Assessment and management of debris-flow risk in a tropical mountain catchment in Santa Teresa, Peru

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INTRODUCTION

In January 1998, a large debris-flow of almost 1010 m3 occurred in the Sacaara valley, about the settlement of Santa Teresa (7 km northwest of Machu Picchu), Peru, causing the destruction of large parts of the town of Santa Teresa and local settlements upstream. Here we present a risk analysis and a risk management strategy for debris-flows and glacier landslides in the Sacaara catchment. Data-scientific and targeted understanding of both physical processes and social processes required a full quantitative risk assessment. Therefore, a bottom-up approach is shown in order to establish an integrated risk management strategy that is robust against uncertainties in the risk analysis.

Right: Location and overview of the study region; location of weather stations and extent of 1998 flood (tributarytrigger area, bottom, the extent of the Sacaara catchment is shown with pink dots with black dot core of SACAARA.)

TRIGGER ANALYSIS

Pre-event precipitation was high, for the 1-, 3-, and 30-day pre-event periods (see figure above). However, the different measurements have a low spatial correlation, indicating that convective precipitation plays an important role. Observed monthly max. temperatures for December 1997 and January 1998 (~ snow melt) was above average at all altitudes, also for December 1997, the maximum value of ME1 (9/15/98) and ME3 (11/15/98, 4 hours before the event) were above 15°C near the damming zone.

We assume that the combination of these factors eventually triggered the debris-flow on 15 January 1998.

Left: Pre-event precipitation for meteorological stations (cumulative precipitation for the 3 days pre-event period, right y-axis, and from 1998 measurements) (left precipitation summations) (January 1998, right y-axis, see introduction placing for location of stations and TIRN titles.

VULNERABILITY ASSESSMENT

Vulnerability was evaluated through interviews with local inhabitants and authorities, field work, the population and housing survey, monitoring of infrastructure (roads, buildings, etc) for building, social (level of organization and preparedness of communities) and economic activities and institutional (resilience and strength of the communities) vulnerability were analyzed. Based on these analyses, a percentage was assigned to each type of vulnerability, where 0% means no vulnerability and 100% indicates total vulnerability, and finally totaled to a total level between (100%-0%) and very high 70% - 100%.

Risk analysis of the fire affected population in the local community for the 1998 event results.

RISK ASSESSMENT

Qualitative hazard maps were compiled for the populated places in the catchment (right panel in the figure below). Besides the results from the RAMMS model run for the large-scale debris flows and GLOF, also topological data, satellite imagery, and webcam were used for the assessment of more local hazards, such as landslide, marginal erosion of rivulets, and debris flow from smaller tributary streams. For the risk assessment, these hazard maps were finally combined with the vulnerability assessment into a risk map, according to the criteria shown at the bottom of the figure below.

Future scenarios

Lake outlet scenarios were modeled with RAMMS for two greater lakes located in the upper reaches of the catchment. One is a magmatic lake forming on a glacier-covered ice dam from a former glacier tongue (SGT), the other is a probable lake, called Huenti Lake (HL). A small, medium, and large sub-catchment were modeled for each, assuming a potential future ice dam collapse. For lake (HL) a risk assessment was assumed not to change.

RISK SHEETS

For each community in the catchment, a standardized risk sheet has been developed, consisting of five following elements: 1) Catchment hazard, vulnerability and risk map (as shown above), 2) a general and socio-economic characterization, 3) a flow diagram for the risk assessment process, 4) the identified risk diagram, and 5) the final risk. Finally (3), stepped intervention measures are proposed.

RISK MANAGEMENT

Several activities together with local inhabitants and the local authorities have been implemented:

- A radio communication system between the local community and the local emergency services to ensure the communication of information on the evolution of the event and to prevent the risk management.
- Information of the local population in precipitation and temperature measurement campaigns.
- Workshops on local risk perception, for creating the local knowledge with scientific findings
- Implementation of a reactivated Leadership School, in order to building capacity of local leaders on topics such as climate change, risk management, and related adaptation measures.
- Establishing a Risk Management Committee in each community that are officially approved by the local government.
- Integrating topographic climate change related maps, and climate change data in the analysis of local schools.
- Community level workshops with women.

INCREASING SOCIAL & INSTITUTIONAL PREPAREDNESS

EARLY WARNING SYSTEM

In order to timely alert the population in case of an event, a simple Early Warning System (EWS) has been designed. The main components of the planned EWS include two measurement stations, located at two bridges crossing the Sacsara Valley, about 19 km (11 mi) long, and the entire stream of the Sacaara river from the Quizzon area (San Pedro de Santa Teresa (the settlement of Yavaron. The station will be equipped with a set of sensors connected across the channel, in case of rupture, trigger the transmission of a signal).

EWS components: 1) rain gauge, 2) temperature gauge, 3) bridge monitoring station, 4) small dam监测 station, 5) communication tower, 6) communication tower.

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