A 3-Dimensional, Gis-Based Model Of Historical Groundwater And Slope Stability

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One important issue in recent climate impact research is the assessment of effects of climatic variability and climate change on geomorphic processes and hazards, such as landslides. Hillslopes in central Germany are heavily affected by landslides. Field experiments and archive analysis for the area around Bonn showed that precipitation-induced groundwater rises are a major contribution to slope instabilities and a dominant cause for failures in that region. However, little is known about the history of landslides and about the impact of climate change on landslide processes. This study presents a scenario model for historical variations of slope stability in the Bonn area. Therefore, a new approach was developed, by coupling proxy-derived climate scenarios with a model for groundwater-controlled slope stability.

A process-based, spatio-temporal model for groundwater variations and slope stability was developed using the GIS environment of the software PCRaster (Utrecht, The Netherlands). The model calculates spatially distributed groundwater heights and failure probabilities in daily time steps for small areas (hillslopes, catchments). The model was used to assess the effects of the scenarios of historic climate on slope stability for different hillslopes in the Bonn area.

The findings indicate that past climate is highly variable, but also shows distinct trends. Three climatic phases with different annual characteristics of temperature and precipitation were derived based on proxy data and weather records. The groundwater / slope stability modelling results show that a climatic scenario representing instable climatic conditions of a transition from more humid little Ice Age conditions to dryer recent conditions produces higher instabilities. The intensity of this impact, however, varies with the sensitivity of the specific geomorphic system, i.e. the specific landform and lithology, and is not related to the stability of a specific hillslope.

The study showed that historical climate scenarios in combination with mechanistic models can be used to assess changing patterns in geomorphic activity, in this case slope stability. A more unstable area is not necessarily more sensitive to climatic changes: the location of permeable layers (prone to groundwater rise) in relation to sensitive layers (lower strength) and higher-gradient areas (higher stress) influences the sensitivity of a site with respect to climate changes. The applied method is capable of modelling landscape sensitivity to climate change with respect to groundwater-controlled landslides.