Understanding the effectiveness of measures aiming to stabilize urban gullies in Congolese cities: a systematic analysis based on field surveys

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Background

- Kinshasa, Kikwit and Bukavu in the D.R. Congo are strongly affected by urban mega-gullies, i.e. large channels that are incised into the soil/regolith by concentrated runoff.
- Hundreds of such gullies, having a total length of >100 km, were inventoried in 2007 in Kinshasa.
- Many of these gullies continue to expand and new gullies are forming, causing major damage to houses and other infrastructure and often claiming human casualties.
- Numerous efforts are being implemented to mitigate these impacts. However, an estimated 50% of the existing urban gullies continue to expand.

Objectives

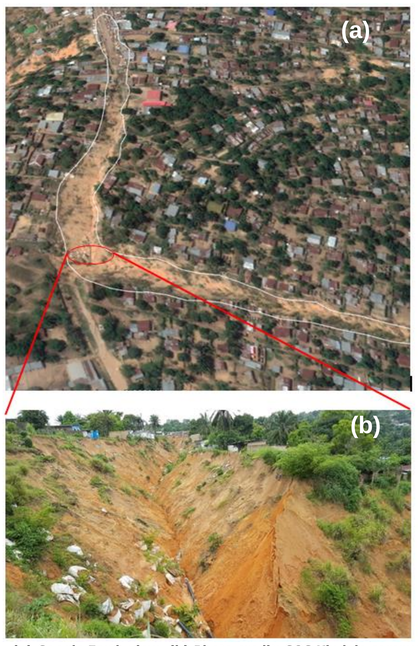
- This work aims to improve our understanding on which stabilization measures are currently implemented and how effective they are. Specifically, we aim to:
  - Create an inventory of existing gully prevention and stabilization techniques;
  - Evaluate the effectiveness of measures implemented to stabilize urban gullies.

Gully erosion

- The rapid and anarchic urbanization in combination with highly erodible soils and high rainfall (Fig.2) leads to the frequent formation of urban mega gullies (Fig.1).

Studied cities (Fig. 2)

- Kinshasa, altitudes between 300 and 675 m, sandy soils.
- Bukavu, altitude of around 1460 m, clayey soils
- Kikwit, altitude of around 485 m, sandy soils



(a) Google Earth view, (b) Photo credit: SOS Kindele community, (c,d,e) Photo credit : E. Lutete

Fig. 1. View of a 30-m wide gully on the Kimwenza road in Kinshasa that destroyed 0.5 km of road (a, b) and destroyed dozens of houses (c). Other gully-related damages (d, e).

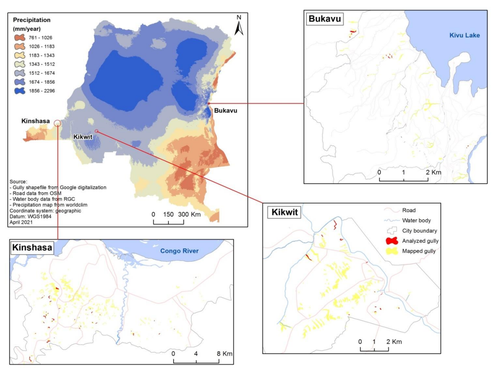


Fig. 2. Location of studied cities: Kinshasa, Kikwit and Bukavu

Methodology

- The methodology consisted of:
  - Construction of a large inventory of gully control measures (based on detailed field surveys) on the 374 gullies visited ;
  - Quantification of gully expansion rates before and after installation of gully control measures, based on high-resolution satellite imagery;
  - Paired Wilcoxon test to assess the effect of gully control measures on gully retreat rates.

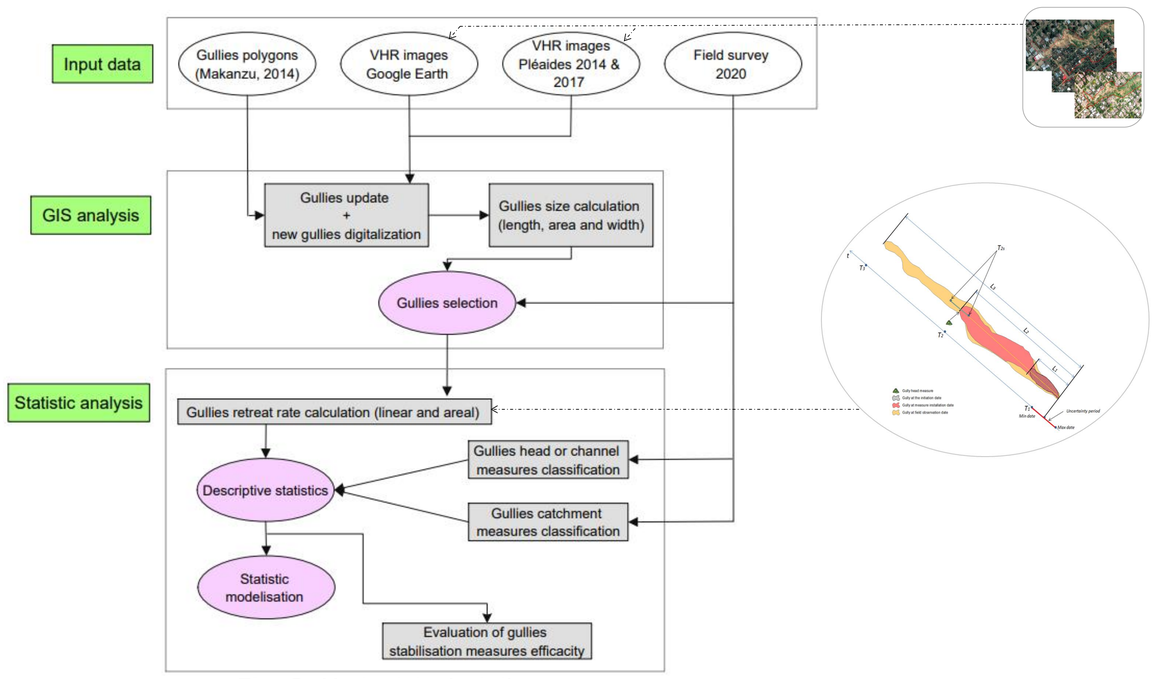


Fig. 3. Methodological diagram

Data collection

Table 1. Overview of the data type used to evaluate gully control measures (at the head, in the channel and in the upstream catchment)

Data type	Unit	Year		Number of gullies
		Minimum	Maximum	
Gully length (initial, during measure installation, and recently)	m	2004	2020	80
Gully area (initial, during measure installation, and recently)	m2	2004	2020	80
Gully age	year	2002	2020	80
Gully age before measure installation	year	2004	2010	80
Gully age after measure installation	year	2010	2020	80
Areal retreat rate before measure installation (RRSb)	m2	2004	2010	75
Areal retreat rate after measure installation (RRSa)	m2	2010	2020	75
Total areal retreat rate (RRS)	m2	2004	2020	80
RRS change	m2	2004	2020	75
Linear retreat rate before measure installation (RRLb)	m	2004	2010	75
Linear retreat rate after measure installation (RRLa)	m	2010	2020	75
Total Linear retreat rate (RRL)	m	2004	2020	80
RRL change	m	2004	2020	75
Gully head/channel key measures	-	2010	2020	80
Gully catchment key measures	-	2010	2020	73
State of gully measures	-	2010	2020	59

Results

Overview of implemented measures

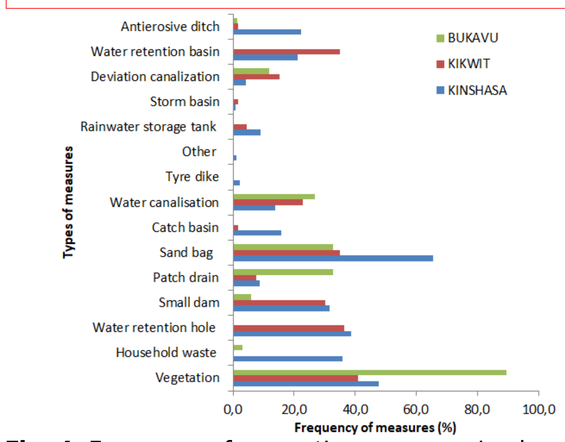


Fig. 4. Frequency of preventive measures implemented in the catchment contributing to gully heads

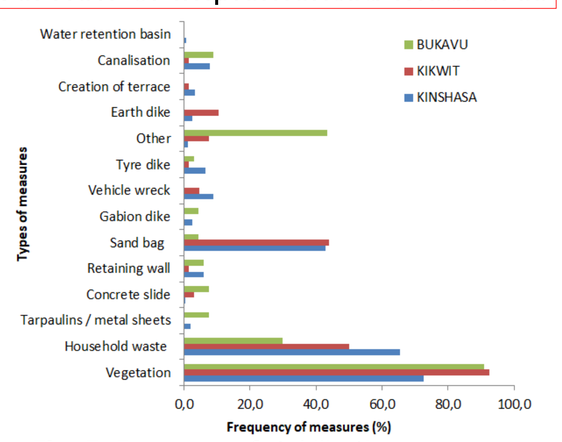


Fig. 5. Frequency of stabilization measures applied to gully heads

Fig. 6. Examples of measures applied in the gully catchments: **a:** Canalization; **b**: Sandbags on roads; **c:** Vegetation; **d:** Water retention basin; **e:** Water retention hole in plots; **f:** Infiltration well; **g:** Water retention dams; **h & i**: Rainwater storage tank (plastic and cement/clay).

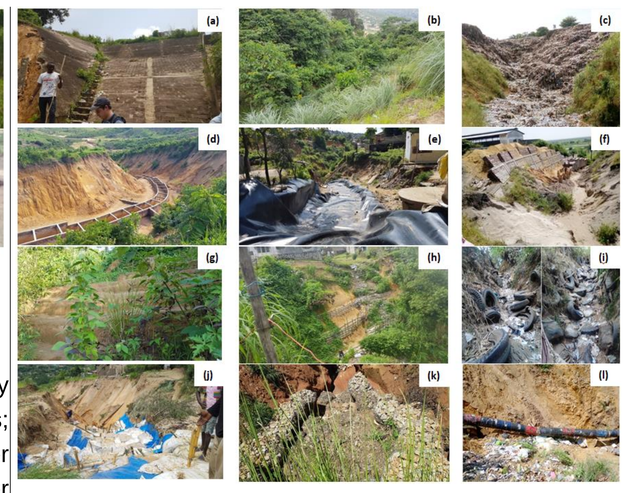


Fig. 7. Examples of measures applied in the gully head or in the channel: **a:** Concrete slide; **b:** Vegetation; **c:** Household waste; **d & l:** Channelization (with concrete and metal); **e:** Tarpaulin/metal sheeting; **f:** Retaining walls; **g & h:** terraces (without and with protection); **i**: Tire dikes; **j:** Sandbag piling; **l:** Old house carpets; **k:** Gabion dikes (Photo credit: E. Lutete).

- The type and scale of measures varies widely
- Most measures are taken through local initiatives
- Vegetation, sandbags and household waste material are the most commonly implemented measures

Measure effectiveness

By comparing the average rate of gully expansion before and after implementation of the measures, the effectiveness of the measures was evaluated:

- A significant reduction could be observed for: canalization, household waste, vegetation at the gully head (Fig 8a) and canalization, vegetation, sandbag, small dam at the gully catchment (Fig 8b).
- The most effective measures apear to be canalization, household waste, and small dams at the gully head and/or in the catchment
- Although popular, the use of household waste carries risks (e.g collapses) as well as other negative impacts (e.g. odour, pollution, sanitation risks)
- Often, retention basins and infiltration pits are filled and not cleaned, which could explain their apparent lack of effectiveness

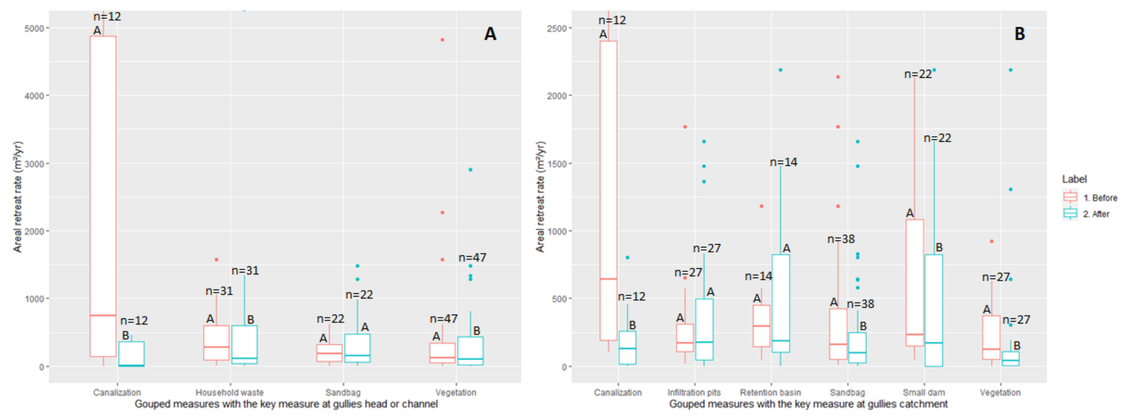


Fig. 8. Comparison of gully areal retreat rates before and after installation of key measures at gullies head/channel (A) or in the gullies catchment (B). Data from all cities combined.

Conclusions

- Many implemented measures only have a limited effectiveness and accurately assessing this effectiveness is difficult
- Our work contributes to a better prevention and mitigation of urban gullies (affecting many tropical cities in the Global South) by providing a first large scale, comparative assessment and evaluation of implemented measures
- More research is needed to better understand why certain measures turn out to be unsuccessful

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