Landslide mobilization rates in the Anthropocene: insights from a 60-year observation period in the North-Tanganyika-Kivu Rift region, Africa

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During the Anthropocene, the impact of humans on Earth surface processes has increased exponentially, often surpassing the importance of natural drivers. Also in mountainous areas, landslide mobilization rates are exacerbated by human disturbances of the landscape such as deforestation, road constructions, and mining processes. However, investigating these interactions remains difficult in many regions due to a lack of sufficiently long observation periods, preferably over a large area, so that the presence of extreme landslide events (triggered by rainfall or earthquakes) does not induce an observation bias. Here, we investigate landslide mobilization rates in the densely populated North Tanganyika-Kivu Rift Region (NTK Rift), a prominent landslide hotspot in Africa. We use ca. 2,400 panchromatic aerial photographs from 1958 in combination with recent satellite imagery to assess the long-term landslide mobilization rates over a large area of ca. 21,000 km^2.

By estimating the volume of the deep-seated and shallow rapidly-moving landslides using empirical volume-area scaling relationships, we estimate that the average landslide mobilization rate in the NTK Rift is ca. 31 m^3 km^{-2} year^{-1} in actively incising, rejuvenating landscapes and ca. 12 m^3 km^{-2} year^{-1} in relict landscapes. The mobilization rates in the NTK Rift are dominated by the largest landslides. For instance, the 15 largest deep-seated landslides account for 50% of the total

rate. Overall, we observe mobilization rates in the NTK Rift that are somewhat lower than what a global model predicts. These relatively low rates could be explained by four factors: (i) the absence of major landslide-triggering earthquakes during our 60-year observation period, (ii) the exclusion of earthflows from our analysis due to a lack of information on the depth and velocity of these instances, (iii) the relatively large size of our study area which reduces biases linked to extreme rainfall, (iv) the fact that the NTK Rift is a mountain range in an extension area, which differs from orogenic mountainous areas, where most landslide mobilization rates are reported; and (v) uncertainties on the global landslide mobilization rate model.

In rejuvenated landscapes, roughly 5% of the sediment mobilization by rapidly-moving landslides is linked to human activity, while in relict landscapes this figure rises to 18%, notably due to mining and road construction. The role of human activity is limited as compared to the recent occurrence of some large landslides, which seem linked to natural causes and dominate the overall mobilization rates. Moreover, the limited role of human activity must be balanced with the fact that the NTK Rift, although highly populated, remains relatively untouched by major road infrastructure constructions. While previous studies have found that deforestation has a large impact on the landside risk (i.e. the incidence of landslide fatalities), its impact on the observed mobilization rates appears to be much less important. The landslides associated with deforestation are commonly shallow debris avalanches with a limited size and rather high mobility.

Overall, our results significantly contribute to a better understanding of landslide mobilization and its controlling factors, especially by proving much-needed long-term observations for a currently under-researched type of environment.