What controls the expansion of urban gullies in tropical environments? Lessons learned from cities in D.R. Congo with contrasting soil types

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Context

- **Urban gullies (UGs)** are a growing concern in many tropical cities of the Global South. Addressing this new geo-hydrological hazard requires good insights into **the rates and controlling factors of this process.**
- The **factors controlling urban gully expansion, and especially their interactions**, **remain poorly understood**. **One element contributing to this knowledge gap is the difficulty to collect data** on this process, especially in data-scarce regions like tropical cities in the Global South.
- Very few studies make **a distinction between** gully expansion through **headcut retreat** or **gully widening**.

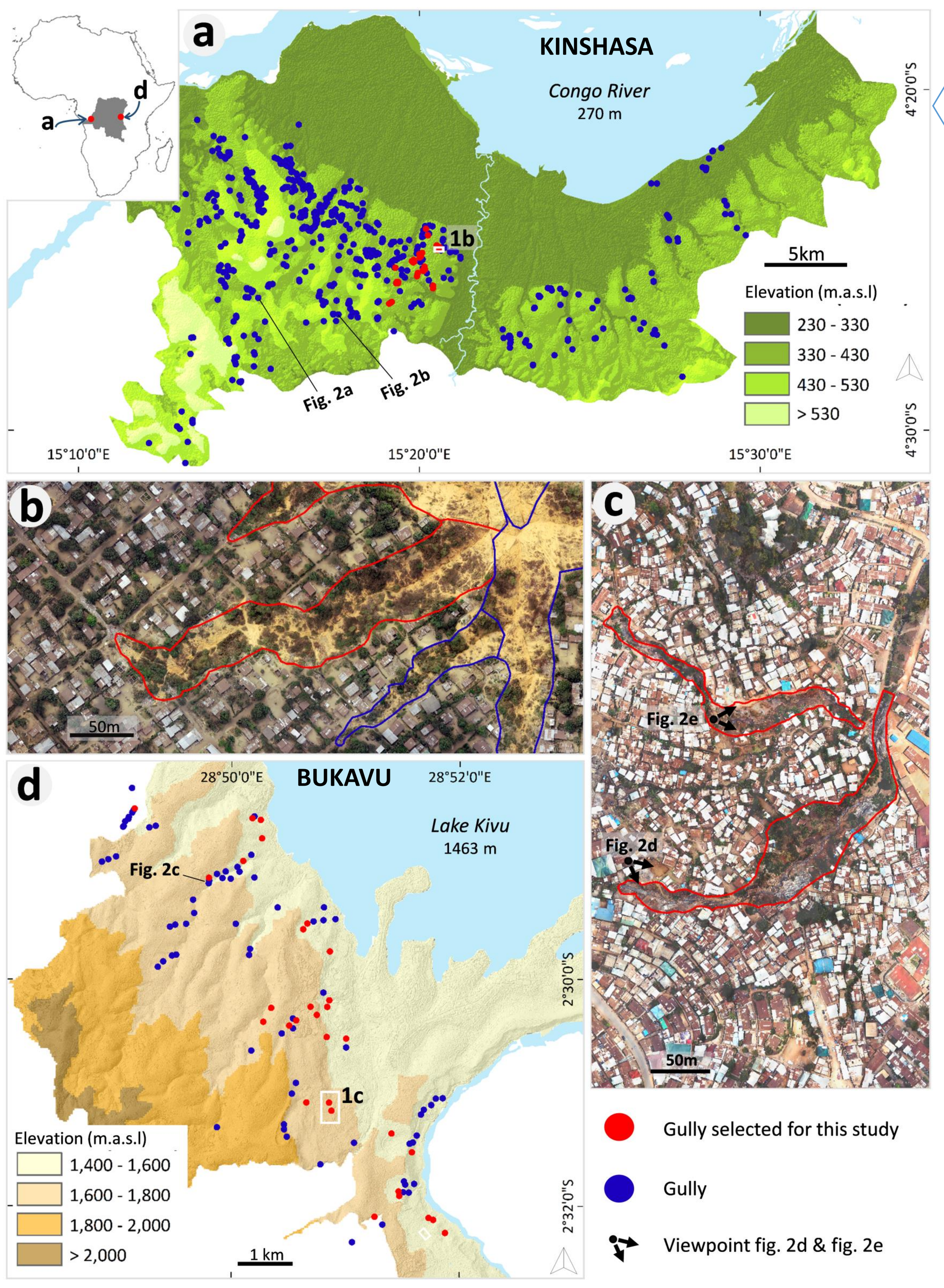
Objectives

- Quantify the urban gully expansion rates and their dynamics, both in terms of gully headcut retreat and gully widening;
- Analyse which environmental factors best explain these expansion rates;
- Explore and discuss to what extent these expansion rates can be modelled, taking into account the data limitations that exist for these regions.

Methodology

➢ *Study areas*

The cities of Kinshasa and Bukavu, located in the D.R. Congo



UGs in Kinshasa (**a**) and Bukavu (**d**). UG in red were selected for this research. UG in blue indicate other urban gullies, mapped by Lutete Landu et al. (2023). (**b**) and (**c**) show UAV images of urban gullies and their surrounding urban fabric in Kinshasa (**b**, image from August 2022) and Bukavu (**c,** images from October 2018).

UGs in Kinshasa (**a**, **b**) and Bukavu (**c, d**, **e**). Note the contrast in soil type and resulting gully morphology. Gullies in Kinshasa incise loose, largely homogeneous sandy soils, resulting in wide gully channels. Soils in Bukavu are clayey and more cohesive.

➢ *Reconstruction of gully expansion rates*

Selection of 46 UGs for further analyses (17 in Kinshasa, 29 in Bukavu) mainly based on the availability of Google Earth images.

- Linear gully headcut retreat rate (*GHRRL*)

$$GHRRL = \frac{LH}{period} \quad \text{(Eq. 1)}$$

- The areal gully headcut retreat rate (GHRRA) :

$$GHRRA = \frac{A3}{period} \quad \text{(Eq. 2)}$$

- The areal gully sidewall widening retreat rate (GSWRRA):

$$GSWRRA = \frac{A2-A1}{period} \quad \text{(Eq. 3)}$$

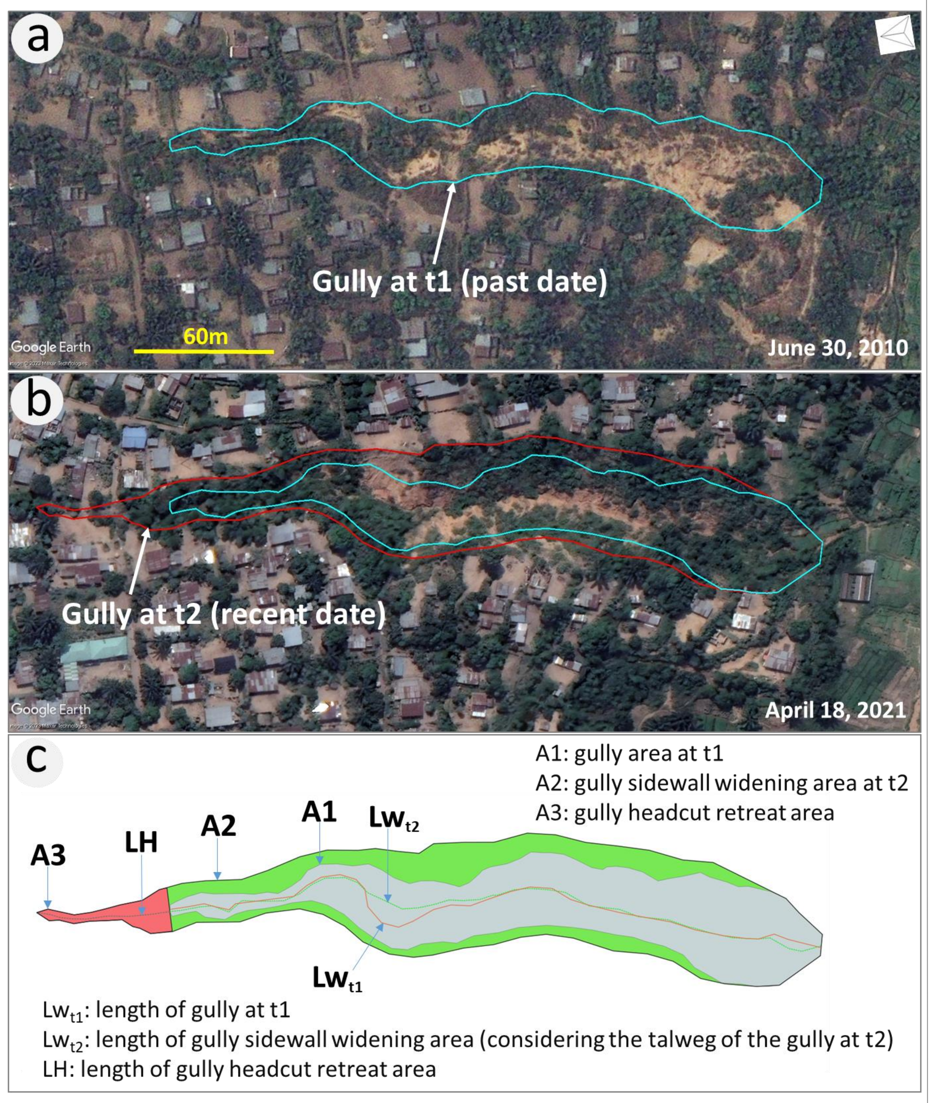
- The linear gully sidewall widening retreat rate (GSWRRL):

$$GSWRRL = \frac{(\frac{A2}{Lw_{t2}})-(\frac{A1}{Lw_{t1}})}{period} \quad \text{(Eq. 4)}$$

- The total areal gully retreat rate (TGRRA):

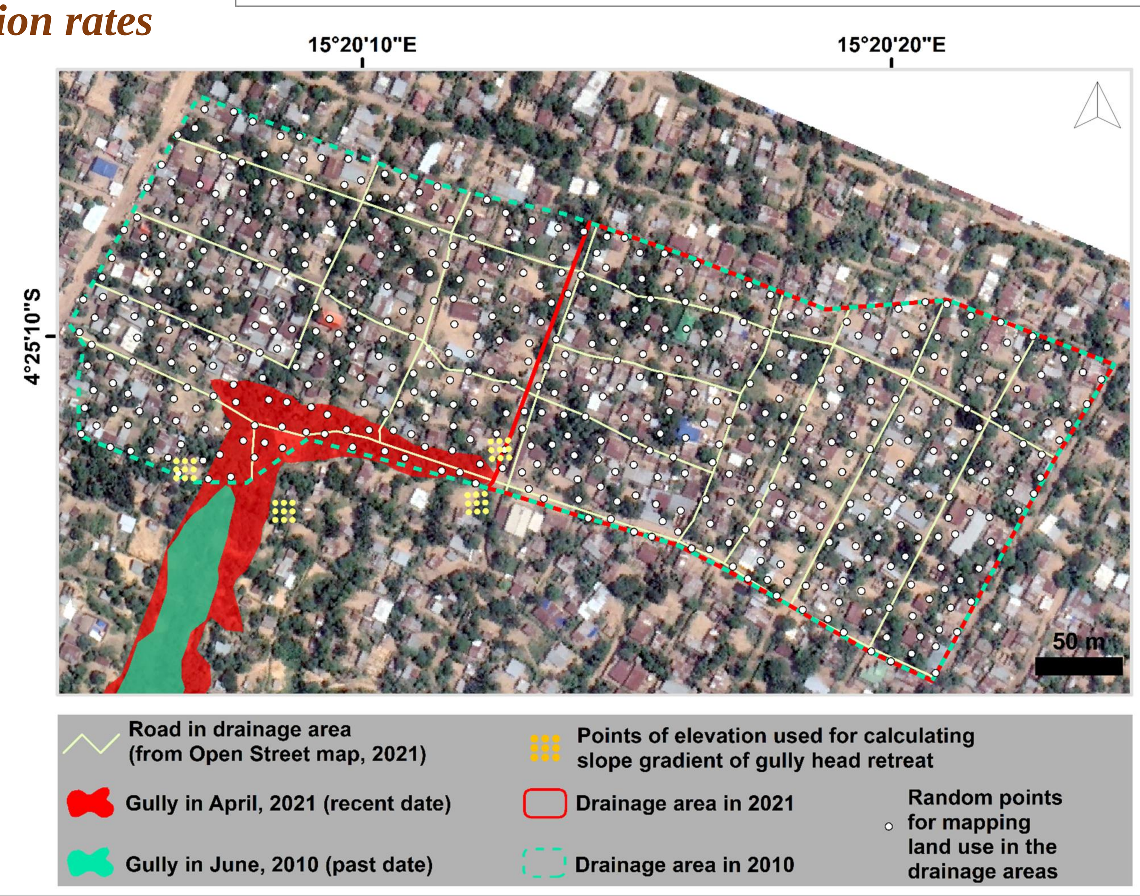
$$TGRRA = GHRRA + GSWRRA \quad \text{(Eq. 5)}$$

Illustration of how headcut retreat (red) and sidewall widening (green) were quantified



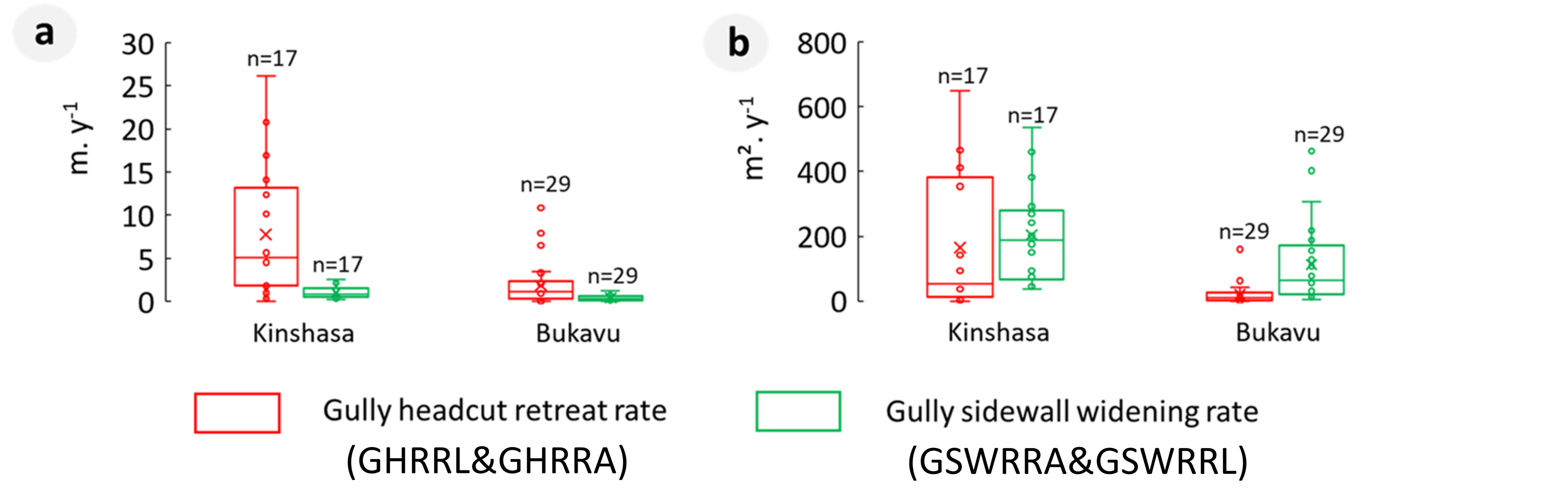
➢ *Factors controlling gully expansion rates*

- Mapping of **drainage area** (terrain surveys).
- **The slope gradient**
- The **presence of landslides** as well as **their relative age** in Bukavu.
- **Land use** in the upslope drainage area (asphalt road, earthen road, bare soil, roofs, and vegetation).
- **Road density in** drainage area **and total road length** in drainage area



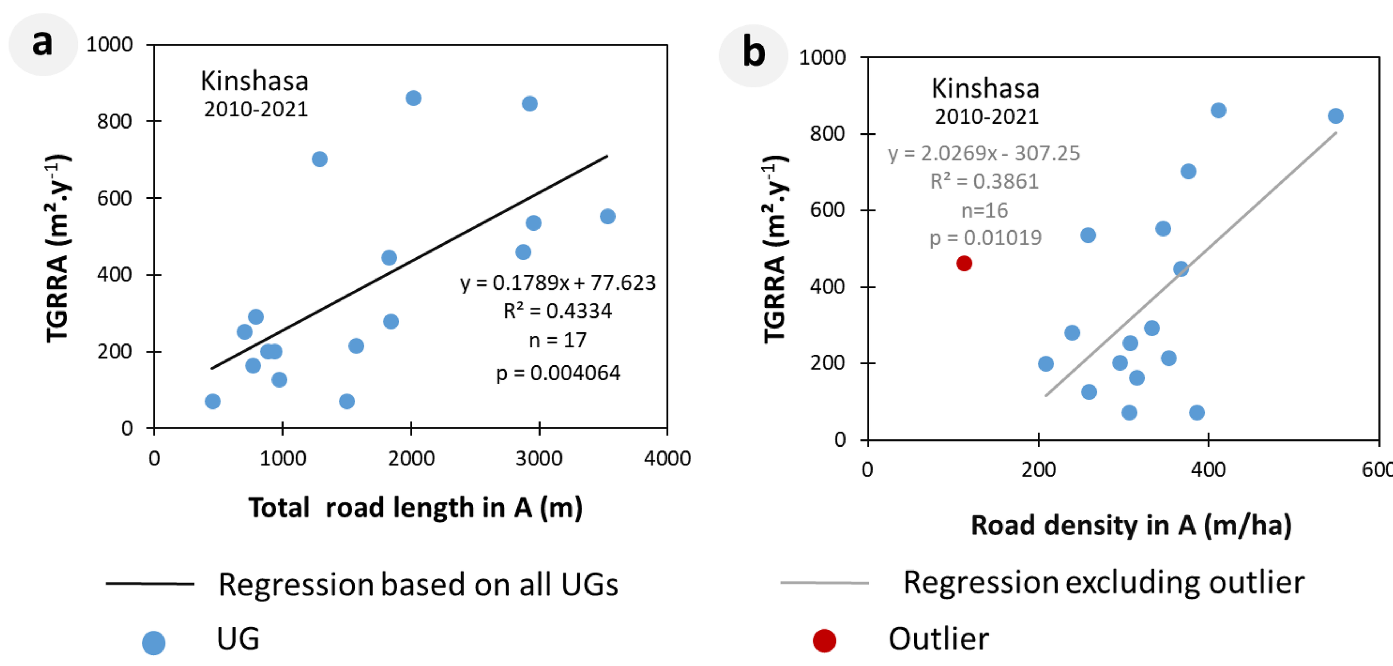
Results

➢Urban gully expansion rates in Kinshasa and Bukavu over the entire measuring period



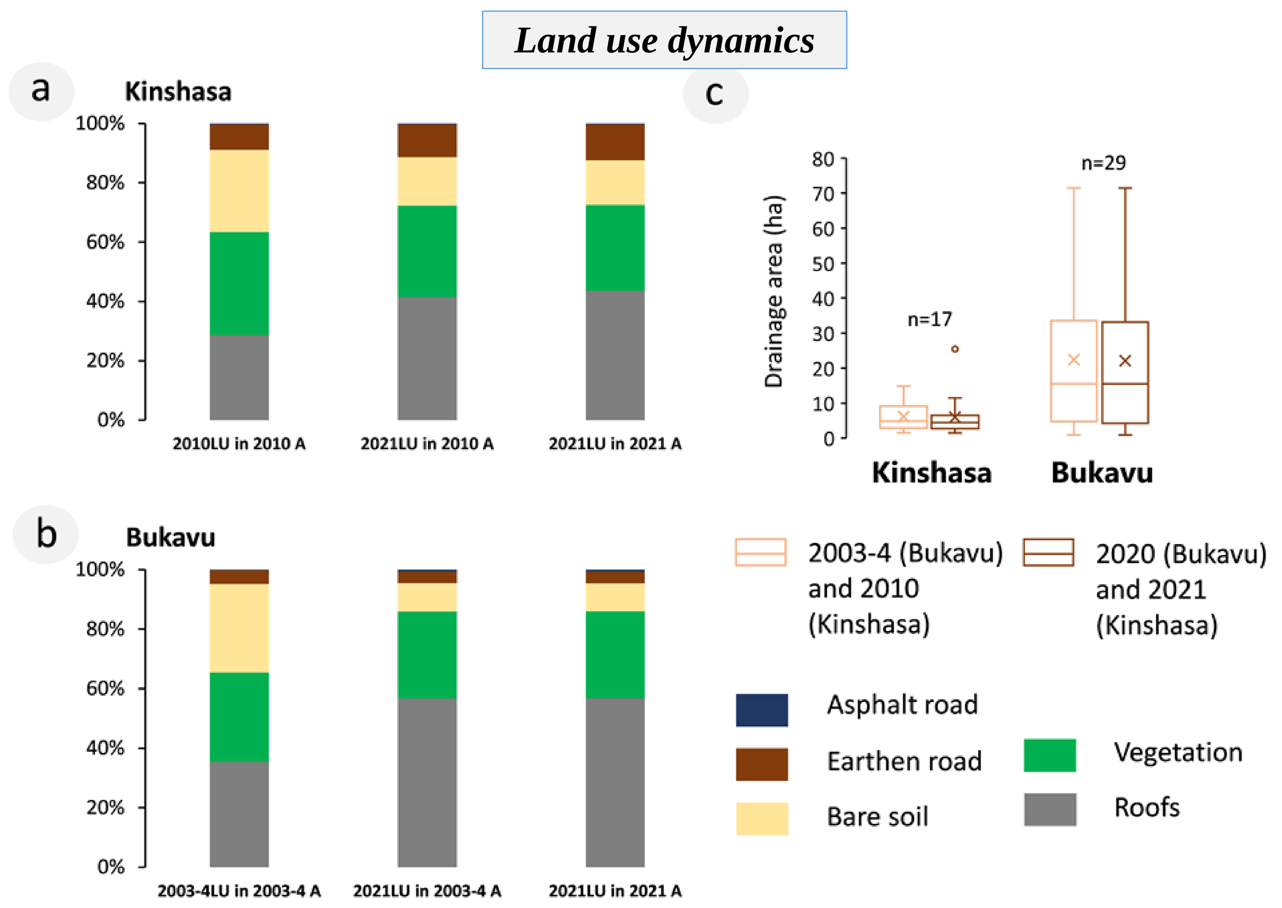
➢Factors controlling gully expansion rates

Road length and road density



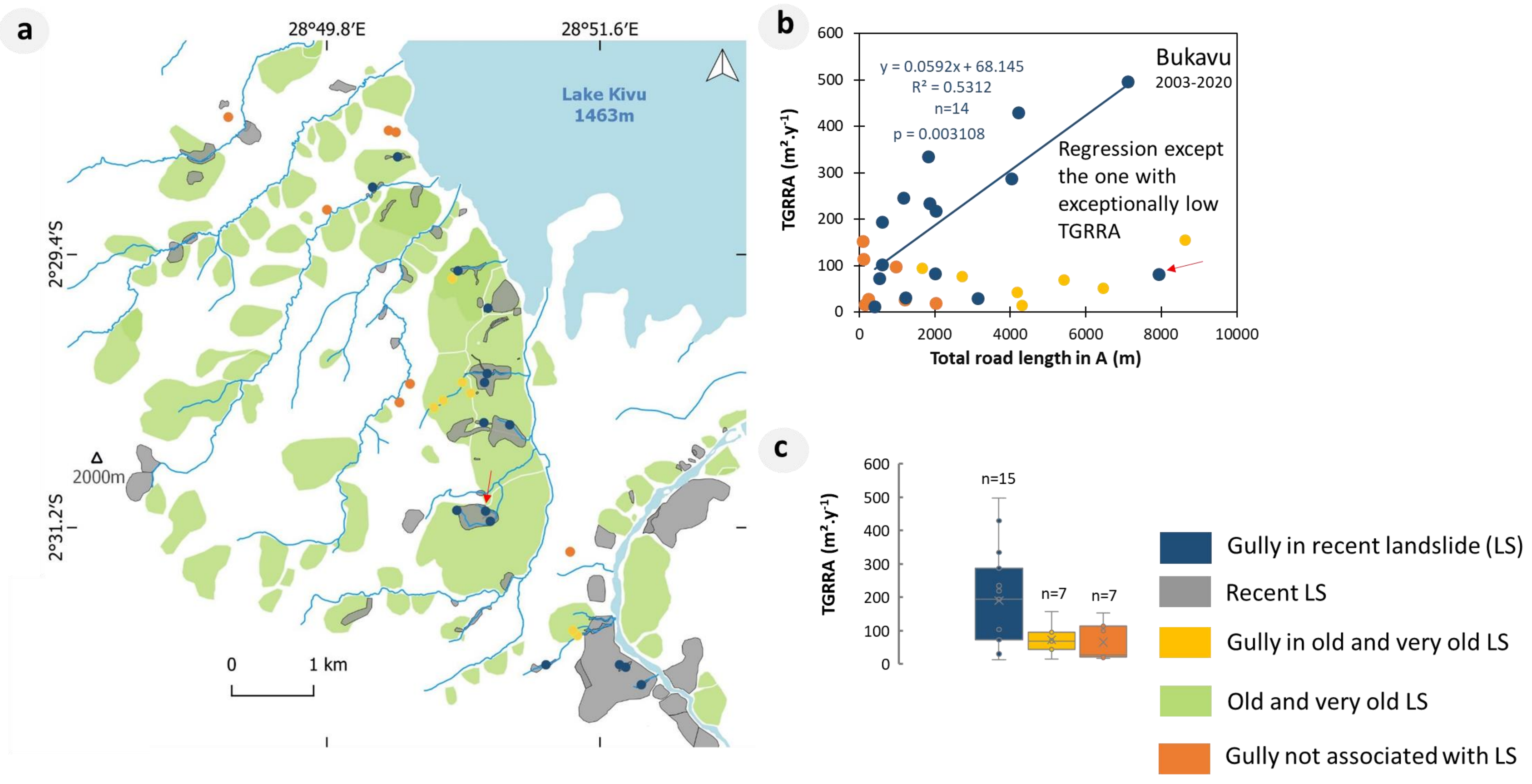
TGRRA: total areal gully retreat rate.

Land use dynamics



Evolution in land use (LU) and gully drainage area of the considered gullies over the entire measuring period.

Interactions with landslides



In short:

- **Long-term expansion rates of 46 Urban Gullies in Kinshasa and Bukavu are quantified**
- **Gully widening is responsible for most of the gully expansion**
- **Expansion rates in sandy soils are mainly controlled by land cover and road density**
- **Expansion rates in clayey soils appear influenced by landslide dynamics**

Reference

Lutete Landu, E., Ilombe Mawe. G., Makanzu Imwangana F. M., Bielders, C., Dewitte, O., Poesen, J., Hubert, A. & Vanmaercke, M. (2023). Effectiveness of measures aiming to stabilize urban gullies in tropical cities: Results from field surveys across D.R. Congo. *International Soil and Water Conservation Research*, ***11***(1), 14-29. https://doi.org/10.1016/j.iswcr.2022.10.003