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Urban growth changes the pulse of a large deep-seated landslide

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While the behaviour of slow-moving landslides – response to seasonal precipitation, seismic shaking, etc. – is well described in natural mountainous environments, little is known on the influence of urbanisation on their dynamics. Yet, gradual urbanisation of hillslopes is commonplace in the outskirts of many cities of the tropics. Typically anarchic, construction on previously undisturbed slopes often initiates or enhances landslide activity, rapidly increasing the number of people exposed to landslide hazard. Aiming at studying how landslides respond to their progressive urbanisation, we here present a detailed analysis of the dynamics of a large, thousand-year-old slow-moving landslide located in the rapidly expanding city of Bukavu (eastern DR Congo). This slope failure developed in highly weathered lava layers hosts today more than 80 000 inhabitants; for many affected by incessant destruction of infrastructures and housing.

We used 4 years of temporally dense 3D kinematic data from satellite interferometry (MSBAS 3D), pixel tracking on satellite and Unmanned Aerial System (UAS) orthomosaics and aerial photograph analysis to examine the relationships between urbanisation, landslide activity and rainfall and seismic patterns. We found a closely tied relationship between subsurface pore-water pressure changes and surface velocities. Seasonal rainfalls are driving the kinematics of the landslide at the weekly timescale, despite the large (~30-100 m) depth of the landslide. Analysing landslide dynamics over the last 60 years, we observed an increased activity over a zone of the landslide that will rapidly become the fastest landslide unit. This destabilisation occurred in the '90s, alongside an intensification of the (informal) urbanisation of the hillslope, at a time when region's violent conflicts and insecurity drove important rural-urban migration. Still the most active today, this landslide unit moves at paces of 0.5-3 meters per year, causing significant and persistent

damages to infrastructures. We here argue that changes in water runoff, concentration and infiltration due to the anarchic and poorly maintained urban extension is modifying the long-term behaviour of the landside, rather than overloading due to buildings (often light and wooden structures) and infrastructures. The very quick response to pore pressure changes could also be associated to the dense urban fabric, even though the tropical characteristics of this environment (wet-dry seasons, high rainfall, very high weathering) should not be ignored. Our analysis help improve the evaluation of landslide hazard and mitigation in the area, but also across the other many cities of the tropics where similar environmental and societal conditions are met. These findings also have implications for our understanding of landslide dynamics and how humans are interfering with landscape evolution.