THE PAST – IMPLICATIONS FOR THE FUTURE

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ABSTRACT

Debris flows represent one of the most common and widespread of all natural hazards in mountain environments, where they repeatedly cause damage to infrastructure or even loss of life. With the projected greenhouse warming, there is much debate about changes in the frequency, magnitude and seasonality of precipitation events and related flooding or mass-wasting processes. Before establishing any cause-and-effect relationship between global warming and the incidence of geomorphic processes, the natural variability of extreme weather events must be examined as well as detailed information obtained on past process dynamics on debris-flow cones, alluvial fans or floodplains. Records of past debris-flow activity may be particularly useful in the recognition of past process dynamics and precipitation events. Individual debris flows are usually released during intense rainfall events and repetitive debris flows usually occur in sediment-rich catchments, as long as the triggering precipitation events are recurring. In addition, debris-flow deposits have a high preservation potential on cones and can therefore be used for the analysis of spatial patterns of past events.

While chronostratigraphic records on past debris-flow activity exist for several case-study areas of northern Europe or the United States, such reconstructions remain widely non-conclusive for the European Alps in general and for Switzerland in particular. It is therefore the purpose of this paper to assess late Holocene debris-flow activity and process dynamics on a forested cone in the Swiss Alps using dendrogeomorphological methods. Through the identification of surface deposits and analysis of tree-ring series disturbed by past debris flows, we (i) investigate the frequency and timing of events, (ii) date the material deposited on the present-day cone surface, and (iii) discuss potential effects of projected changes in climatic conditions upon the frequency and magnitude of events in a future greenhouse climate.

Debris-flow activity on the forested cone of the Ritigraben torrent (Valais Swiss Alps) was assessed from growth disturbances in century-old trees, providing an unusually complete

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record of past events and deposition of material. The study of 2246 tree-ring sequences sampled from 1102 *Larix decidua* Mill., *Picea abies* (L.) Karst. and *Pinus cembra* ssp. sibirica trees allowed reconstruction of 123 events since A.D. 1566. Geomorphic mapping permitted identification of 769 features related to past debris-flow activity on the intermediate cone. The features inventoried in the study area covering 32 ha included 291 lobes, 465 levées and 13 well-developed debris-flow channels. Based on tree-ring records of disturbed trees growing in or next to the deposits, almost 86% of the lobes identified on the present-day surface could be dated. A majority of the dated material was deposited over the last century. Signs of pre-20th century events are often recognizable in the tree-ring record of survivor trees, but the material that caused the growth anomaly in trees has been completely overridden or eroded by more recent debris-flow activity.

Tree-ring records suggest that cool summers with frequent snowfalls at higher elevations regularly prevented the release of debris flows between the 1570s and 1860s; the warming trend combined with greater precipitation totals in summer and autumn between 1864 and 1895 provided conditions that were increasingly favorable for releasing events from the source zone. Enhanced debris-flow activity continued well into the 20th century and reconstructions show a clustering of events in the period 1916–1935 when warm-wet conditions prevailed during summer in the Swiss Alps. In contrast, very low activity is observed for the last 10-yr period (1996–2005) with only one debris-flow event recorded on August 27, 2002. Since sediment availability is not a limiting factor, this temporal absence of debris-flow activity is due to an absence of triggering events, which not only shifted from June and July to August and September over the 20th century, but also seemed to occur more frequently in the form of cyclonic rainstorms in autumn rather than convectional rainfall in summer. From the reconstructions, based on Regional Climate Modeling (RCM) simulations, there are indications that debris-flow frequencies might continue to decrease in the future, as precipitation events are projected to occur less frequently in summer but become more common in spring or autumn. However, even if the frequency of summer events decreases in a future greenhouse climate, the magnitude and related impacts of future summer debris flows could be greater than currently. This is because warmer temperatures and higher precipitation intensities could result in greater runoff, an increase in the transport capacity of surges leading to a greater erosive potential of debris flows.

Keywords: debris flows, tree rings, dendrogeomorphology, frequency, magnitude, climate change, Swiss Alps