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A method towards integrative assessment of vulnerability to glacial lake outburst-floods in developing-country communities: a case study in the Cordillera Blanca, Peru

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The Rio Santa valley in the Cordillera Blanca, Peruvian Andes, has been repeatedly affected by severe flood disasters with glacial origin in the past decades. The continuing high rate of glacier retreat leads to the formation and rapid growth of a large number of glacial lakes. Owing to the risk of lake outburst-floods downstream communities are confronted with serious hazards. The regional capital Huaraz is one of the major sites exposed to these hazards. Mainly due to a lack of resources a systematic evaluation of the existing hazards and related risks has not been performed so far nor have adequate warning systems been installed. The strong financial limitations make a prioritization of mitigation measures a necessity. Vulnerability assessments are an effective tool to this end. In this contribution, we present a method to measure the vulnerability of Huaraz to hazards from glacial lake outbursts integrating both physical (i.e. hazards-related) and socio-economic factors. The difficulty of quantifying socio-economic variables and its combination with physical factors, as well as a lack of corresponding concepts, is a challenge for measuring vulnerability. The physical, natural hazard-related factors consider the lake-outburst probability, flood magnitude and trajectory characteristics while the socio-economic variables consist of the demographic structure, degree of informed population, existing mitigation structures, warning systems and other emergency-preparedness factors. The variables were assessed by field work, interviews, publicly available socio-economic data, satellite image analysis, and terrain and flood modeling. All variables were consistently transformed into a quantitative scheme. The resulting map shows a high vulnerability for several parts of Huaraz distinguished on an urban district level. The results of this study thus are an

important contribution to effectively address the identified protection deficit and to efficiently assign the limited resources in the context of a developing country. However, it also shows the strong need for more vulnerability research integrating both physical and social science components and related theoretical frameworks to be readily applied in practice.