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## Landslide risk trends in the Kivu Rift and the impact of environmental and societal dynamics

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On the nexus of humans and their environment, landslide risk is in essence dynamic. In mountainous areas over the world, the need for agricultural land incites people to settle on steeper (more landslide-prone) terrain at the expense of ecosystems. At the same time, the degradation of ecosystems, for example through deforestation, leads to a considerable increase in landslide hazard. Although the link between deforestation and landslide hazard/risk has been widely recognized, it remains poorly quantified. This is especially the case in the Global South where historical land cover and landslide records are scarce.

In this study, we investigate 58 years of forest cover changes, population dynamics, and landslide risk in the Kivu Rift. This mountainous region presents similar geomorphic and climatic conditions across three countries: Burundi, the eastern part of the Democratic Republic of the Congo (DRC), and Rwanda. First, we use contemporary landslide and deforestation data (2000-2016) to explicitly quantify the interactions between these two processes. Second, we reconstruct the annual forest cover changes between 1958 and 2016 by means of a cellular automaton of which the output converges to four forest cover products (1958, 1988, 2001, 2016). We derive the 1958 forest data from an inventory of nearly 2,400 panchromatic aerial photographs, available at the Royal Museum for Central Africa. The forest data for 1988, 2001, and 2016 are readily available and derived from satellite imagery. Next, we estimate the yearly historical landslide hazard dynamics by applying the contemporary deforestation-landslide relationship to the historical forest cover changes. Finally, an approximation of the landslide risk (expected fatalities per 100,000 inhabitants), is calculated for four epochs (1975, 1990, 2000, 2015) and derived from the product of the corresponding hazard map and population density grids.

During our entire period of observation, the landslide risk is higher in the DRC than in Rwanda and Burundi. While the risk in Rwanda and Burundi displays a slightly decreasing trend, the risk seems more volatile in the DRC. Here, the initial risk in 1975 is high due to the concentration of a small

population along the steep northwestern coast of Lake Kivu. In the following 15 years, the risk in the DRC decreases sharply, only to soar again in the nineties. This sudden increase in risk can be linked to two factors: demographic changes and environmental degradation. During the nineties, the location of the Congolese people shifted towards steeper terrain. This shift is explained by the relocation of hundreds of thousands of Rwandan refugees and internally displaced people following the First and Second Congo War, but also by the economic opportunities provided by the booming, often informal, mining industry. Deforestation has also contributed to the higher landslide risk in the DRC, as large parts of the primary forest have been cut to satisfy the land and fuelwood demand of the fast-growing population.

With our analysis, we demonstrate that a landslide risk assessment is more than the reflection of the current environmental conditions. The legacy of environmental and societal dynamics resonates in contemporary landslide risk.