Hydro-climatological thresholds to enhance early warning systems for landslides in Rwanda

Jun 25 – 26, 2025
German Weather Service, Offenbach, Germany

Jean D'Amour Dusabimana[1 5], Judith Uwihirwe[2], Olivier Dewitte[3], Thom Bogaard[4], Bugenimana Derrick[6], Musemakweli John[6], Ricardo Reinoso-Rondinel[1]

[1] KU Leuven , [2] RICA , [3] RMCA , [4] TU Delft , [5] INES-Ruhengeri , [6] University of Rwanda

✉ *correspondent: jeandamour.dusabimana@kuleuven.be*

Context

Landslides rank among the world's most dangerous natural hazards, and in mountainous settings like Rwanda, where steep terrain, variable rainfall and few rain gauges prevail, they pose a particular threat. Current rainfall thresholds and alert systems lack the spatial detail needed for reliable, location-specific warnings. This PhD, part of the VLIR-UOS–funded Supporting Early-warning systems and Nature-based Solutions using Opportunistic Rainfall Monitoring in Rwanda (SENSOR2) project, will:

(1) refine hydro-climatic landslide forecasting thresholds using rainfall data from Commercial Microwave Links, and

(2) develop a more accurate, localized early-warning system for Rwanda's highest-risk areas.

Landslides & Rain Gauges in Rwanda

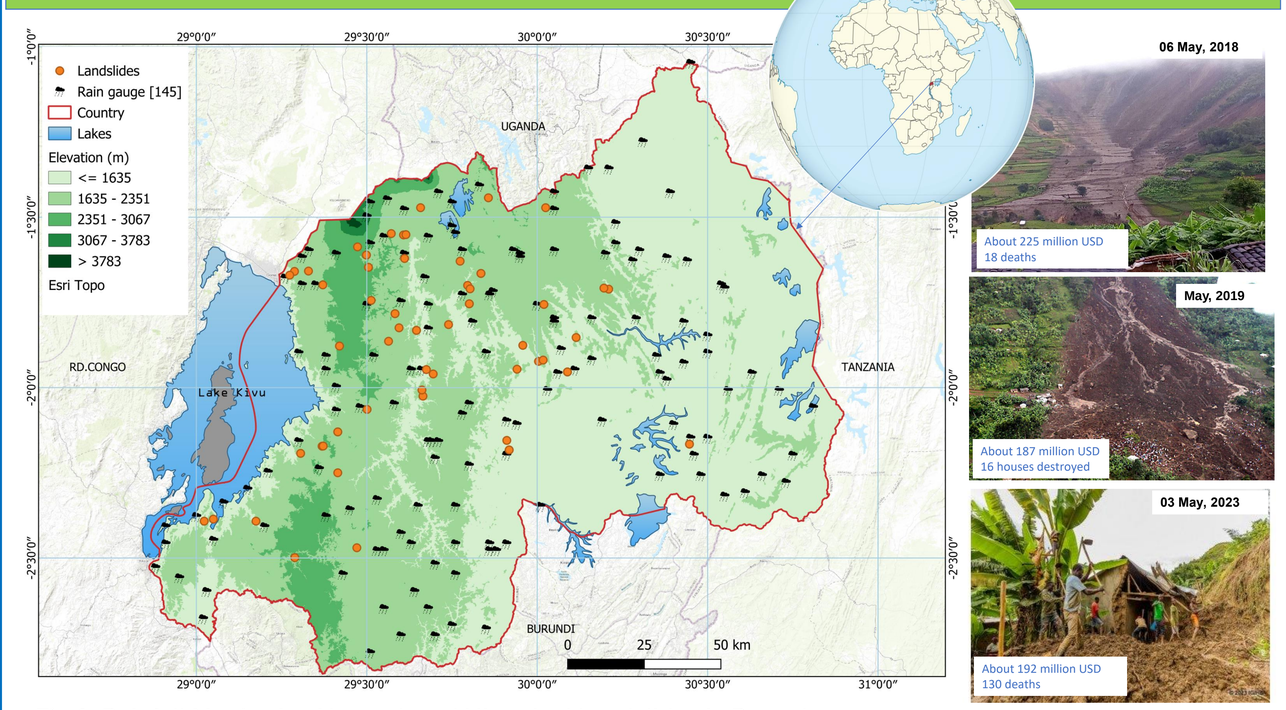

Fig 1. Rainfall Monitoring Network and Historical Landslides in Rwanda

Baseline Rain-Gauge API-Driven Early Warning (Next: CML Upgrade)

***Antecedent Precipitation Index (API) Computation**

We compute the 10-day API as a weighted sum of daily rainfalls:

$API_{10} = \sum_{j=0}^{9} k^i R_{t-j}, \quad k=0{,}95$ where R_t is the rainfall (mm) on day $t-j$, k is the decay factor (95% memory retention per day).

***Threshold Comparison**

The API-10 value is continuously compared to an empirical landslide trigger threshold (42.5) from Uwihirwe et al. (2020). A warning is issued when $API_{10} \geq 42.5mm$.

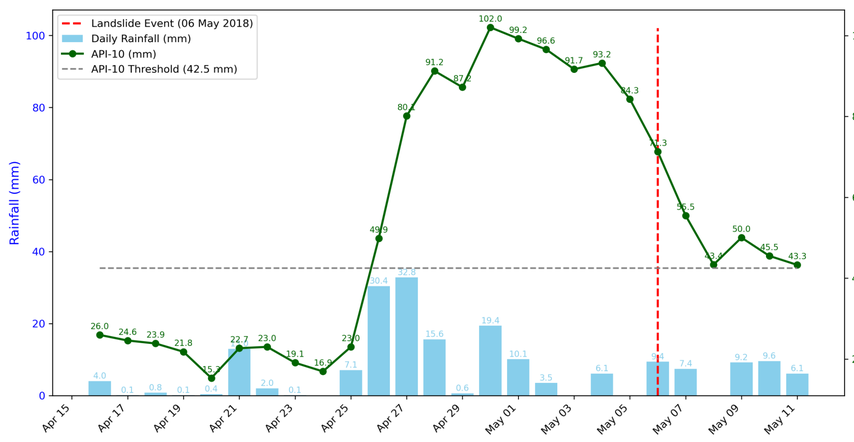

Fig 2. Antecedent Rainfall Index (API-10) and Landslide Trigger on 06 May 2018

API-10 rose above 42.5 mm on 25 Apr and peaked at 102 mm on 28 Apr
Despite API-10 falling to ~71 mm by 06 May, soil remained critically saturated
Landslide triggered by antecedent wetness, not event-day rain (9.4 mm)
Highlights need for continuous, high-res rainfall monitoring (e.g., **CML**).

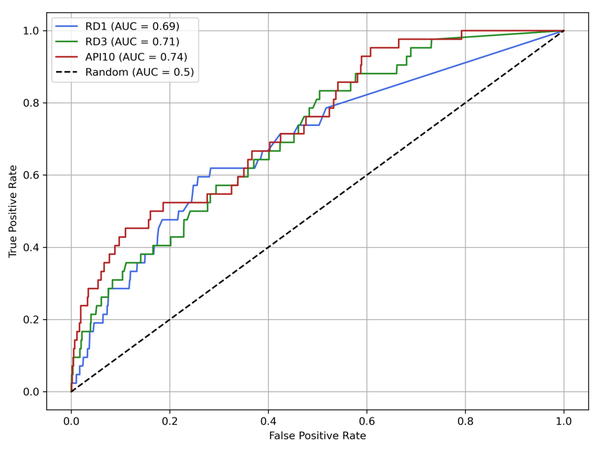

Fig 3. ROC Curves for Rainfall-Based Landslide Predictors

RD1: Cumulative 1-day rainfall
RD3: Cumulative 3-day rainfall

- **API-10 (AUC = 0.74)** seems slightly outperforms **RD3 (0.71)** and **RD1 (0.69)** in distinguishing landslide vs. non-landslide days.
- **Higher AUC** for API-10 confirms the strength of antecedent moisture over short-term rain.
- Integrating **CML-derived rainfall** into API-10 is expected to further boost predictive skill.

Rainfall Patterns and Satellite Data for Rwanda

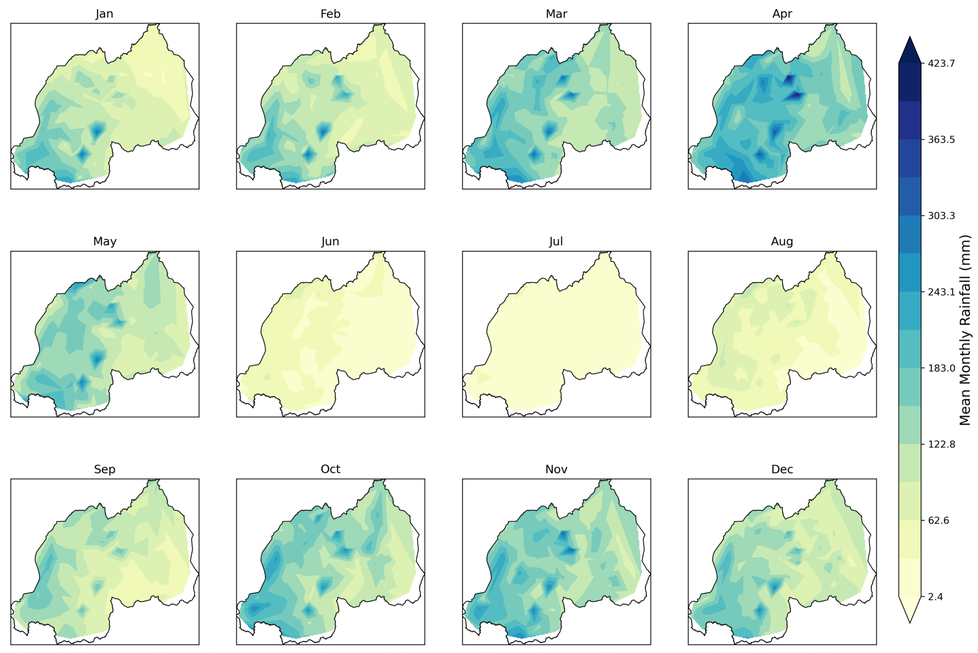

Fig 4. Spatial Distribution of Mean Monthly Rainfall in Rwanda (1981–2021)

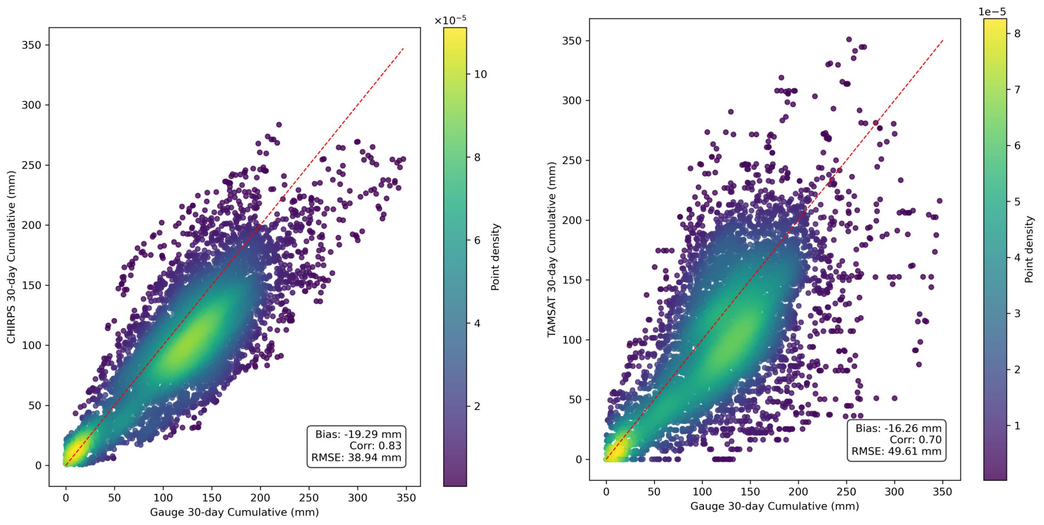

Fig 5. Satellite vs Gauge Comparison of Rolling 30-Day Rainfall (1981-2021)

How Well Do Satellites Capture Rainfall Thresholds?

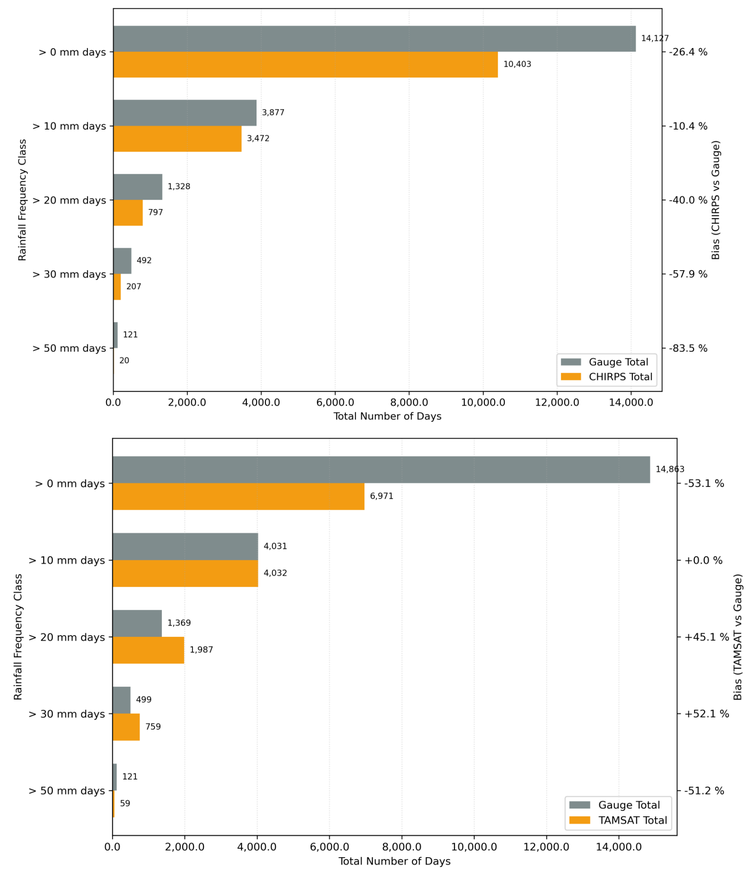

Fig 6. Bias in Rainfall Threshold Detection: CHIRPS & TAMSAT vs Gauges

Bias patterns indicate that satellite products may not fully capture the frequency of rainfall events across thresholds, which is important for applications like landslide early warning in Rwanda.

Conclusion and way forward

- Potential of satellite data to supplement sparse gauge networks, though bias corrections are needed.
- Integration of **CML from (1200 antennas)** holds great promise for enhancing rainfall monitoring in Rwanda.
- We foresee that **CML** can significantly improve the spatial and temporal resolution of rainfall estimates, essential for Landslide Early Warning Systems.