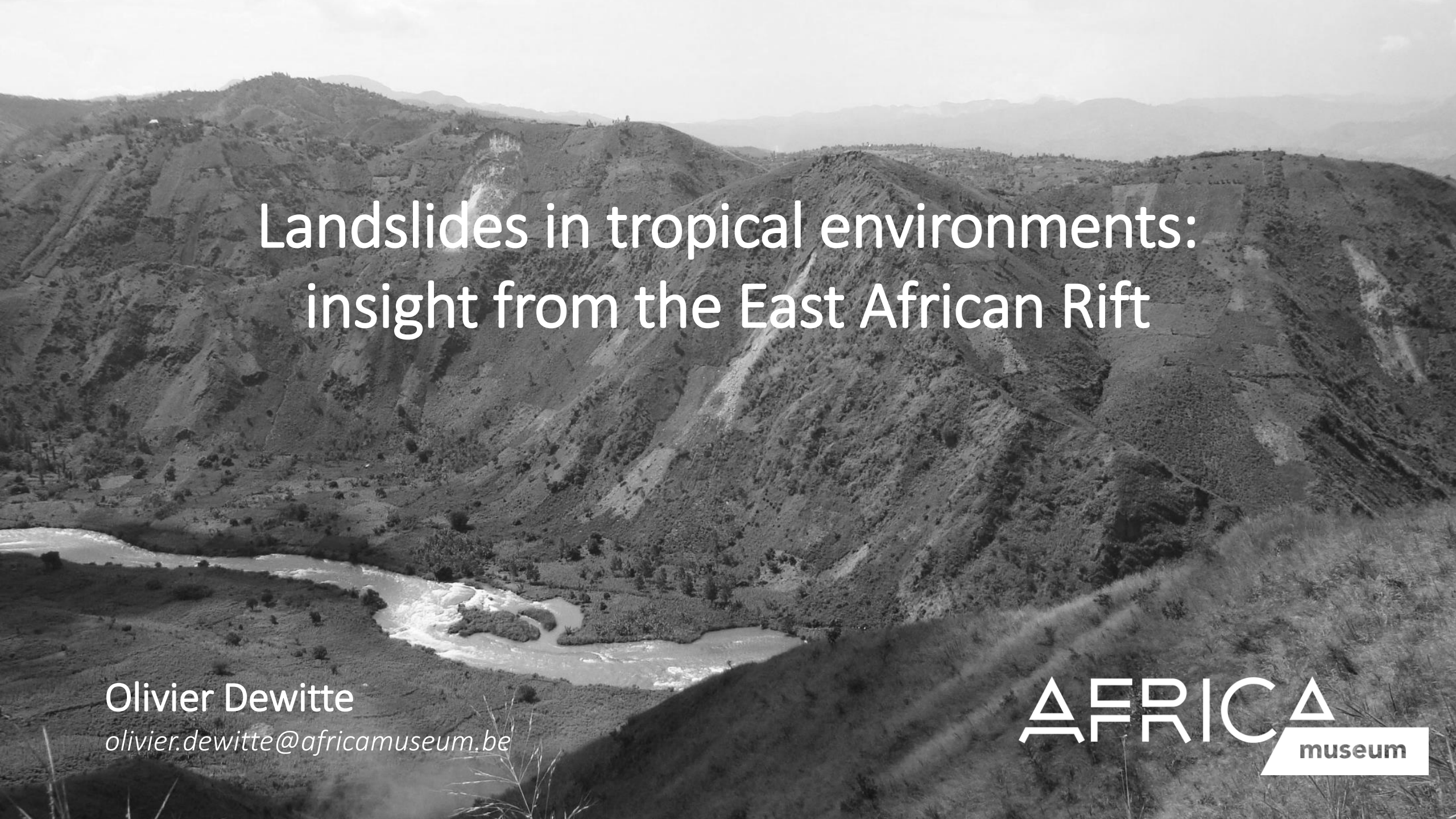


Landslides in tropical environments: insight from the East African Rift

Olivier Dewitte
olivier.dewitte@africamuseum.be

AFRICA museum

The Ruzizi River – a unique geomorphological landscape at the border between three African countries


Bukavu (DR Congo) - a city built on landslides
~80,000 inhabitants live on this active landslide

Bukavu (DR Congo) - a city built on landslides

~80,000 inhabitants live on the landslide

Comment

A mudslide in August 2017 killed hundreds of people in Freetown, Sierra Leone.

How climate change and unplanned urban sprawl bring more landslides

Ugur Ozturk, Elisa Bozzolan, Elizabeth A. Holcombe, Roopam Shukla, Francesca Pianosi & Thorsten Wagener

More settlements will suffer as heavy rains and unregulated construction destabilize slopes in the tropics, models show.

The first half of 2022 was one of the deadliest on record for landslides. In January and February, cities across South America were hit by devastating soil, rock and mud flows – burying at least 14 people in their homes at Dosquebradas in Colombia, and killing 24 people in Quito, Ecuador, and at least 220 in Petrópolis, Brazil. In April, May and June, hundreds more were killed in Pilar in the Philippines, Durban in South Africa, Recife in Brazil and across Bangladesh.

That's fast approaching the roughly 4,500 people who are killed on average worldwide each year by landslides[1]. Economic damages from these events amount to US$20 billion annually[2], which is roughly one-quarter of those resulting from floods.

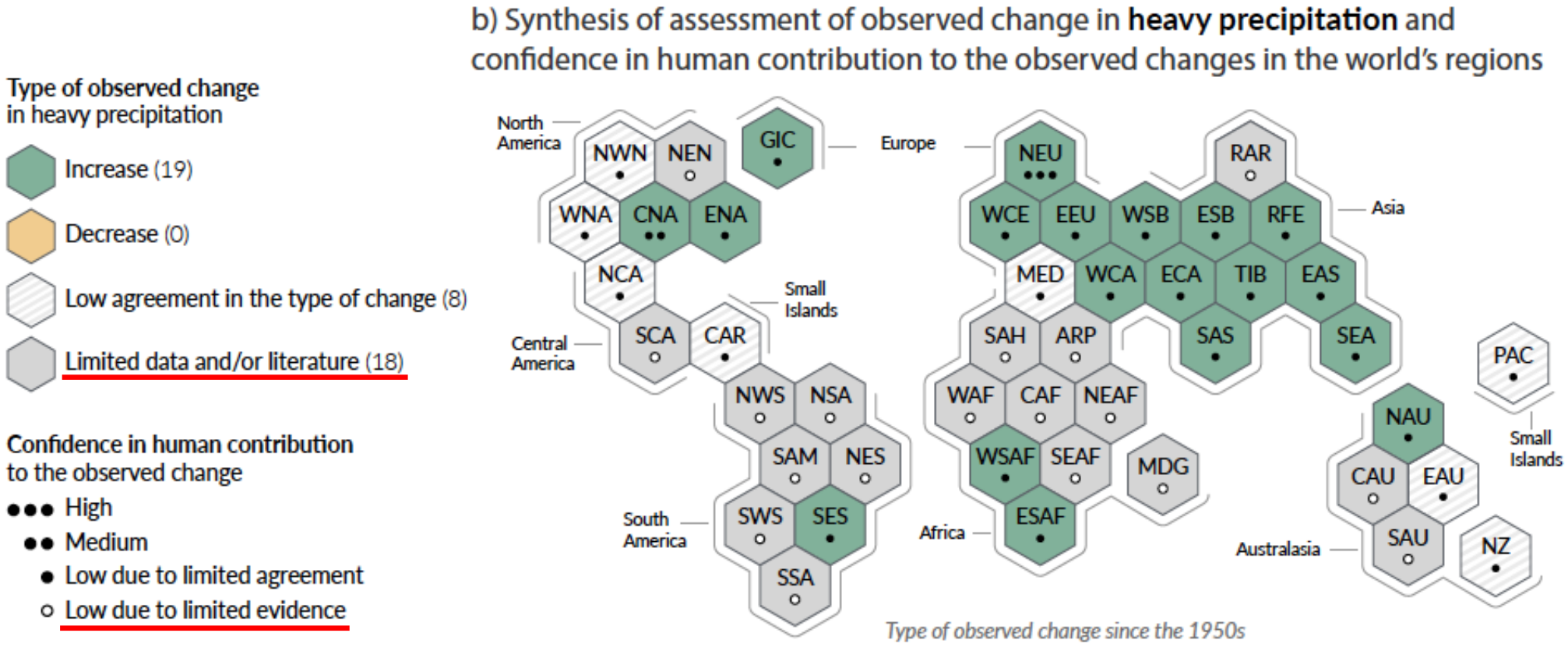
Over the past 50 years, disasters caused by landslides have become ten times more frequent[3]. And landslide risk is set to escalate, owing to two increasing trends – climate change and urbanization. Now, researchers need to assess where and to what extent such risks will rise.

More than 80% of fatal landslides occur in the tropics[1]. They are triggered mainly by heavy rain, often during cyclones and monsoons. Climate projections show that, on average, the intensities of tropical deluges could double by the end of the century[4]. But it's hard to say what will happen in any given place.

The rapid pace of urbanization, especially in low- and lower-middle-income nations in tropical regions, will put more people in the path of landslides. For example, the population of Freetown in Sierra Leone has nearly doubled, to more than 1.2 million, since 2000. Many people arriving in the city end up living in poor or informal settlements on hills and floodplains at the city margins. Informal housing practices such as unregulated deforesting, slope cutting and household water drainage, can increase the chance of landslides. And such communities are hit disproportionately hard. For example, in Latin America and the Caribbean, 81% of the people

WHY IN THE TROPICS?

Context of data scarcity – lack of research



IPCC Sixth Assessment Report, 2021

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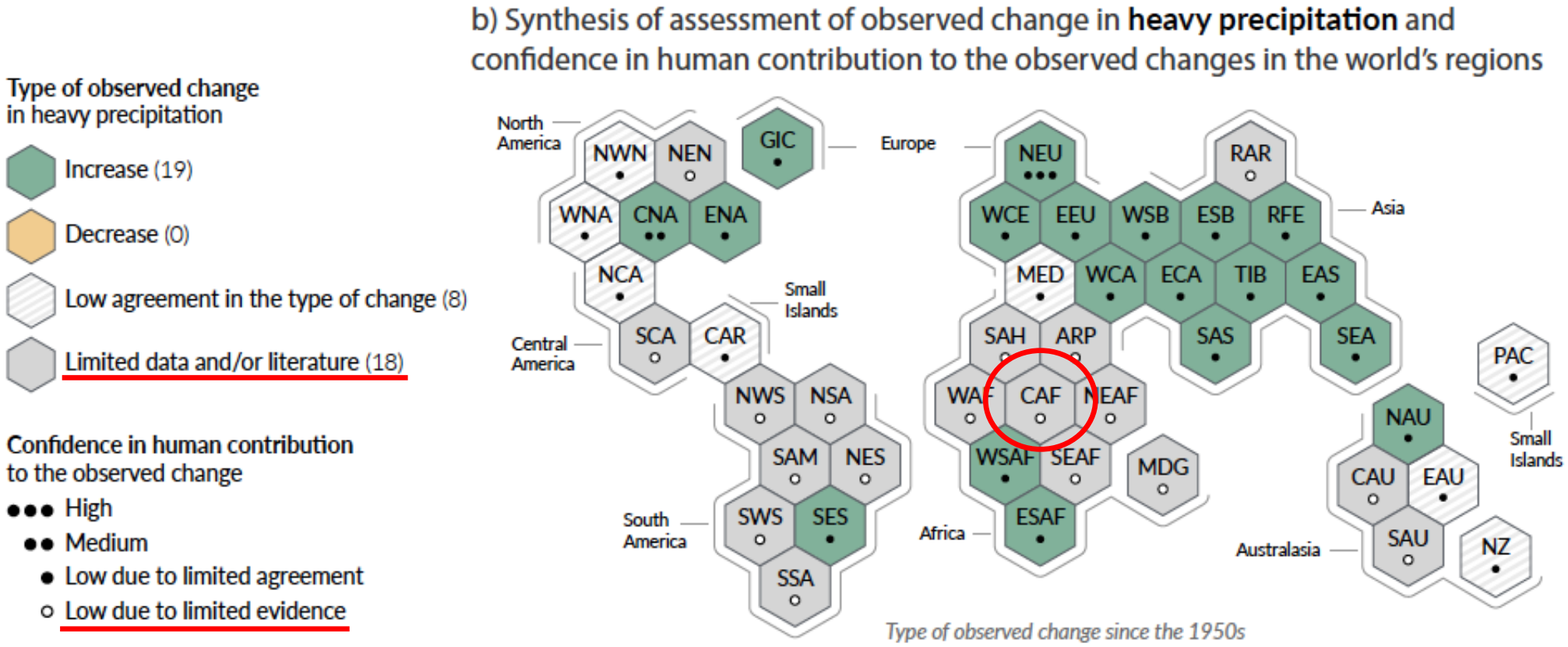
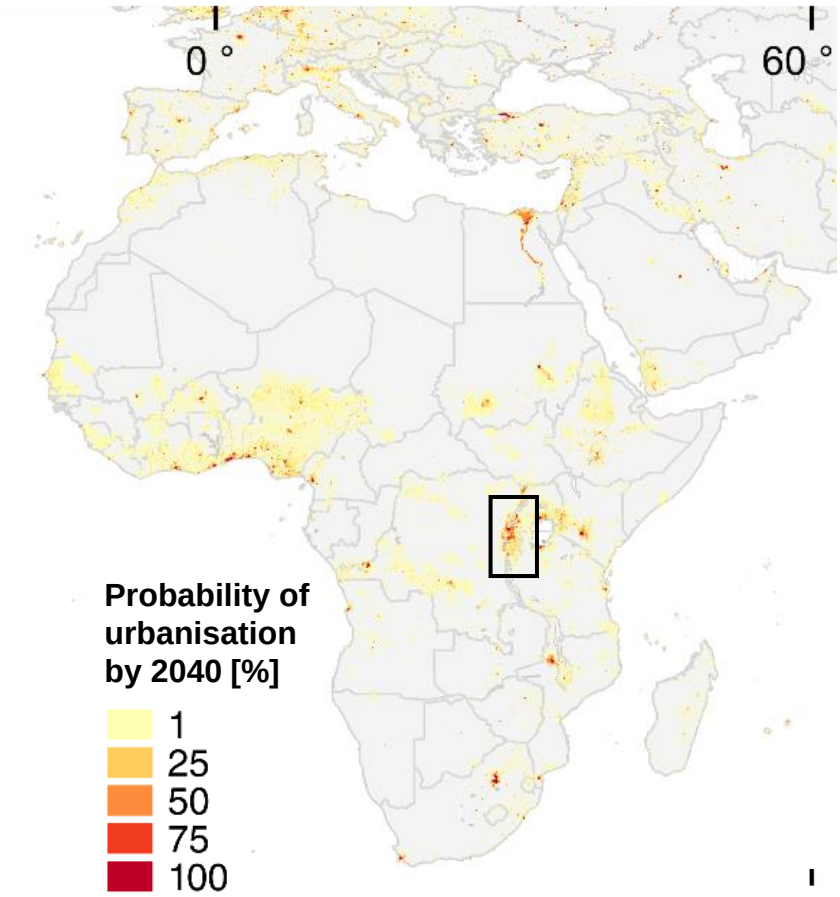


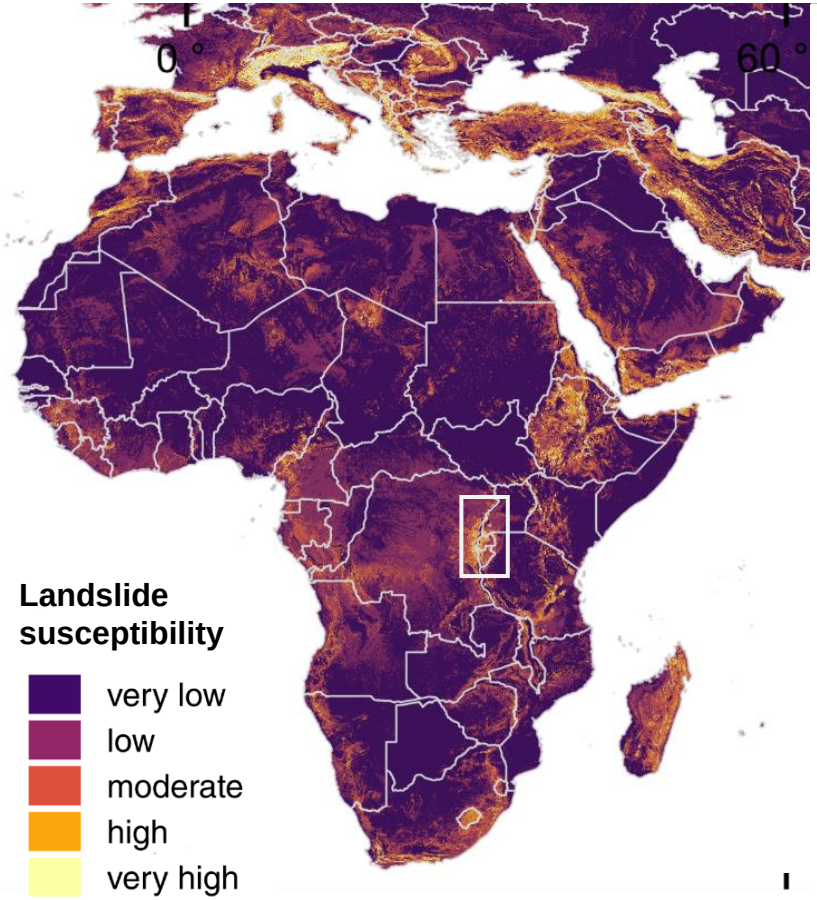
IPCC Sixth Assessment Report, 2021

A landslide hotspot in Africa and at the global level

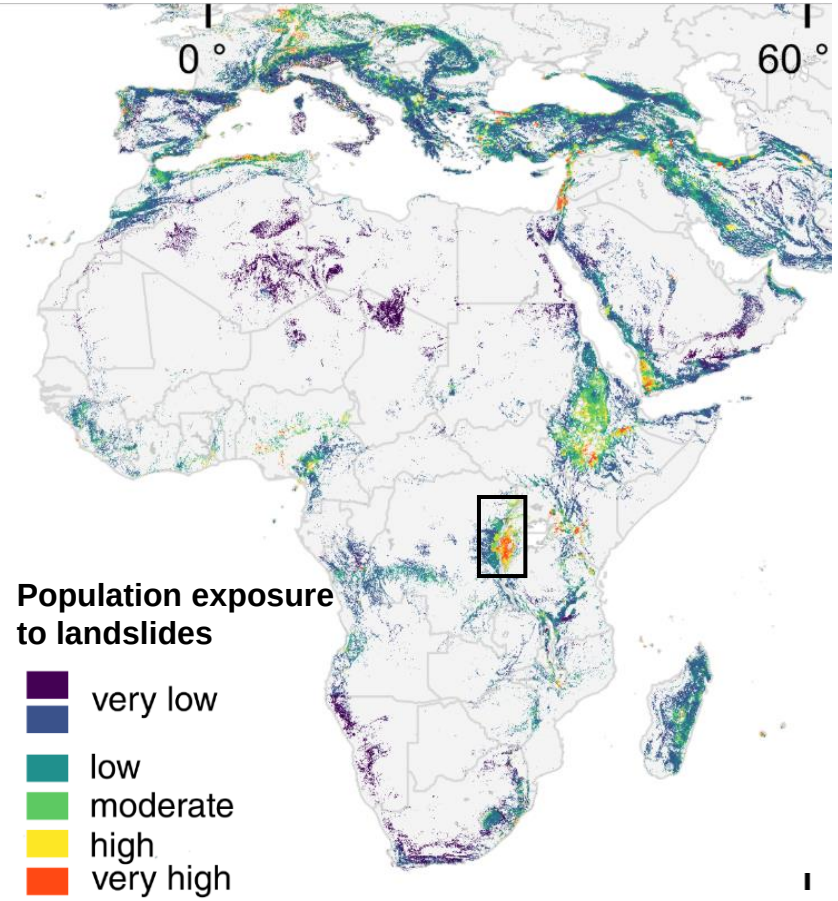
The western branch of the East African Rift



Zhou et al. (2019)
Sci. Data



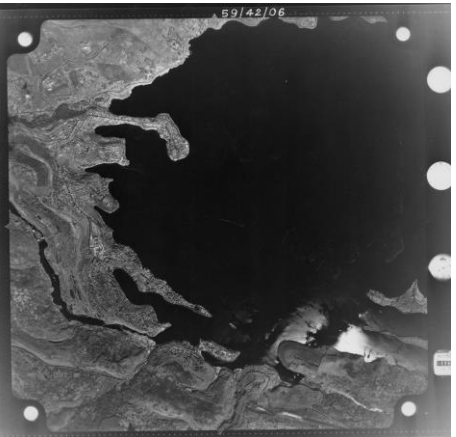
Stanley and Kirschbaum (2017)
Natural Hazards



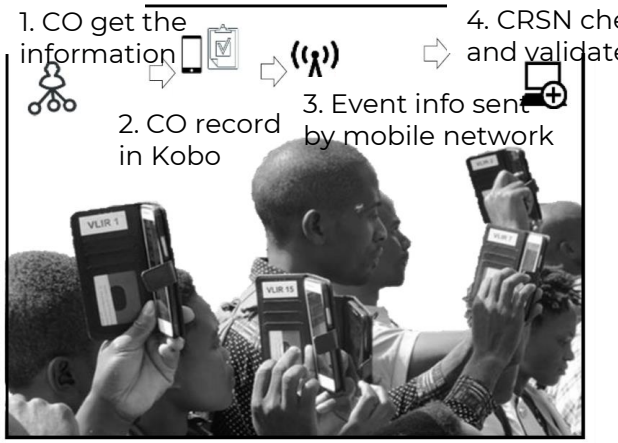
Emberson et al. (2020)
NHESS

[Dewitte et al., 2022. Treatise on Geomorphology]

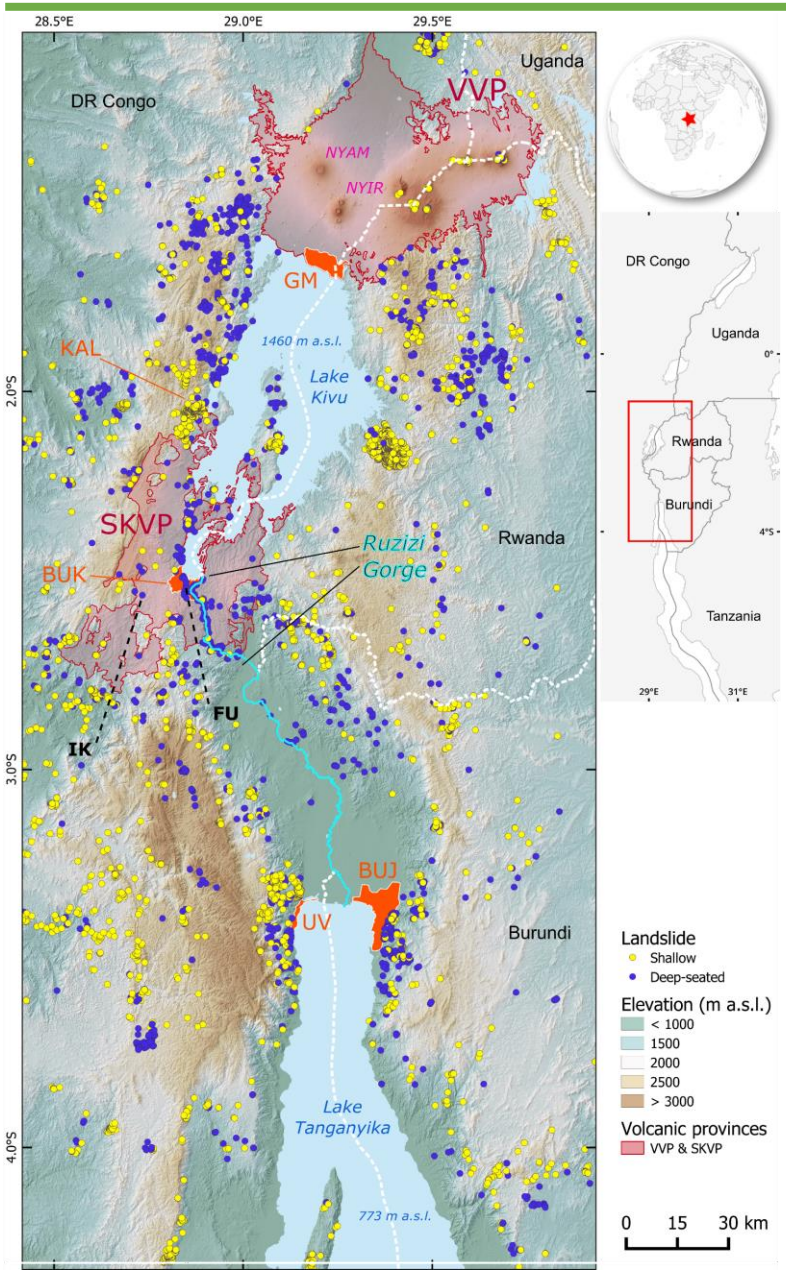
A pluridisciplinary and holistic approach



- **Satellite remote sensing (SAR, optical)**
- **Field work, drone image acquisition, climate data, etc.**
- **Historical aerial photographs (RMCA archives)**
- **Citizen science**
- **Strong partnership with African institutions**
- **Research strategies in data-scarce context**



Regional inventory and susceptibility



30,000 landslides
from satellite imagery
+ field validation

Dewitte et al., 2021. Landslides

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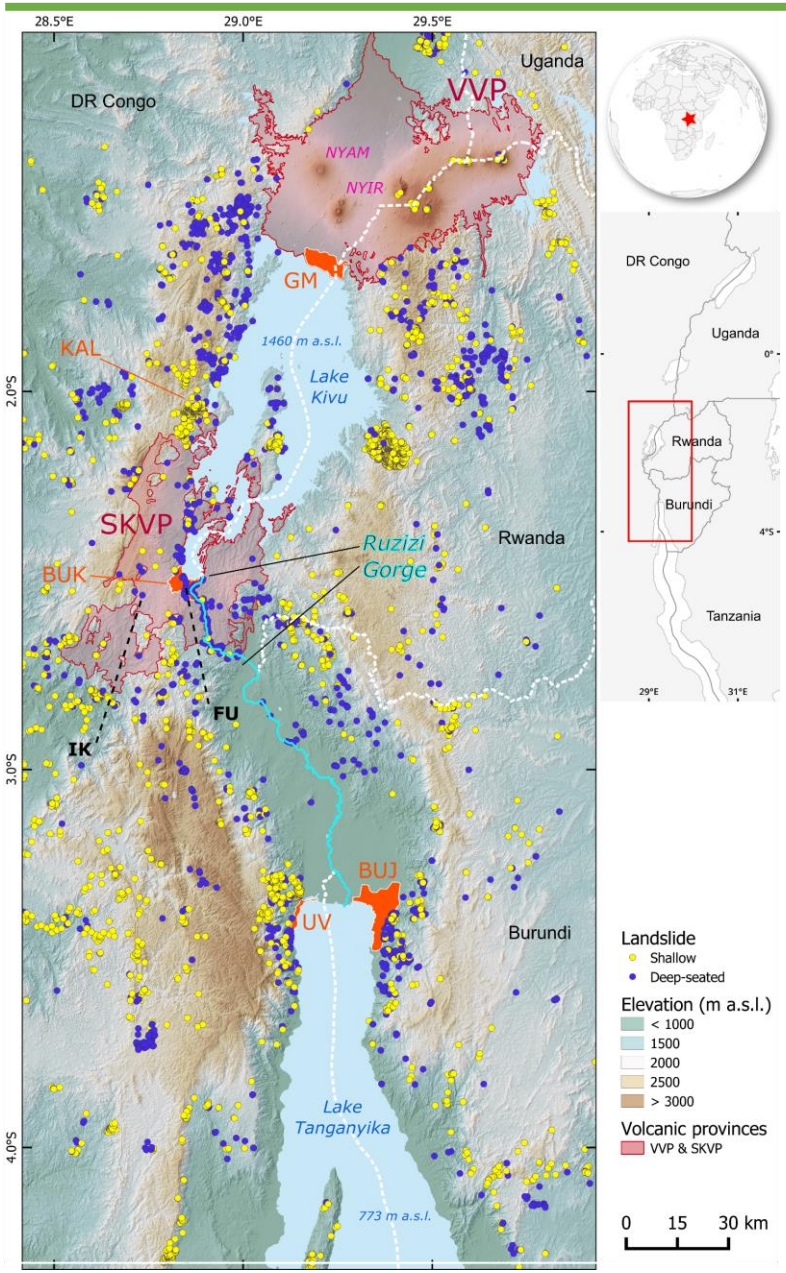

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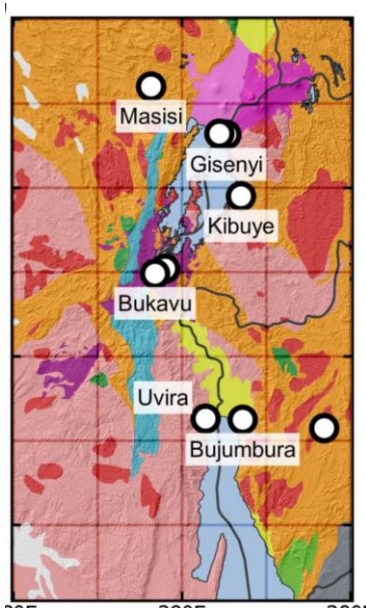
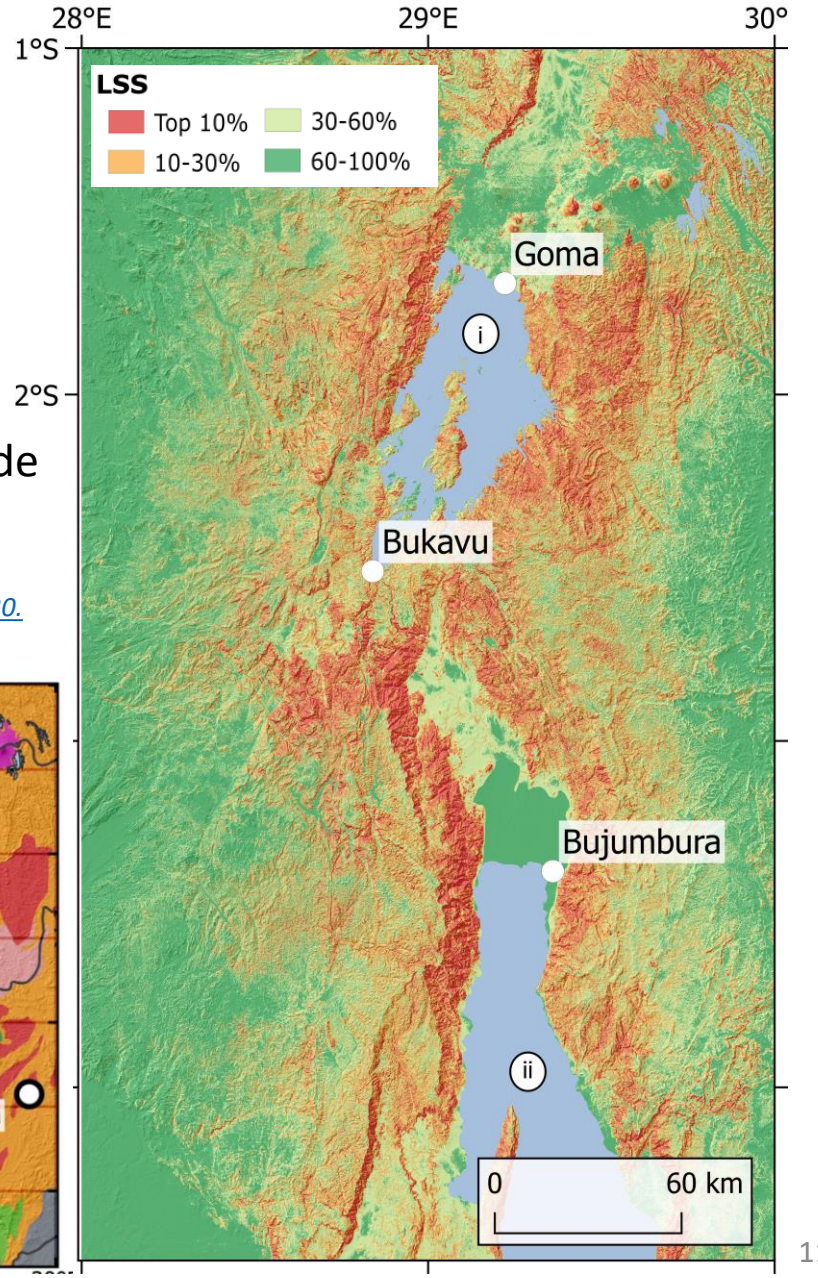
Regional landslide susceptibility

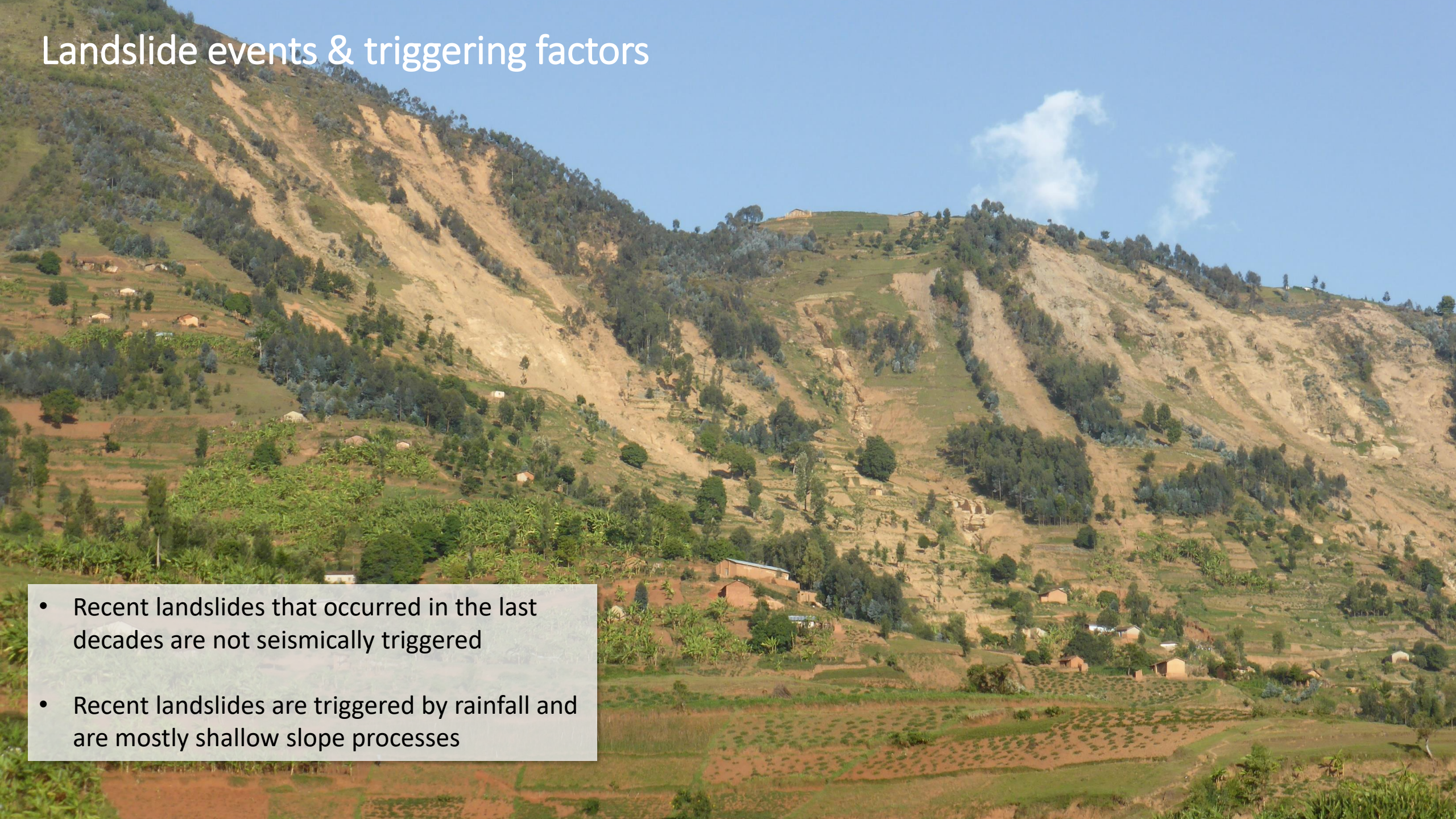
Depicker et al., 2020. Geomorphology





Debris avalanches in Rwanda – May 2018

Landslide events & triggering factors



- Recent landslides that occurred in the last decades are not seismically triggered
- Recent landslides are triggered by rainfall and are mostly shallow slope processes

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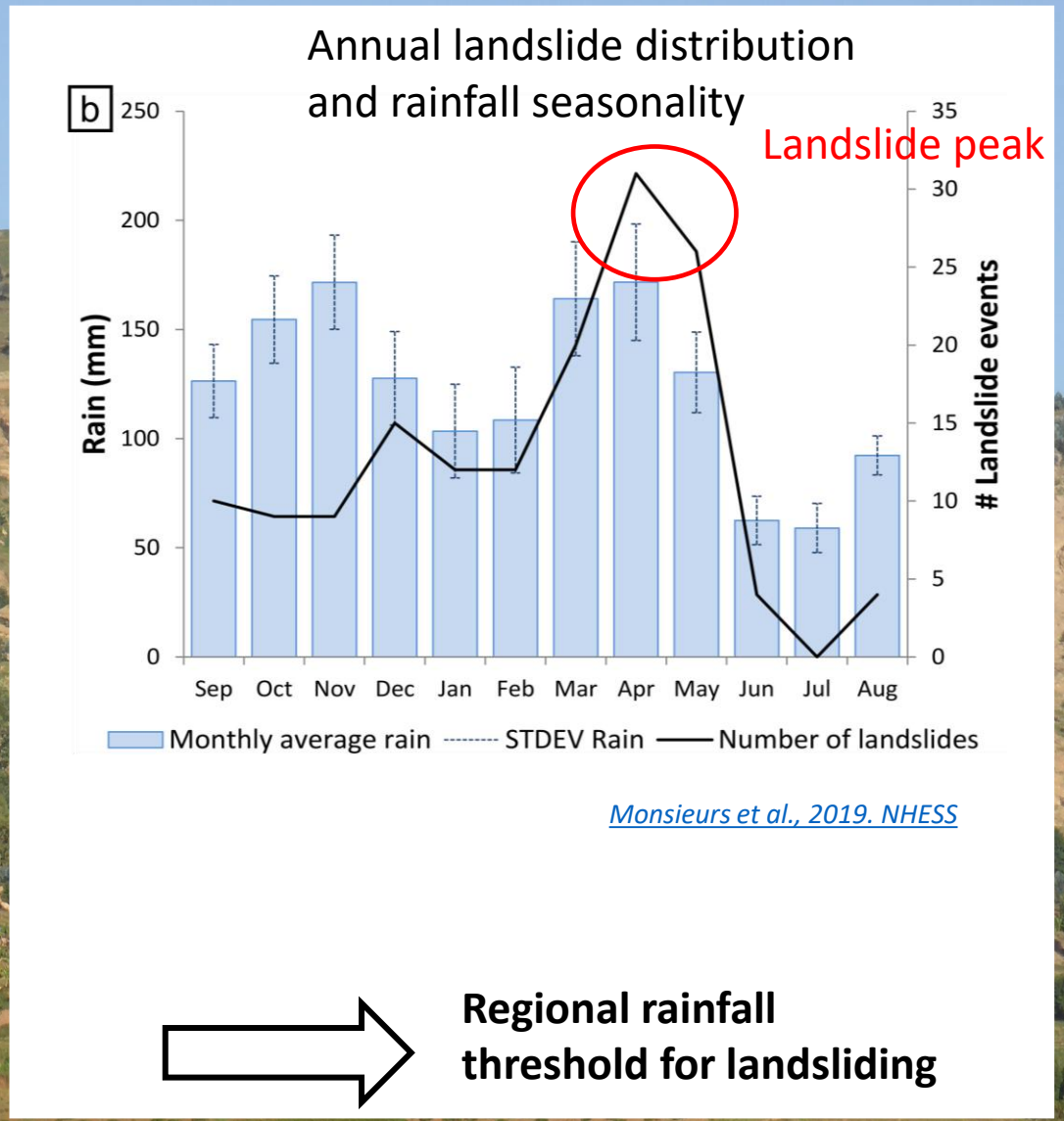
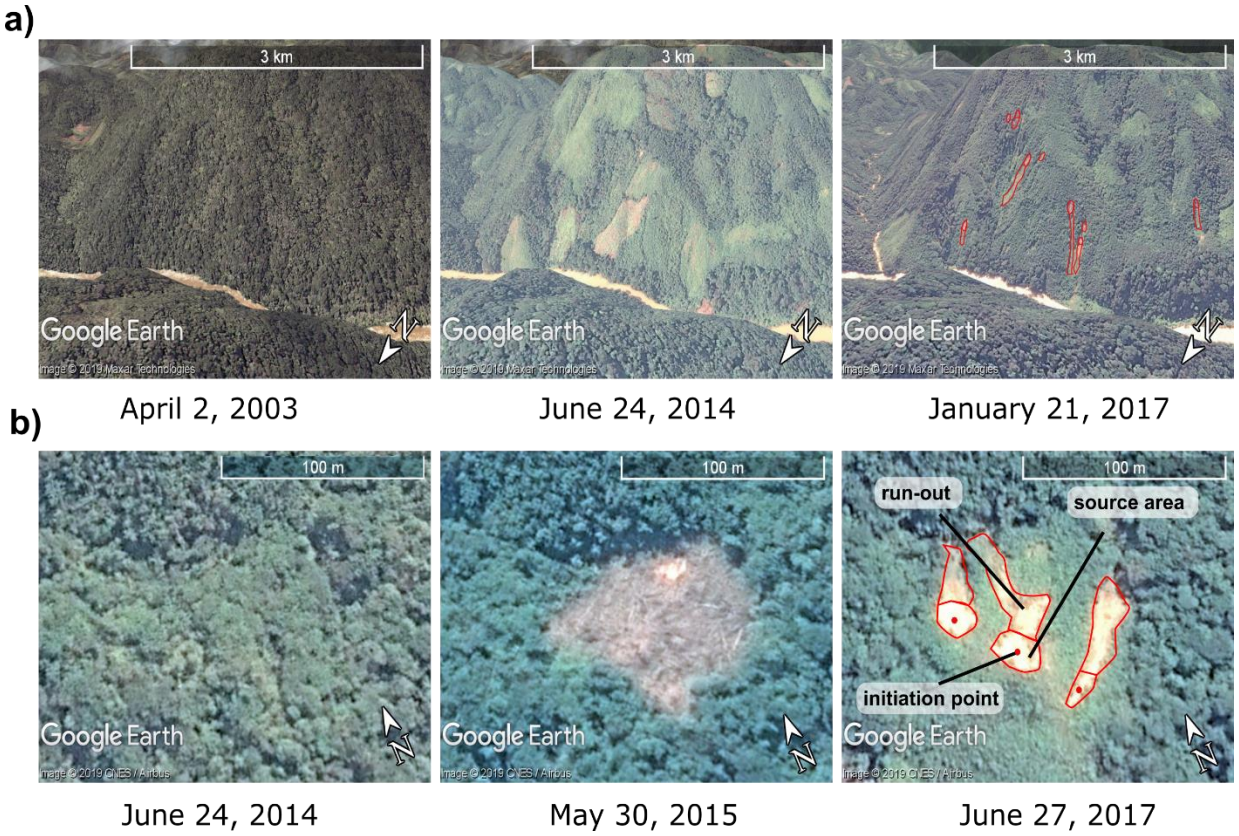


Monsieurs et al., 2019. NHESS

Regional rainfall threshold for landsliding

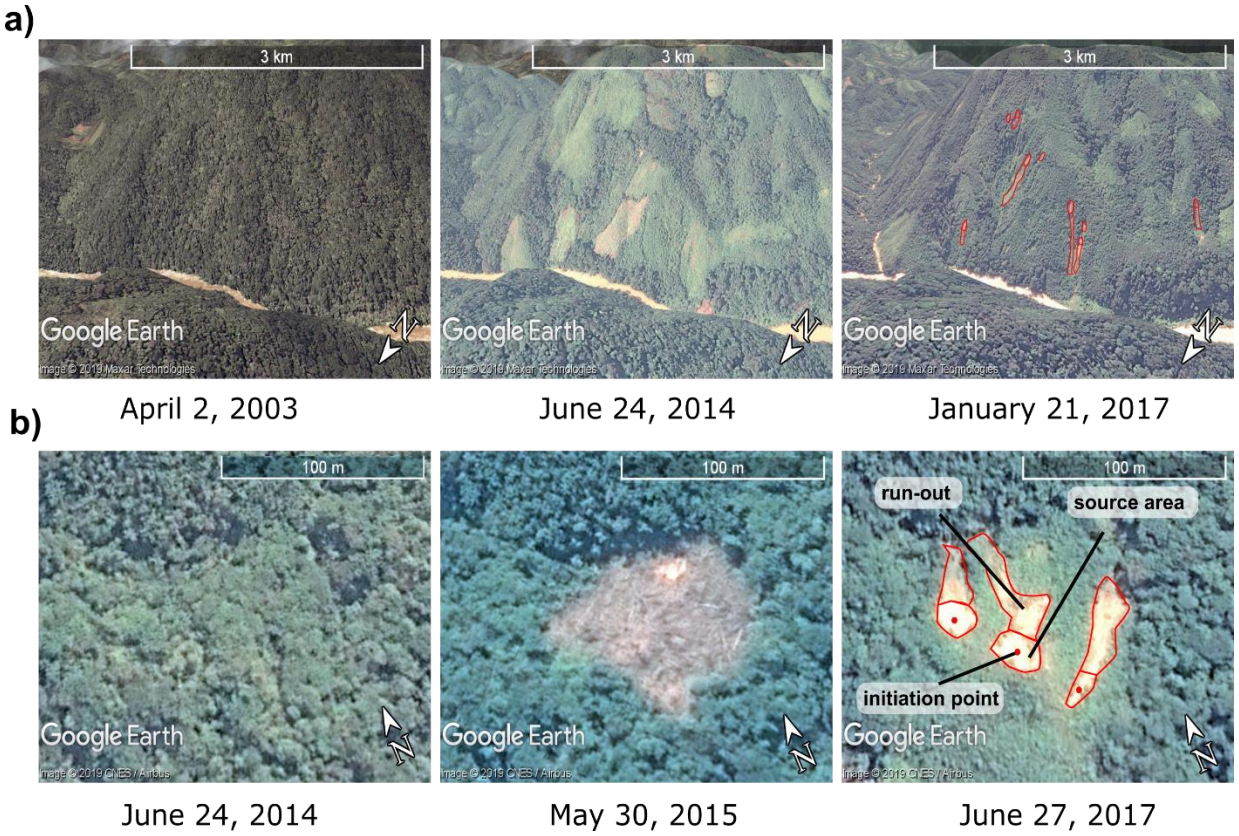
Shallow landslides, deforestation and landscape rejuvenation



Examples of landslides that followed deforestation. © Google Earth 2021

Depicker et al., 2021. Earth Surface Dynamics

Shallow landslides, deforestation and landscape rejuvenation



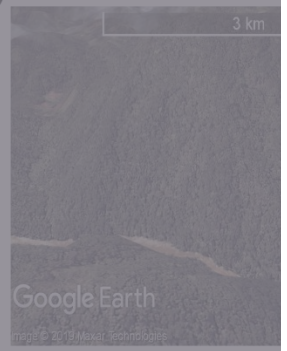
Examples of landslides that followed deforestation

Example of a knickpoint (waterfall) in Rwanda

[Depicker et al., 2021. Earth Surface Dynamics]

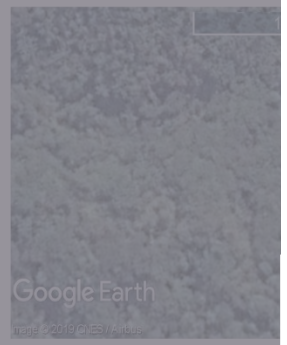
Shallow landslides, deforestation and landscape rejuvenation

a)



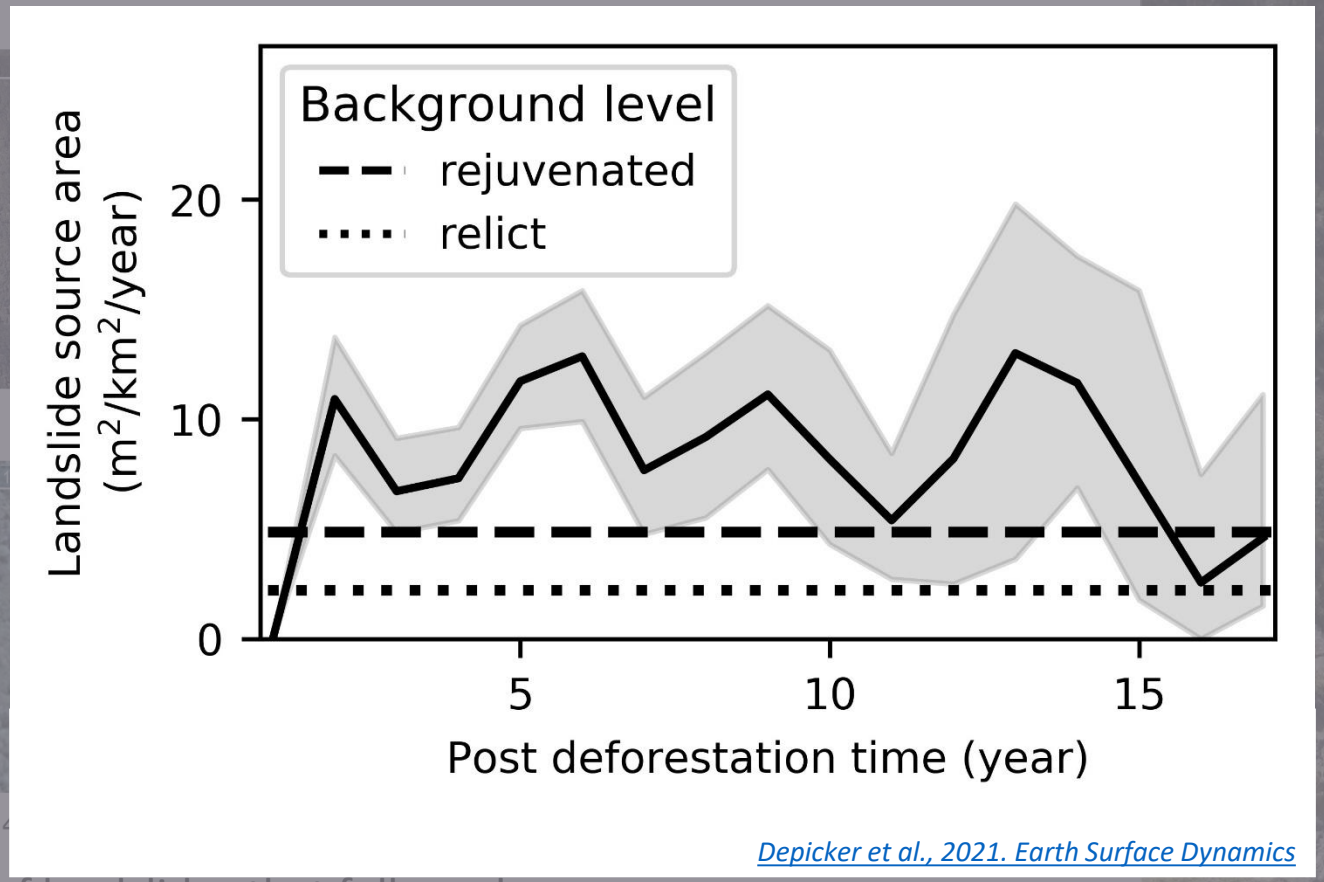
April 2, 2003

b)



June 24, 201

Examples of landslides that followed deforestation. © Google Earth 2021



[Depicker et al., 2021. Earth Surface Dynamics]

Deforestation increases landslide activity for a period of roughly 15 years

Example of a knickpoint (waterfall) in Rwanda

Landslide risk and the legacy of societal and environmental changes

1. Reconstruct forest cover changes 1958-2016
2. Link forest cover changes to landslide susceptibility
3. Link susceptibility to hazard
4. Risk = hazard x exposure x vulnerability

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- Risk in the eastern DR Congo higher due to widespread deforestation, mining, conflicts

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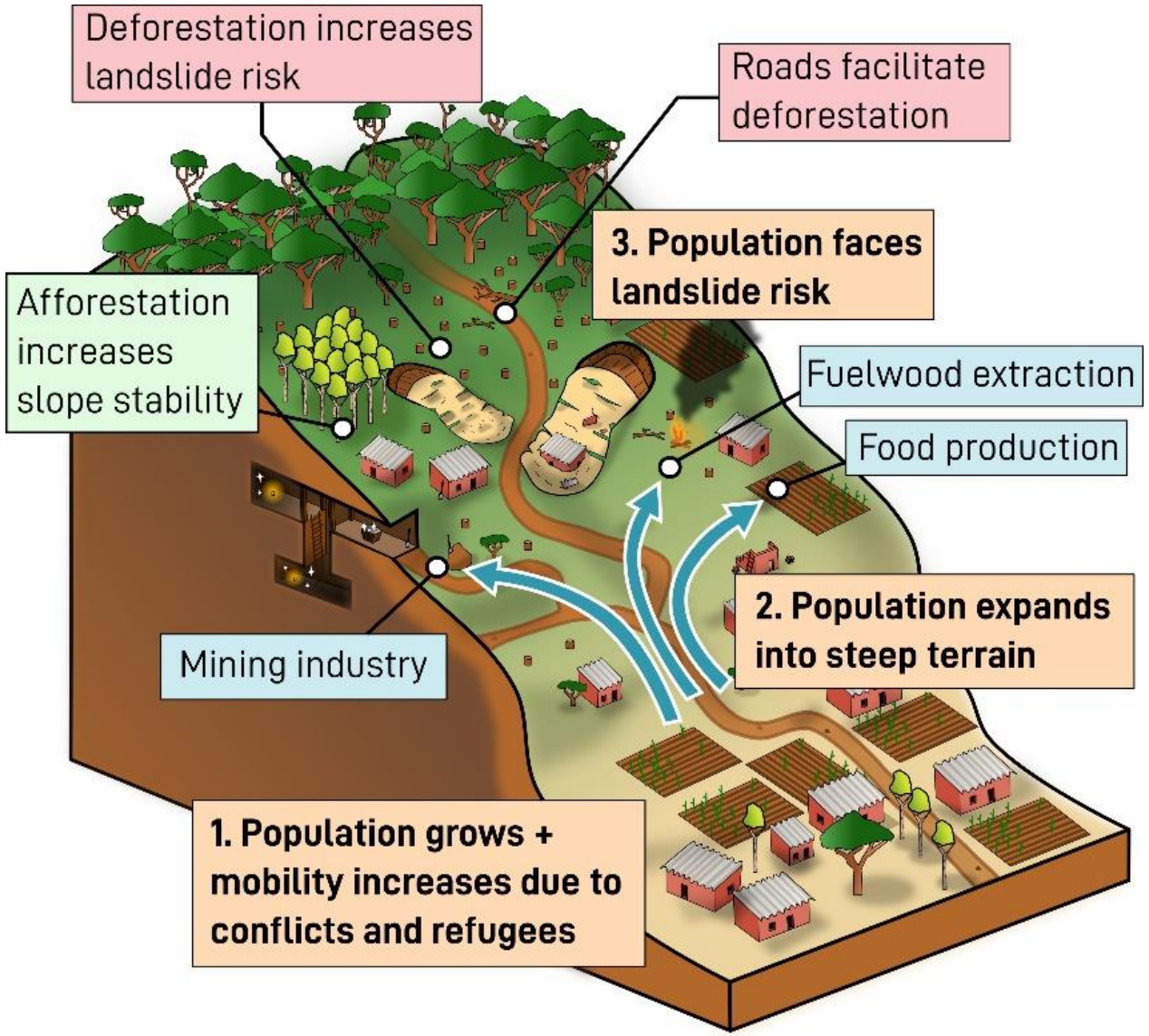

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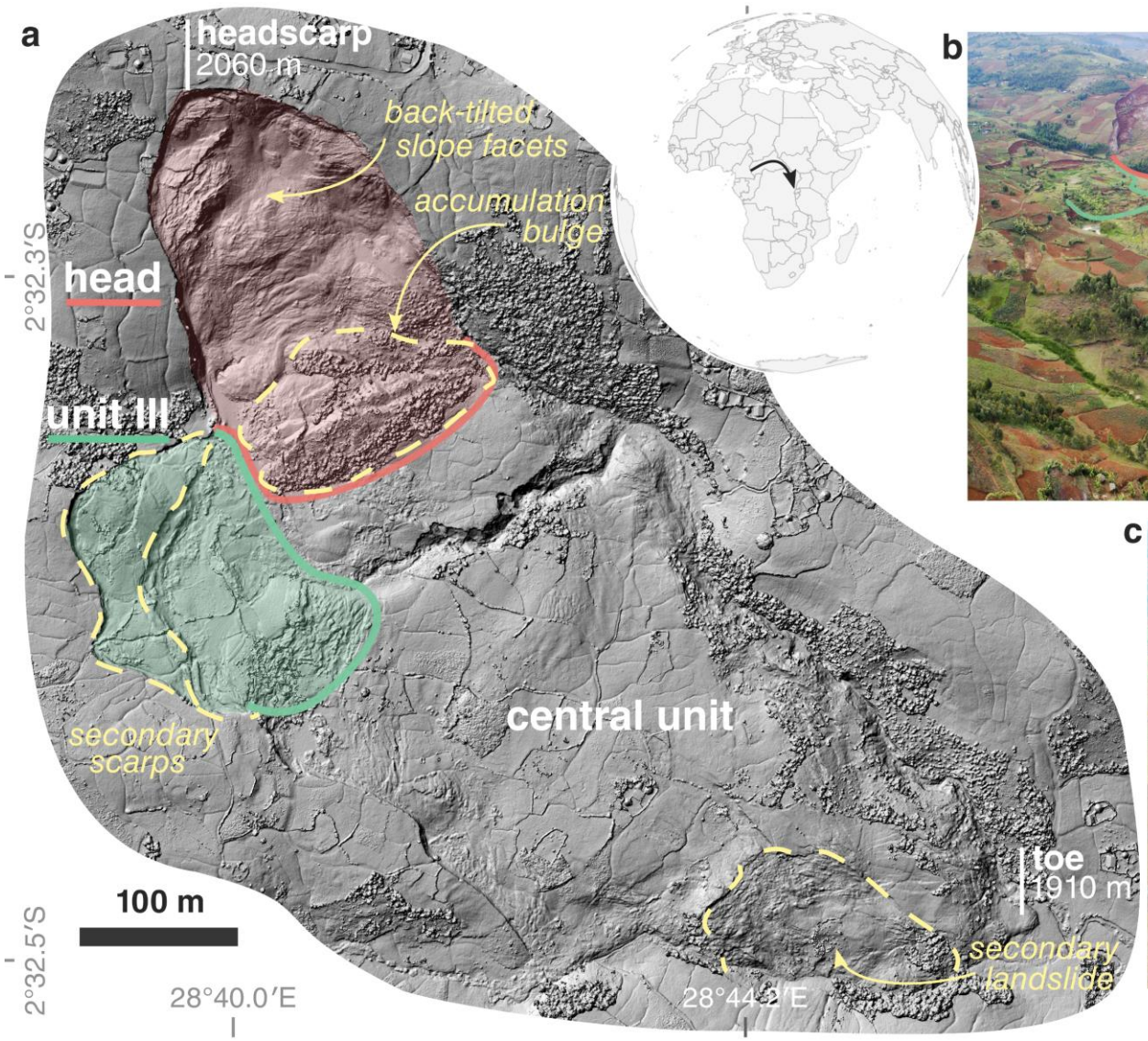
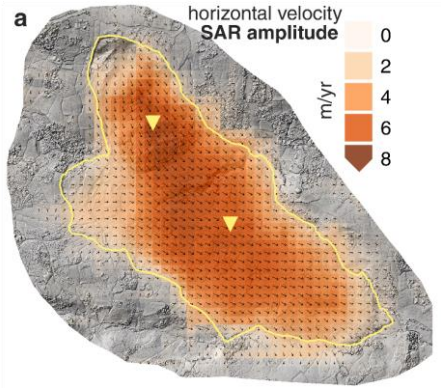
Depicker et al., 2021. Nature Sustainability

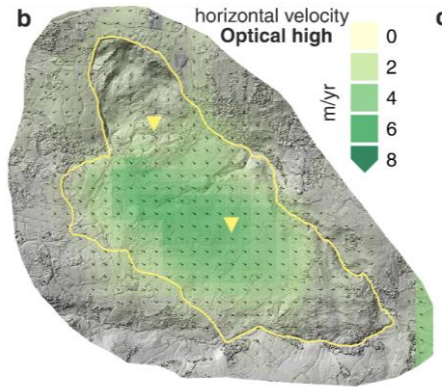
Maki Mateso et al., 2023. NHESS

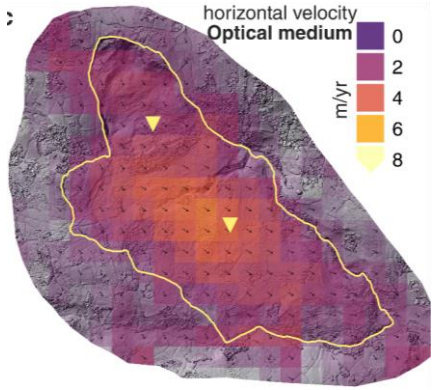
Dynamics of slow-moving landslides

Example of the Ikoma landslide (DR Congo)









[Dille et al. 2019, Geomorphology]

[Dille et al. 2021, Remote Sensing of Environment]

Dynamics of slow-moving landslides

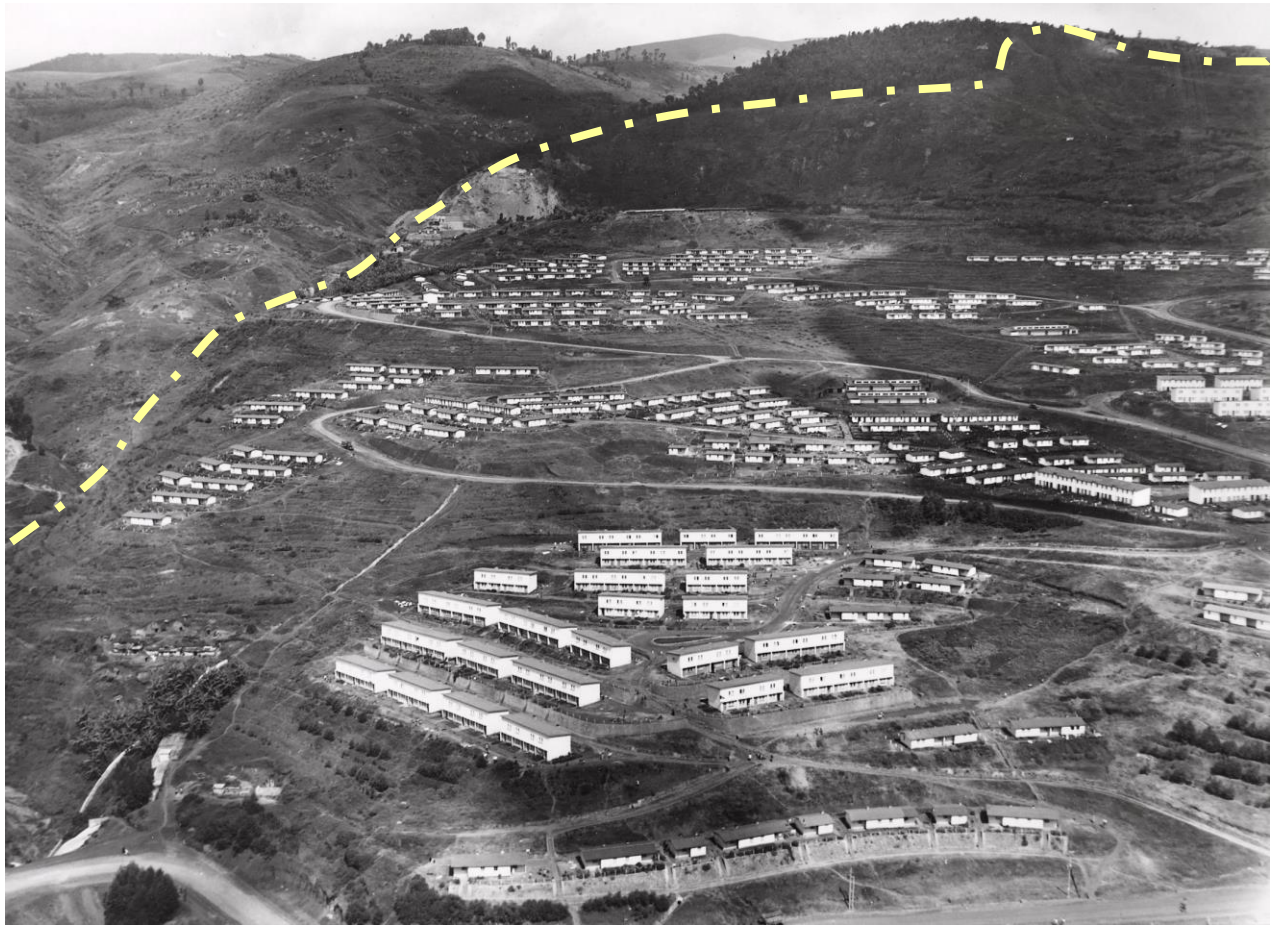
Example of the Funu landslide (Bukavu - DR Congo)

2018

Dynamics of slow-moving landslides

Example of the Funu landslide (Bukavu - DR Congo)

1959



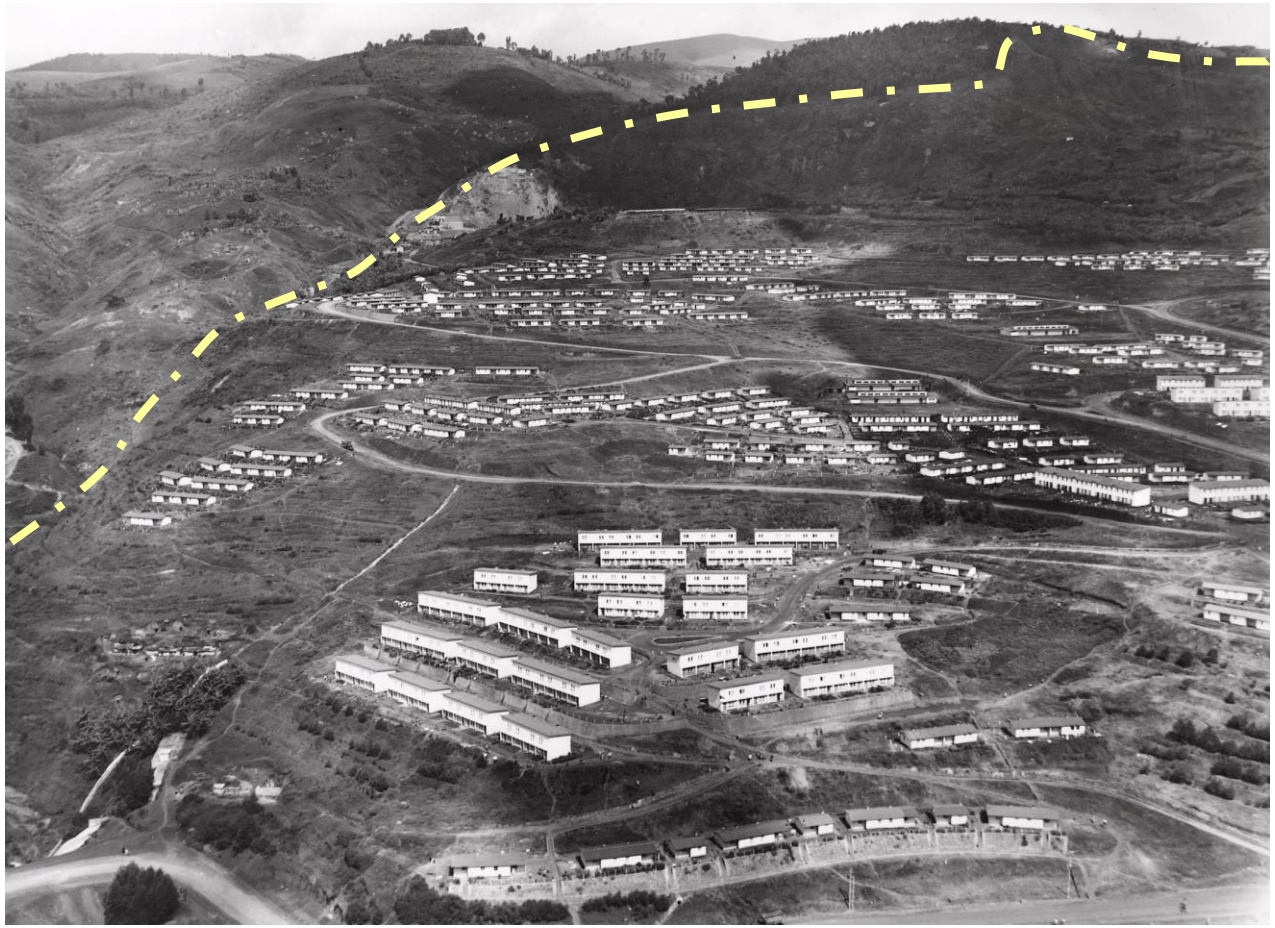
2018

[Dille et al., 2022. Nature Geoscience]

Dynamics of slow-moving landslides

Example of the Funu landslide (Bukavu - DR Congo)

1959

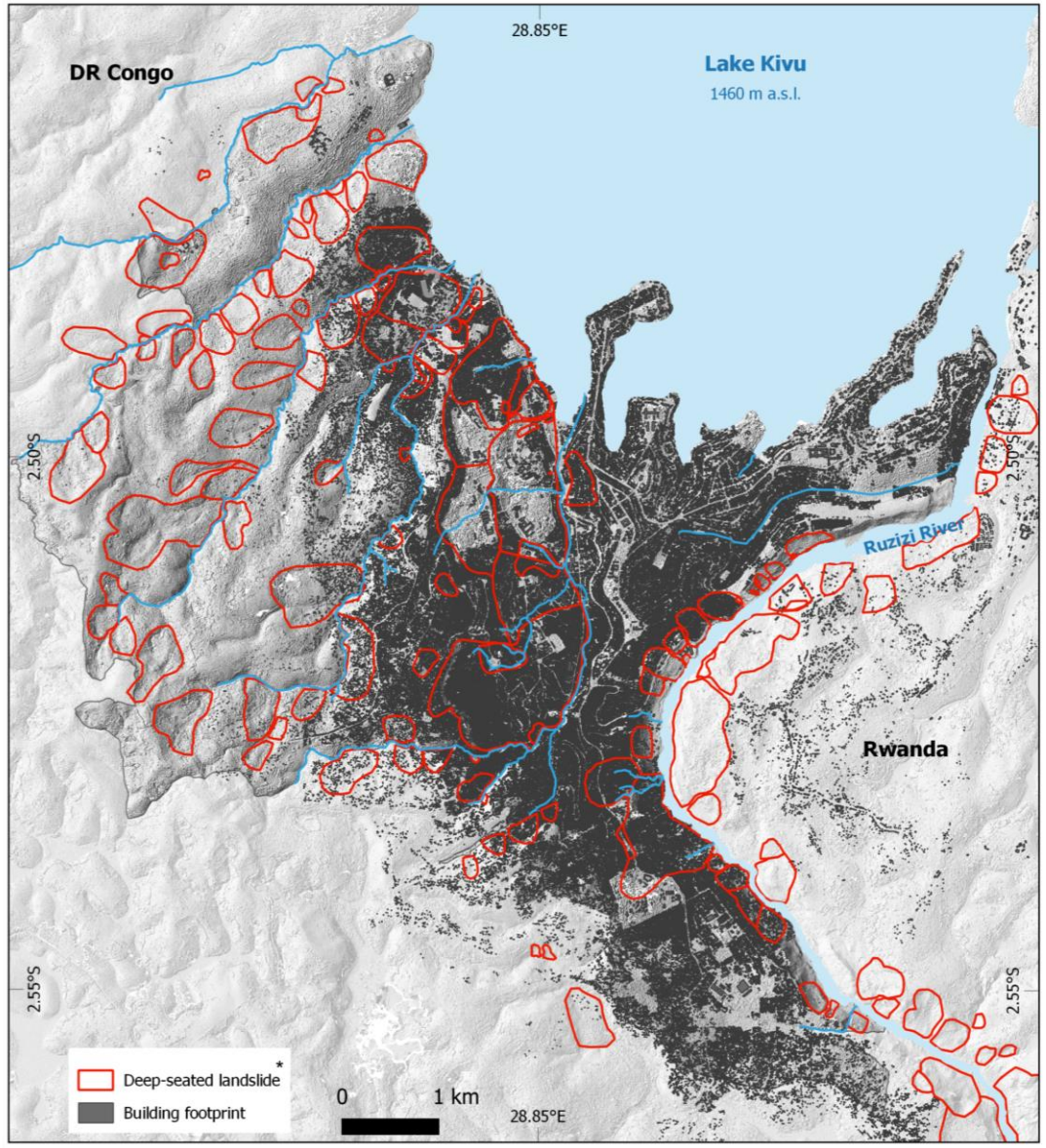


2018

Urbanisation interferes with the natural behaviour of the landslide through **modifications of slope hydrology**

Dille et al., 2022. Nature Geoscience

Bukavu (DR Congo)



30% of the city is built on landslides

Bukavu (DR Congo) – towards risk assessment

Hazard

Step 1.1: landslide multi-temporal inventory & process classification

3 hazard scenarios:
- shallow landslides
- reactivation of d/s slides
- deformation within d/s landslides

Step 1.2: landslide intensity & frequency

Step 1.3: hazard zonation

→ **3 hazard maps**

Population density

Step 2.1: visual characterisation of the urbanised area and identification of homogenous *morphological zones* (MZ) based on remote sensing & field survey

Step 2.2: population demographic survey in representative MZ plots

Step 2.3: population density zonation (= exposure)

→ **1 population density map**

Social vulnerability

Step 3.1: identification of key socio-economic variables (stakeholder survey, qualitative approach)

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Step 3.3: development of an Operational Vulnerability Index

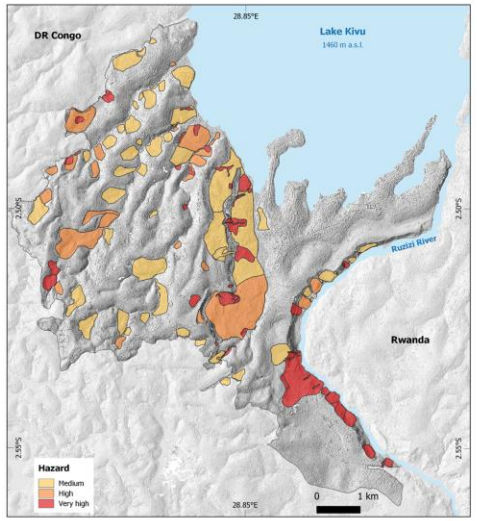
→ **1 contextualised vulnerability map**

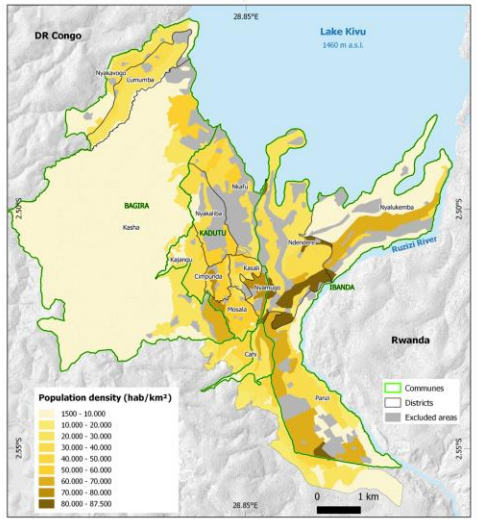
Risk

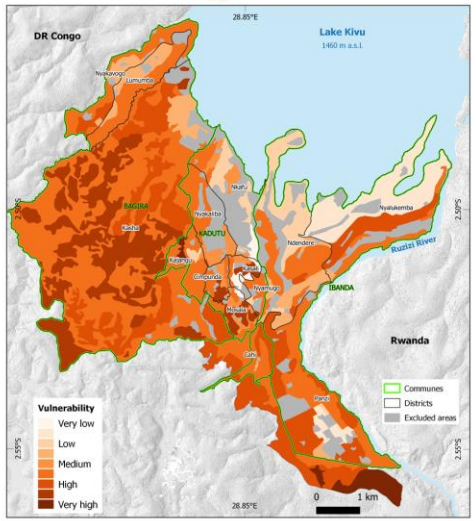
Risk zonation for 3 types of landslide constraints

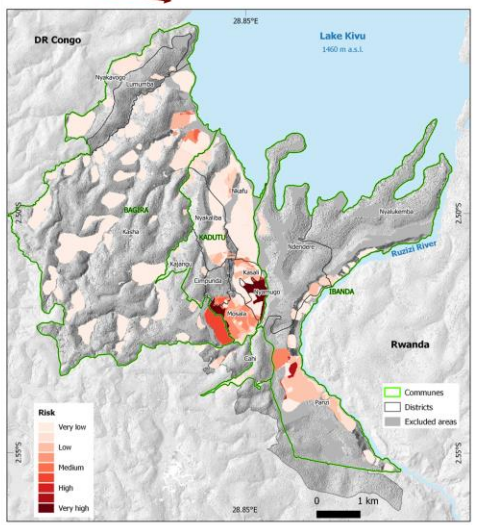
Each zonation is the product of one hazard map with the density map and the vulnerability map

→ **3 risk maps**









Michellier et al., *in preparation*

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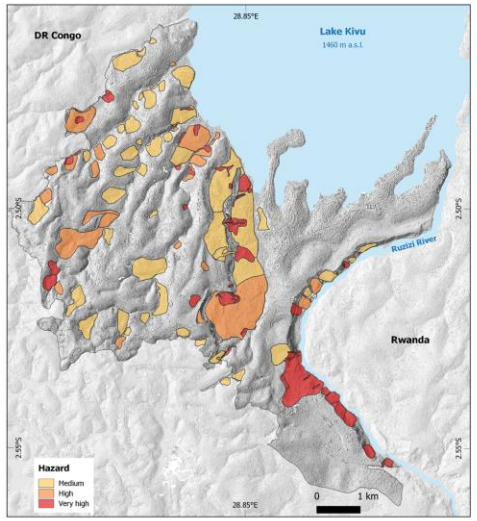
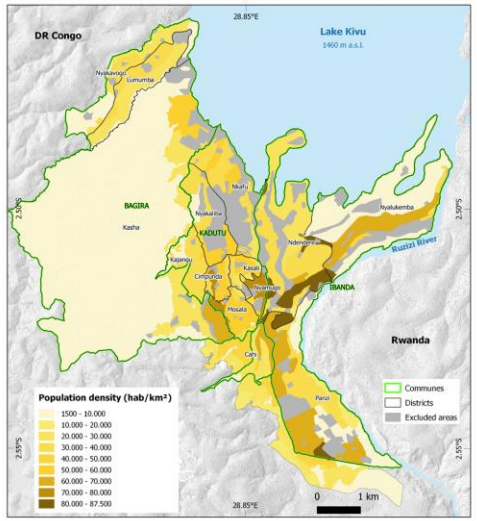
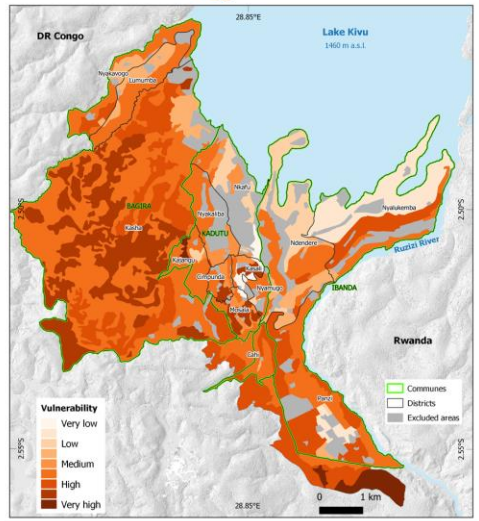
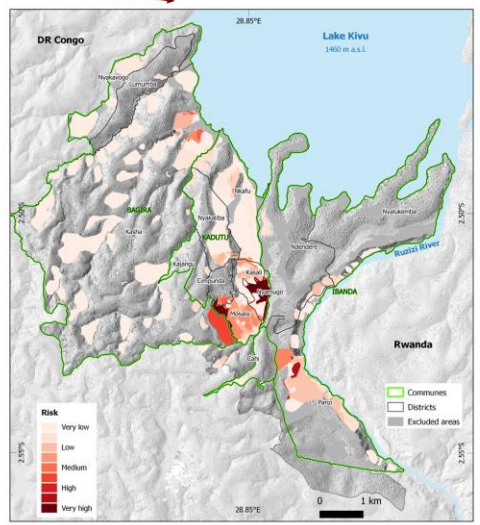






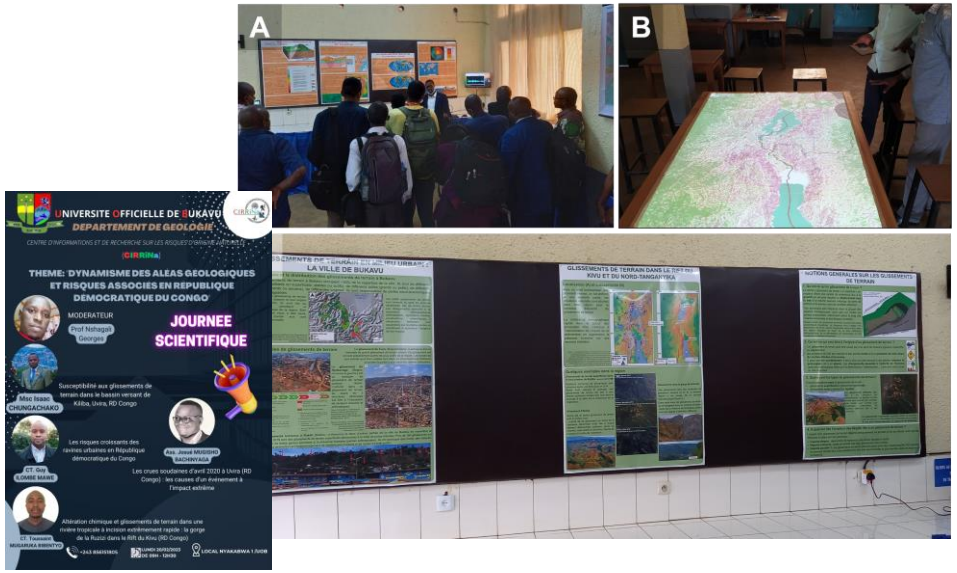


Field survey & transdisciplinarity

Michellier et al., *in preparation*

Bukavu (DR Congo) – awareness raising

Information centre (CIRRINa) on natural hazard risks at Université Officielle de Bukavu

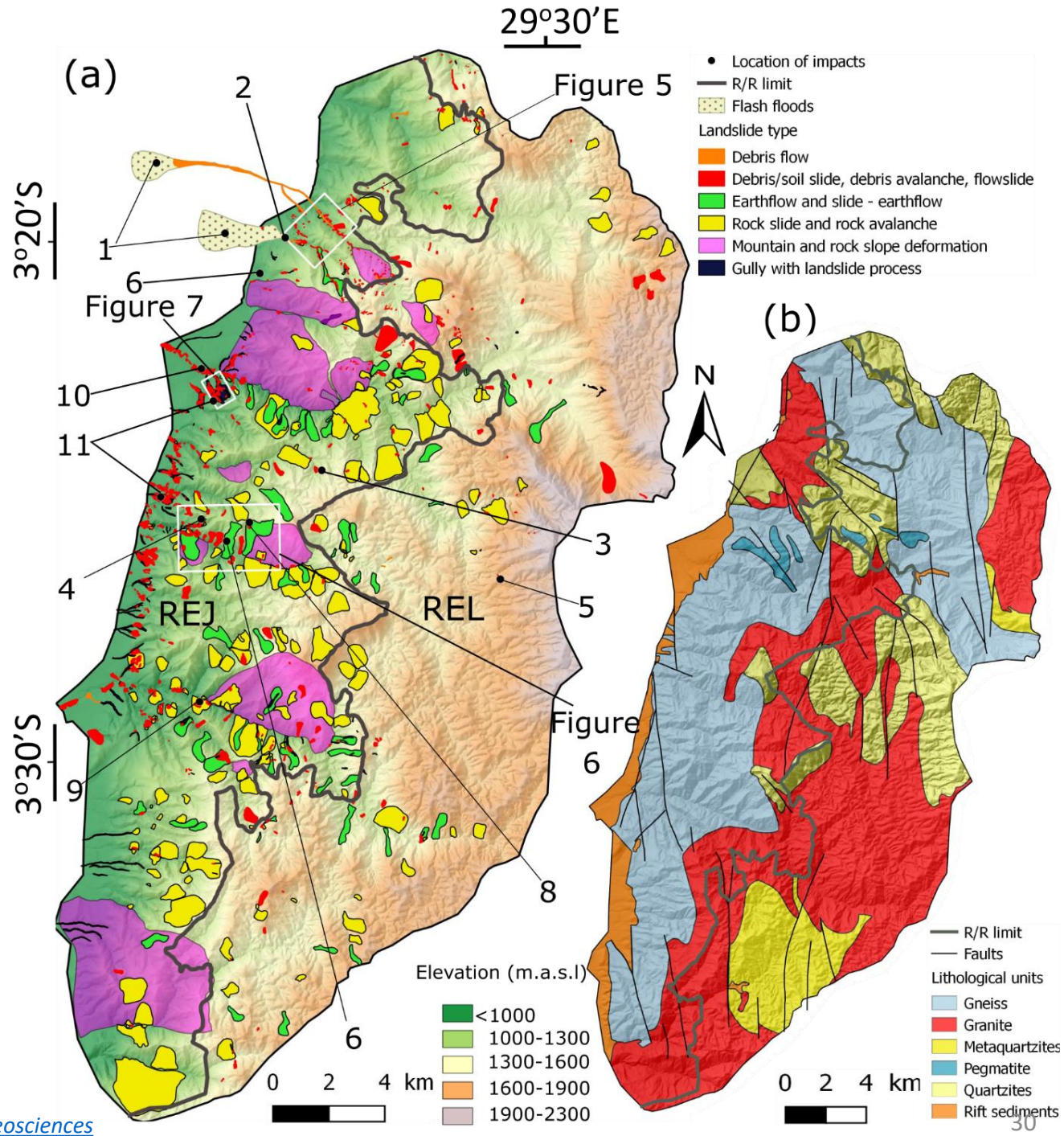


Michellier et al., *in preparation*

Serious games | stakeholders & schools

Bujumbura (Burundi)

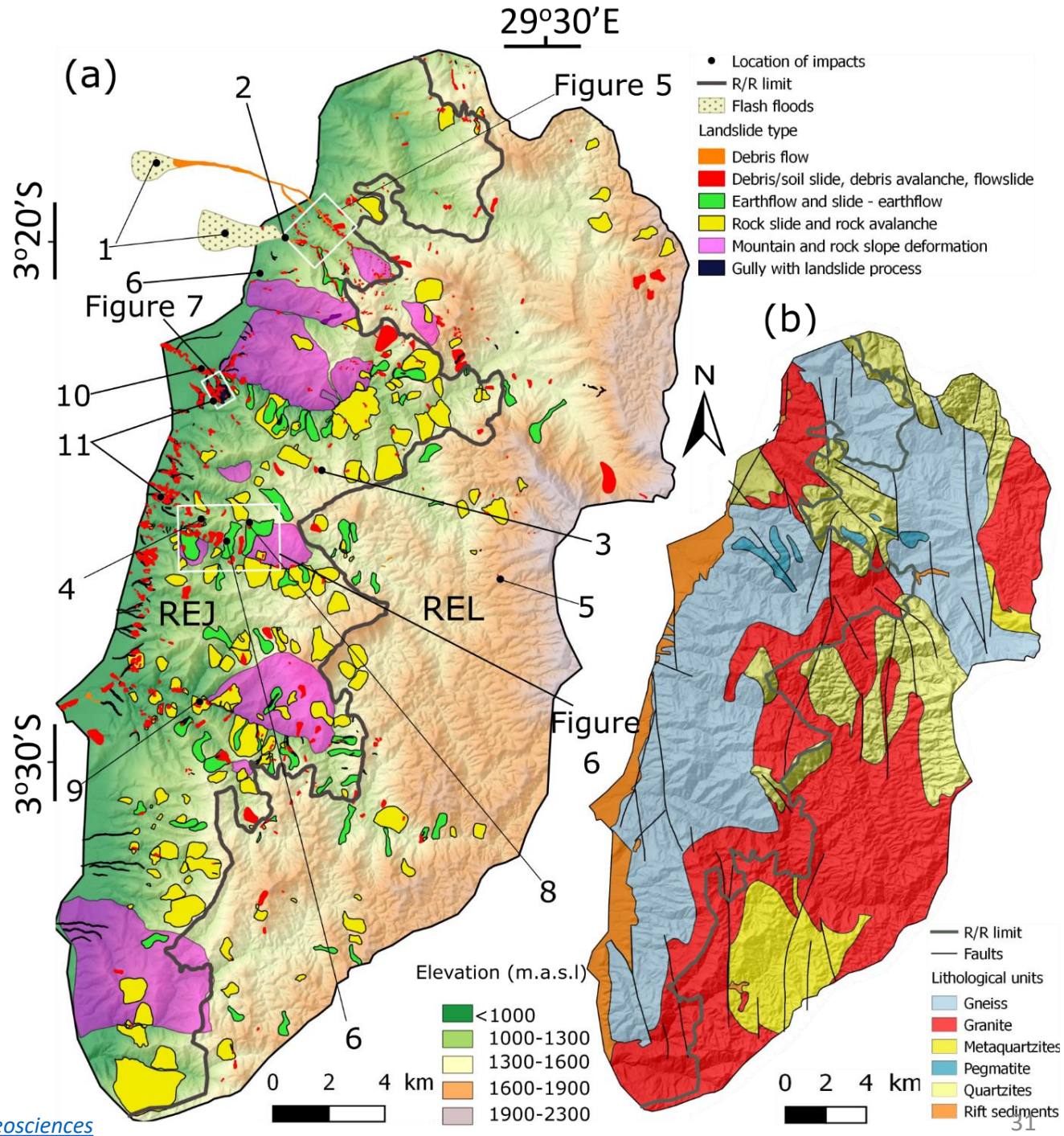
Bujumbura (Burundi)



[Kubwimana et al., 2021. Geosciences]

Bujumbura (Burundi)

Large (urban) gullies – landslides

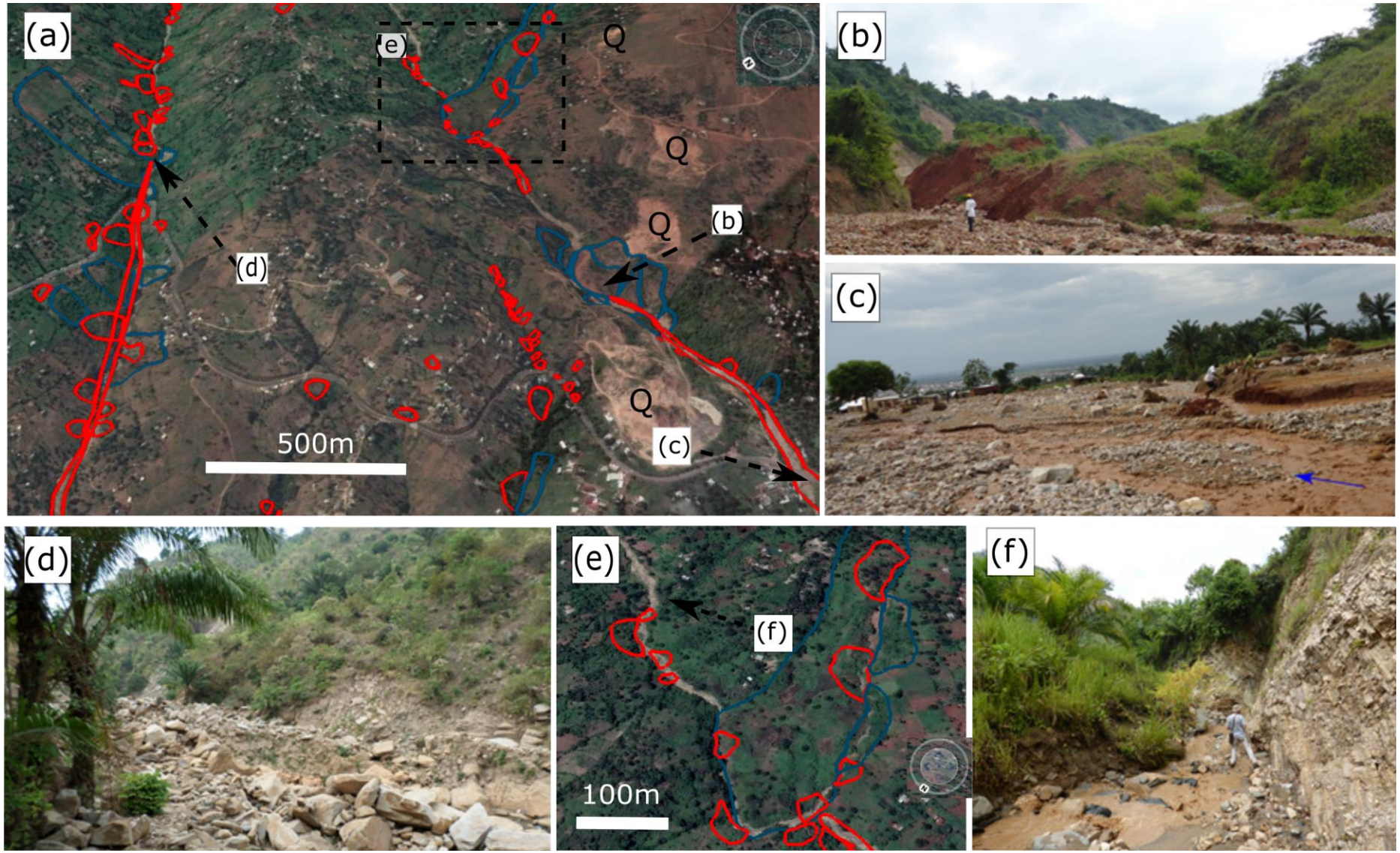


Kubwimana et al., 2021. Geosciences

Bujumbura (Burundi)

Example of a compound - cascading event

- Intense rainfall
- Hundreds of landslides
- Debris flows
- Flash floods
- Quarrying (Q) activities
- Dam breaching



Kubwimana et al., 2021. Geosciences

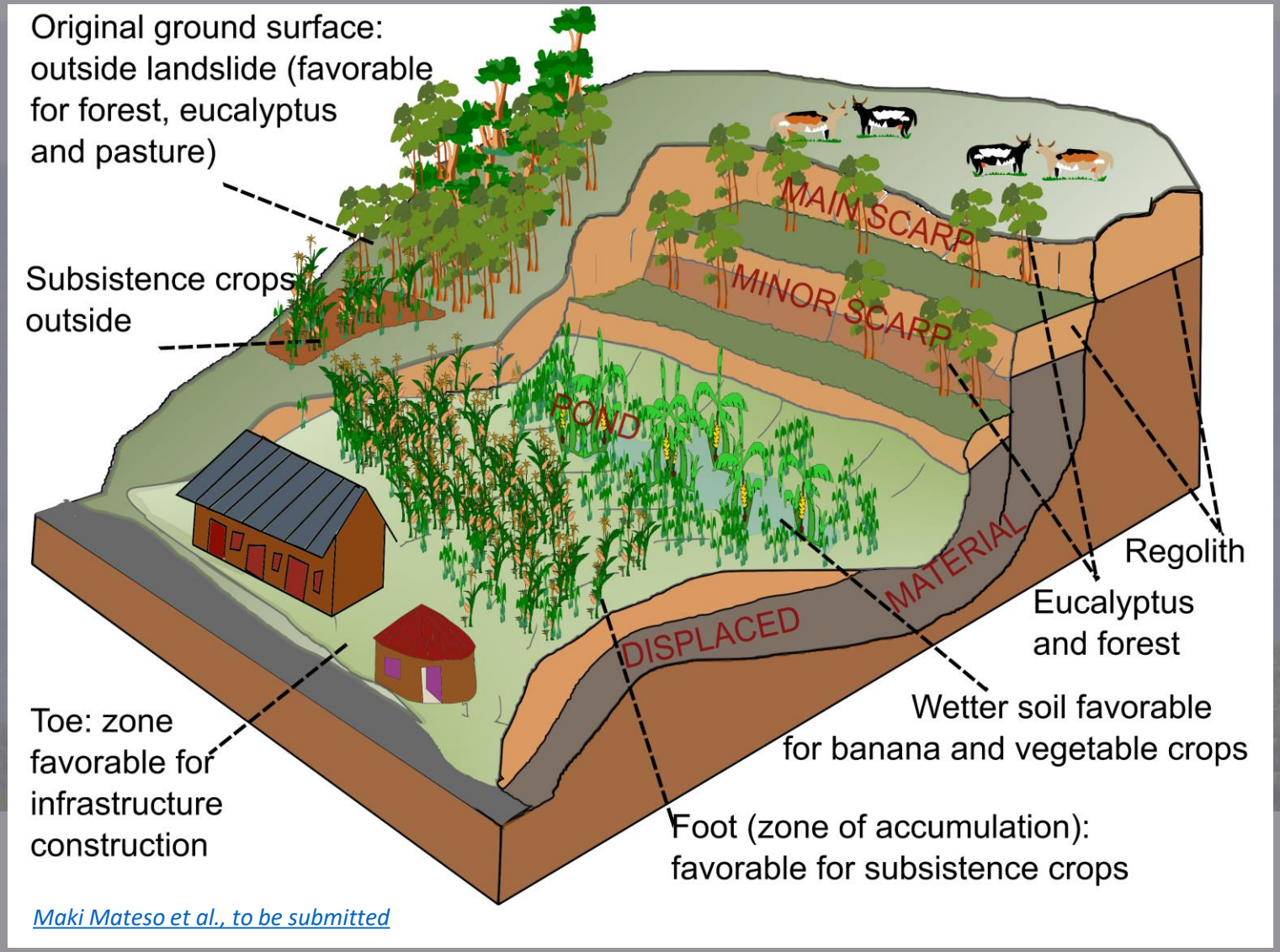
Landslides… risk or opportunity?

Rural environment west of Lake Kivu (DR Congo)

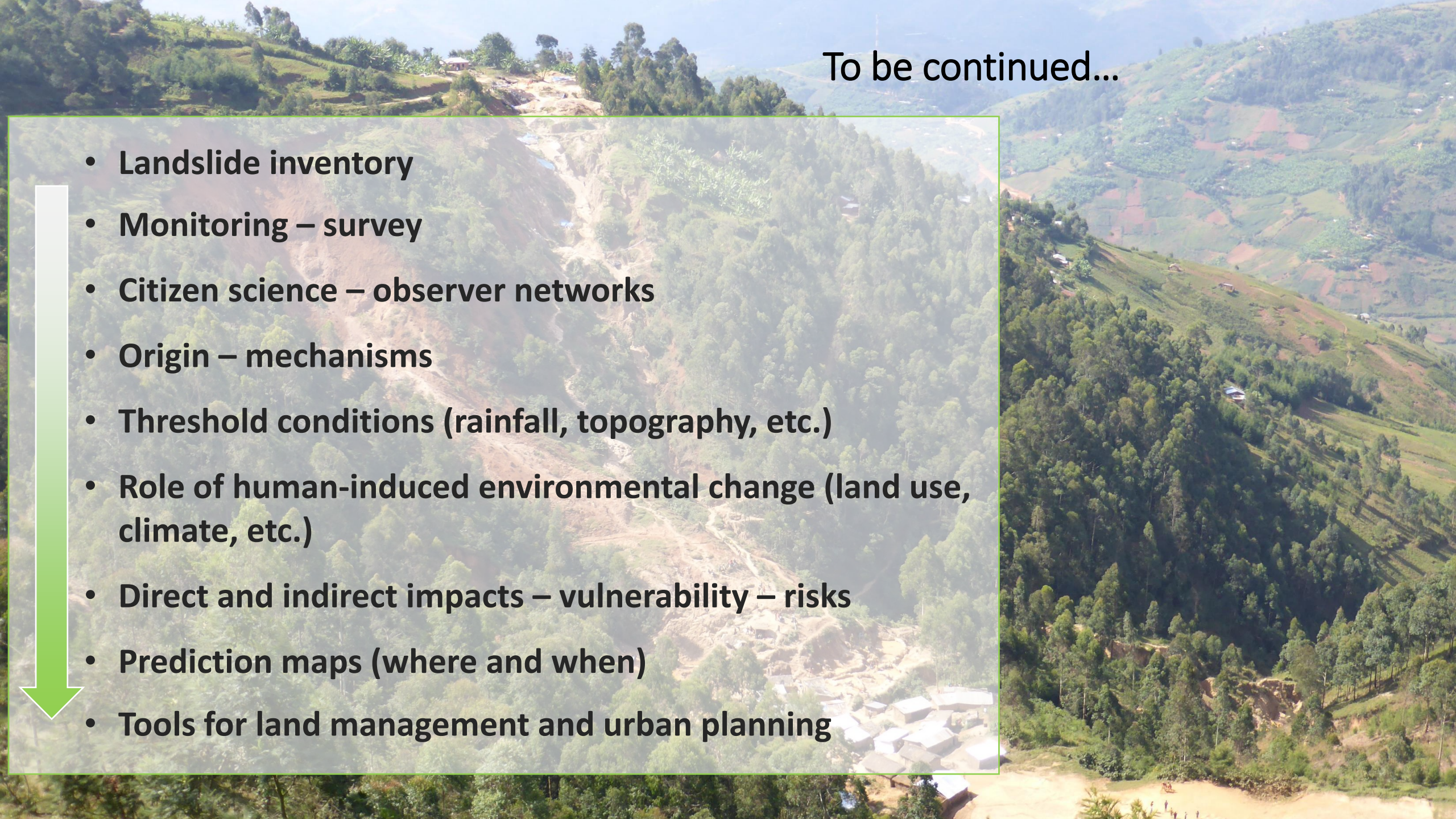
Landslides… risk or opportunity?

Rural environment west of Lake Kivu (DR Congo)

Landslides… risk or opportunity?



Maki Mateso et al., to be submitted



To be continued…

- Landslide inventory
- Monitoring – survey
- Citizen science – observer networks
- Origin – mechanisms
- Threshold conditions (rainfall, topography, etc.)
- Role of human-induced environmental change (land use, climate, etc.)
- Direct and indirect impacts – vulnerability – risks
- Prediction maps (where and when)
- Tools for land management and urban planning

A diverse partnership

Axel Deijns
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