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

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The behaviour of slow-moving landslides is well described in natural environments – simplified mechanisms showing that rainfall-induced changes in pore-water pressure are principally regulating their motion.

Yet, while hydrologists have long recognized that urbanisation has dramatic impacts on catchment hydrology, very little is known on the influence of urbanisation on landslide behaviour.

Aiming at studying how landslides respond to urbanisation, we here present an analysis of the dynamics of a slow-moving deep-seated landslide sited in the tropical environments of the rapidly expanding city of Bukavu (eastern DR Congo).
building on 4.5 years of very dense InSAR times series, we show that changes in slope velocity are closely tied to changes in slope pore-water pressure. Without being able to unambiguously disentangle the effects of different environmental factors acting on the slope, we show that the impact of urbanisation on slope groundwater circulation and saturation may explain the unusual landslide behavior.
Looking back at hillslope changes over the last 70 years, we show the timing of the acceleration of a large landslide unit to coincide with the intensification of the informal urbanisation of the hillslope.
Our results suggest that urbanisation can interfere with the natural behaviour of long-lived, deep-seated landslides. As hillslopes of the world’s cities are being urbanised at accelerating paces such understanding is crucial to ensuring a valid evaluation of landslide hazard and optimise mitigation strategies.
OVERVIEW

- **environmental context**: the Kivu Rift
- **study of seasonal landslide controls** from SAR interferometry (MSBAS 3D)
- **analysis of long-term hillslope changes** - urban development and slope instability
Kivu Rift

Tropics
- intense rainfall events
- deep weathering

East African Rift System
- steep topography
- moderate seismicity
- heavily faulted

Bukavu (DR Congo)
- old basaltic province
- high population pressure
- context of data scarcity
Seasonal controls on urban landslide

SAR interferometry to measure 3D surface displacements over 4.5 years (MSBAS 3D)

For more info on MSBAS 3D see Samsonov et al. 2020, Engineering Geology
Seasonal controls on urban landslide

A closely tied relationship between slope velocity and pore-water pressure changes indicating that near-surface groundwater flows play a key role in the week-to-week kinematic; no apparent effect of nearby earthquakes.
Long-term hillslope changes

Progressive hillslope urbanisation

• only the landslide toe was urbanised in 1947

• intensification of informal urbanisation in the ’90s alongside rural-urban migration driven by regional conflicts

• from early 2000, 80 % of the landslide is urbanised – mostly light, informal dwellings

• adduction and drainage systems become more and more inadequate and subjected to leaks
Long-term hillslope changes

- important velocity increase for a zone of the landslide between 1974 and 2001
- this period corresponds to a time of intensification of informal urbanisation
- stresses from deformation and mismanagement of water distribution system led to rupture of water pipe within slope and the formation of two deep gullies

landslide displacement vs urban development

Historical aerial photos (1947, 1959 and 1974) and satellite imagery (2001, 2013 and 2018) are used to constrain landslide velocity changes and progressive urbanisation of Funu landslide.

- important velocity increase in parallel to near-doubling of urban footprint
- constant rates
- uncertainty

aerial photos satellite imagery

- central units
- active toe
- fastest unit
- urban footprint
Urbanisation influences slope hydrology

- modifies how and where water infiltrates
- changes sources and location of slope recharge
- involves drastic and extensive reorganisations of surface and subsurface infiltration pathways
- water distribution systems bring water from outside the catchment

→ impacts slope groundwater circulation and saturation
→ may directly influence hillslope stress state // strong controls of pore-water pressure on landslide behaviour
Our results suggest that urbanisation can interfere with the natural behaviour of long-lived, deep-seated landslides.

As hillslopes of the world's cities are being urbanised at accelerating paces better understanding the processes at play is crucial to ensuring a valid evaluation of landslide hazard and optimise mitigation strategies.
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