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Characteristics and consequences of ancient mass movements in the Northern Ethiopian highlands

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The present study focuses on the impact and characteristics of ancient mass movements in the Northern Ethiopian highlands. A 500 km^2 study area, located in the Geba-Werei watershed, was selected because of the presence of a complete geological section representative for the region. The region is characterised by tabular and monoclinal landforms, etched out by intense differential erosion, triggered by 1 to 2 km of tectonic uplift of the area since Tertiary times. A landslide inventory map was prepared from aerial photograph interpretation in combination with field interpretations carried out by at least two geomorphologists. The map shows the location of 57 mass movements, mainly debris flows, and 6 zones with unindividualized mass movements. Together, they cover 15.8% of the study area. They were mainly identified along the transition of the plateau to the valley floor.

Availability of the landslide inventory allowed application of a statistical model, i.e. weights of evidence, to estimate landslide susceptibility and to explore the importance of environmental factors (i.e. terrain height, hillslope gradient, slope aspect, plan and profile curvature, lithology and presence of faults) to mass movement occurrence. Weights of evidence is a Bayesian approach in a log-linear form, that can be implemented in a GIS framework. We used IDRISI Andes, and adopted grid cells with a 30 m resolution as terrain units. Given the large dimensions of the mass movements,

susceptibility models were not only calibrated for the complete mass movements, but also for depletion and accumulation areas separately. The creation of contingency tables and Receiver Operating Characteristic (ROC) curves allowed critical evaluation of the resulting susceptibility models. Values between 0.78 and 0.86 for the area under the ROC curve indicated that models with a relatively high quality were calibrated. Hence, the creation of susceptibility maps was meaningful. The statistical modelling confirmed the hypothesis that debris flow initiation generally occurred on the plateau after the mobilisation of weathered basalts. Flowing down over a sandstone cliff, the debris often entrained large blocks of sandstone. The blocks were tilted, and are nowadays clearly visible in the field as reverse slopes. In the accumulation area, the fertile weathered basalt was deposited upon dry unproductive soils on limestones. Given this downslope displacement of large amounts of fertile soil, an important consequence of the occurrence of ancient mass movements is an increase of the agricultural production on the footslopes.

Mass movements, however, also constitute a negative factor in environmental security. The created landslide susceptibility maps, not only show the propensity of an individual grid cell to be located in one of the known flows. By inference, they also show the propensity to generate new flows or reactivations of existing failures. In this context, especially soil water conservation measures taken on the basalt plateaus, inside or outside depletion areas of ancient debris flows, must be mentioned. These measures might result in the build-up of pore water pressures and eventually in slope failure. The results obtained allow delineating zones where human interventions decreasing slope stability should be limited in order to avoid damage to infrastructure and buildings. The method could be used in similar areas where knowledge on the characteristics of ancient mass movements is essential for present-day risk analysis.