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# Susceptibility-informed hydro-meteorological thresholds for rainfall-triggered landslides in Rwanda

Supporting Early-warning systems and Nature-based Solutions using Opportunistic Rainfall monitoring in Rwanda (SENSOR2)

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# Why do we need better landslide initiation thresholds?

- Landslides in Rwanda are causing significant impacts

Example: Severe impacts in Western Rwanda (**2 May 2023**)
>4,900 houses destroyed
>8,000 households affected (Source: RRCS, 2023)

# Limitations of existing approaches?

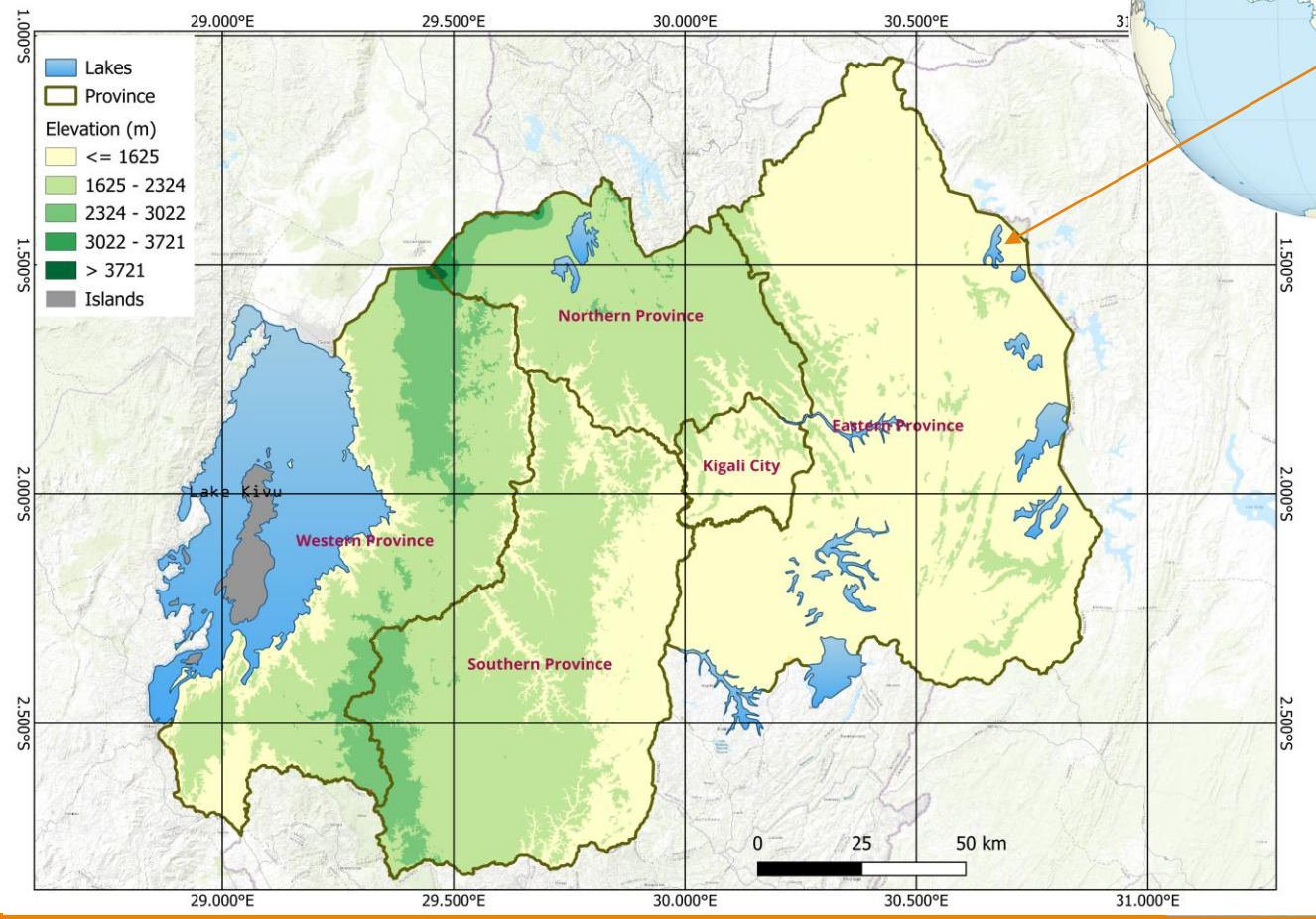
Recent studies in Rwanda have developed hydro-meteorological thresholds incorporating rainfall, soil moisture, and groundwater conditions (Uwihirwe et al., 2020; 2022)

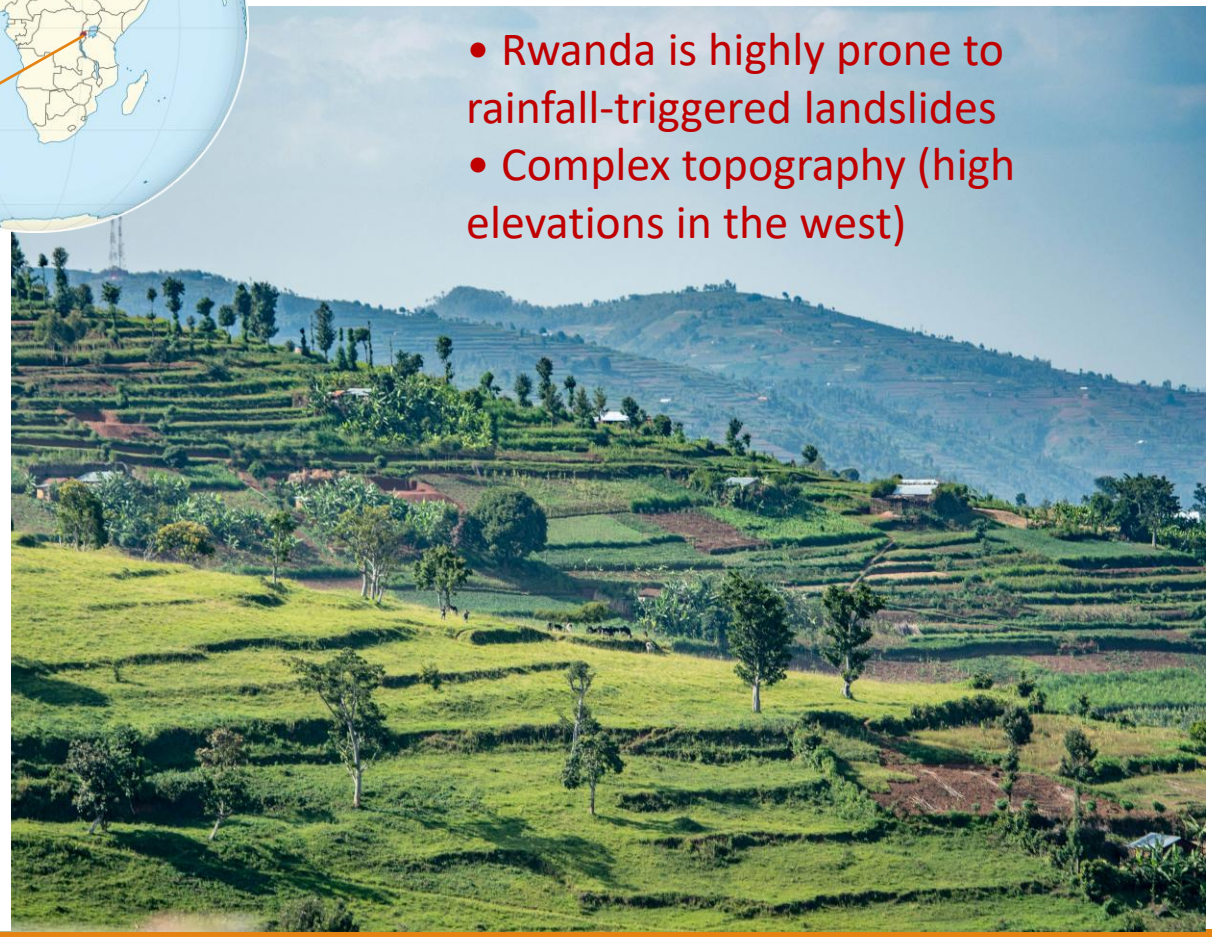
However, these approaches remain spatially uniform, do not explicitly integrate landslide susceptibility, and rely on rainfall data with limited spatial resolution (sparse gauges or coarse satellite products)

# Research objective

This research aims to develop landslide initiation thresholds that account for landslide susceptibility, supported by high-resolution (downscaled) rainfall data to better capture spatial variability in rainfall conditions leading to landslide initiation

# Study area



- Rwanda is highly prone to rainfall-triggered landslides
- Complex topography (high elevations in the west)

# Methodology

1. Data
- Landslide inventory **(82 events from 2000-2024)**
- Rainfall:
  **(IMERG + downscaling)**
  **Gauge data: 10-min (2022–2024, 11 stations)**
- Susceptibility map **(regional from Depicker et al., 2020)**

2. Metrics
- Rainfall triggering
- Antecedent wetness (leaky bucket model)

3. Thresholds
- Cause–trigger relationships

4. Evaluation
- ROC / POD / CSI

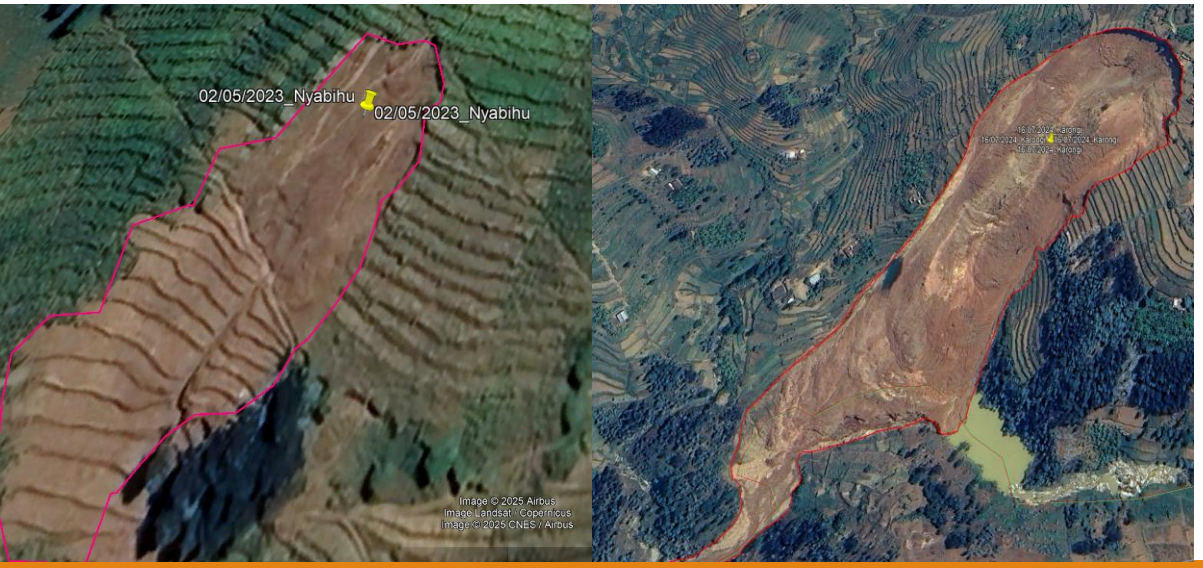
# Methodology

**Landslides inventory**

Search

Store

Validate




IMERG Data downscaled using Rainfall Filtered Autoregressive Model (RainFARM)

IMERG Rainfall (10kmx10km, daily)

Spectral Analysis (IMERG rainfall field)

Spectral Extrapolation

Generate Gaussian Random Field

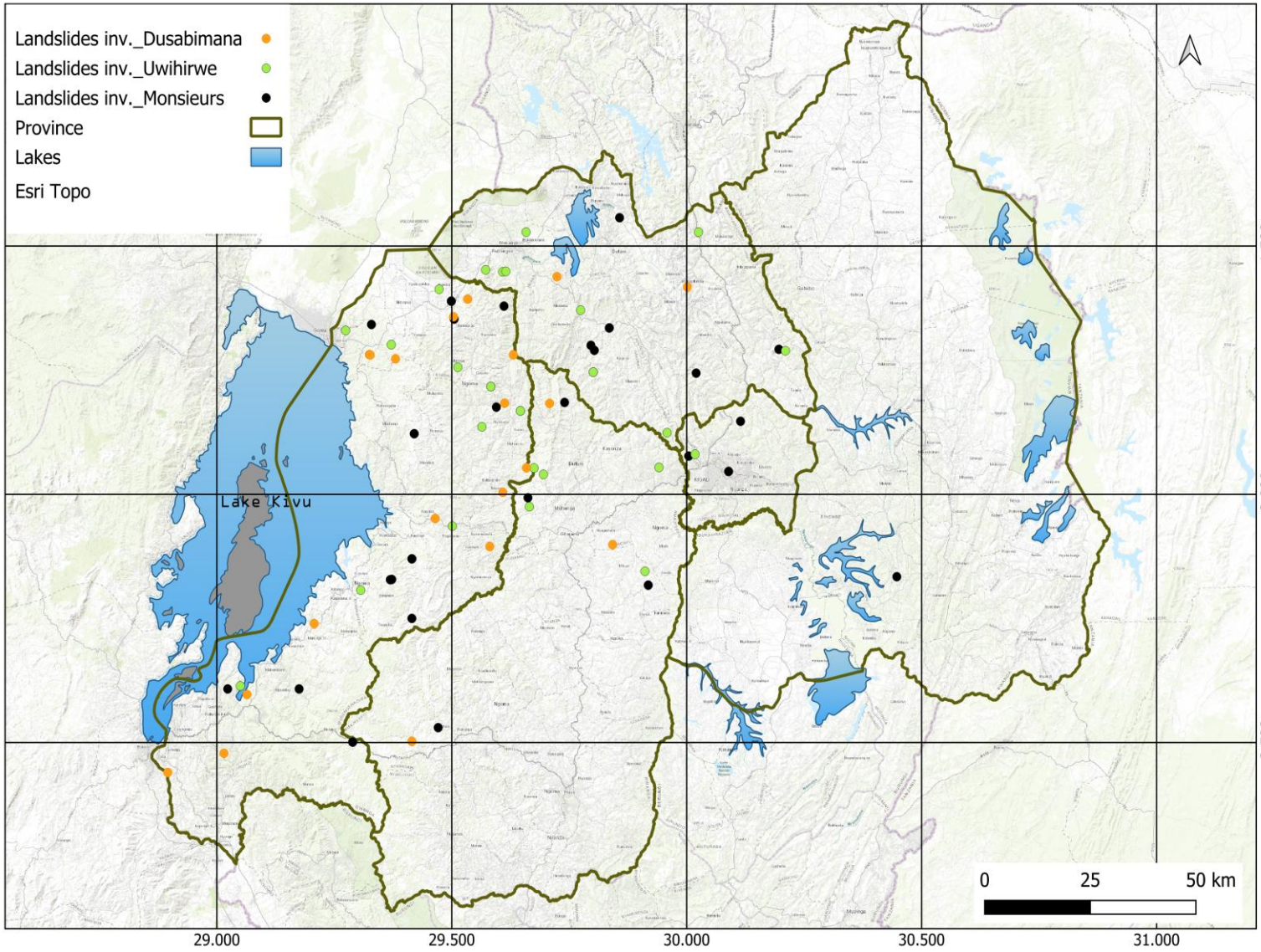
Nonlinear Transformation (match rainfall distribution)

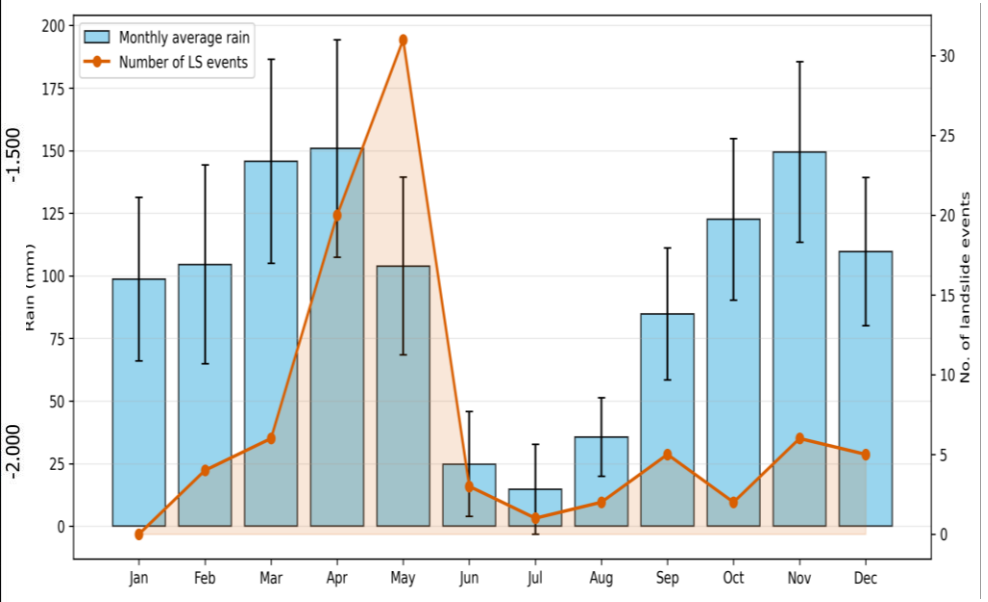
Rescaling (Mass Conservation of IMERG totals)

High-Resolution Rainfall (1kmx1km, daily)

Ensemble Members (Uncertainty)

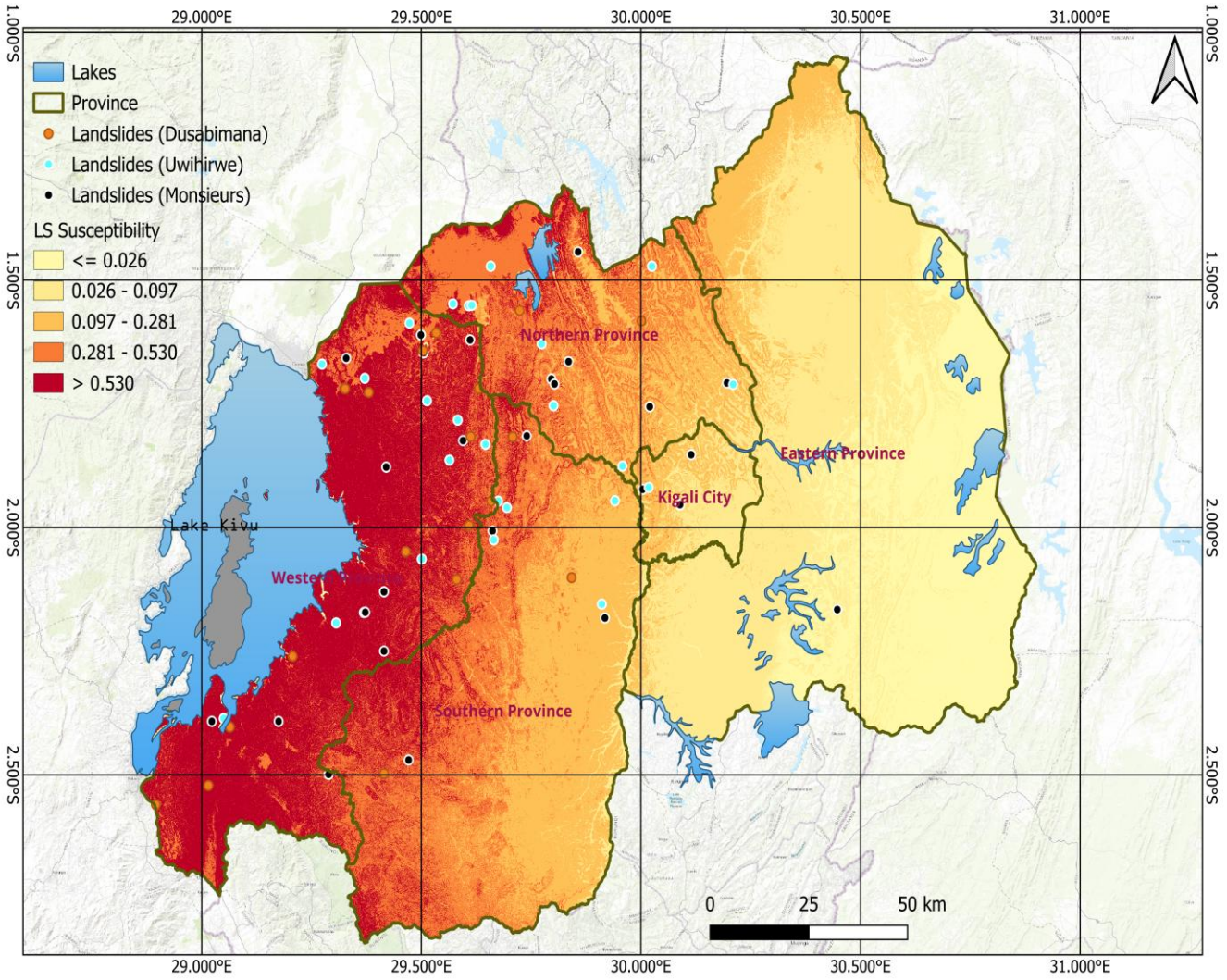
# Preliminary results

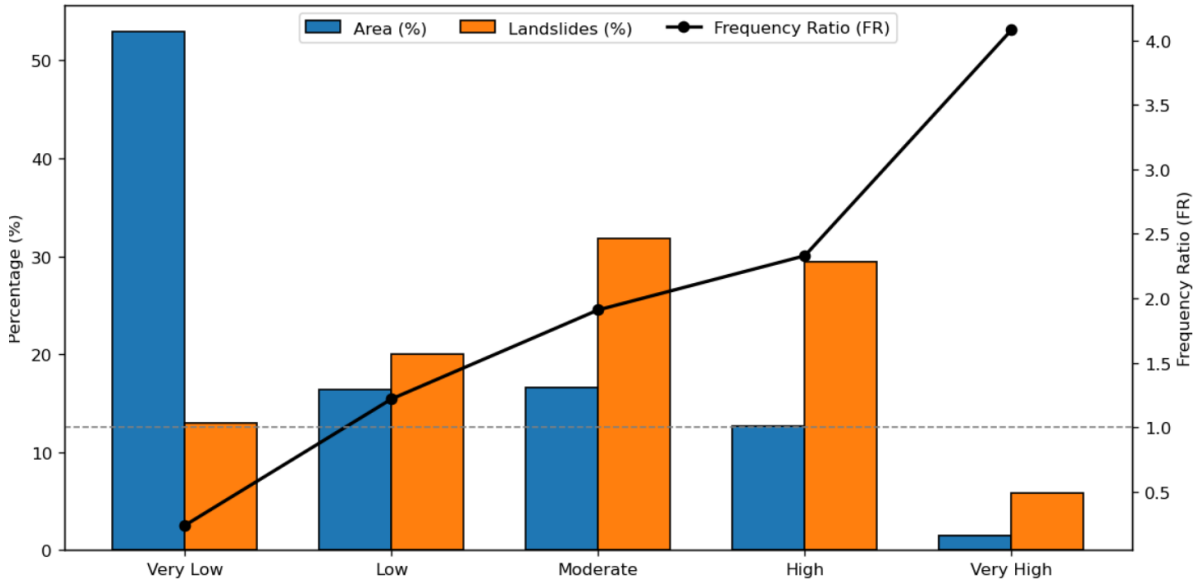



- Landslides cluster in western and northern Rwanda
- Strong seasonal pattern (peak during rainy months)
- The lag between peak rainfall (April) and peak landslides (May) highlights the critical role of antecedent soil moisture conditions

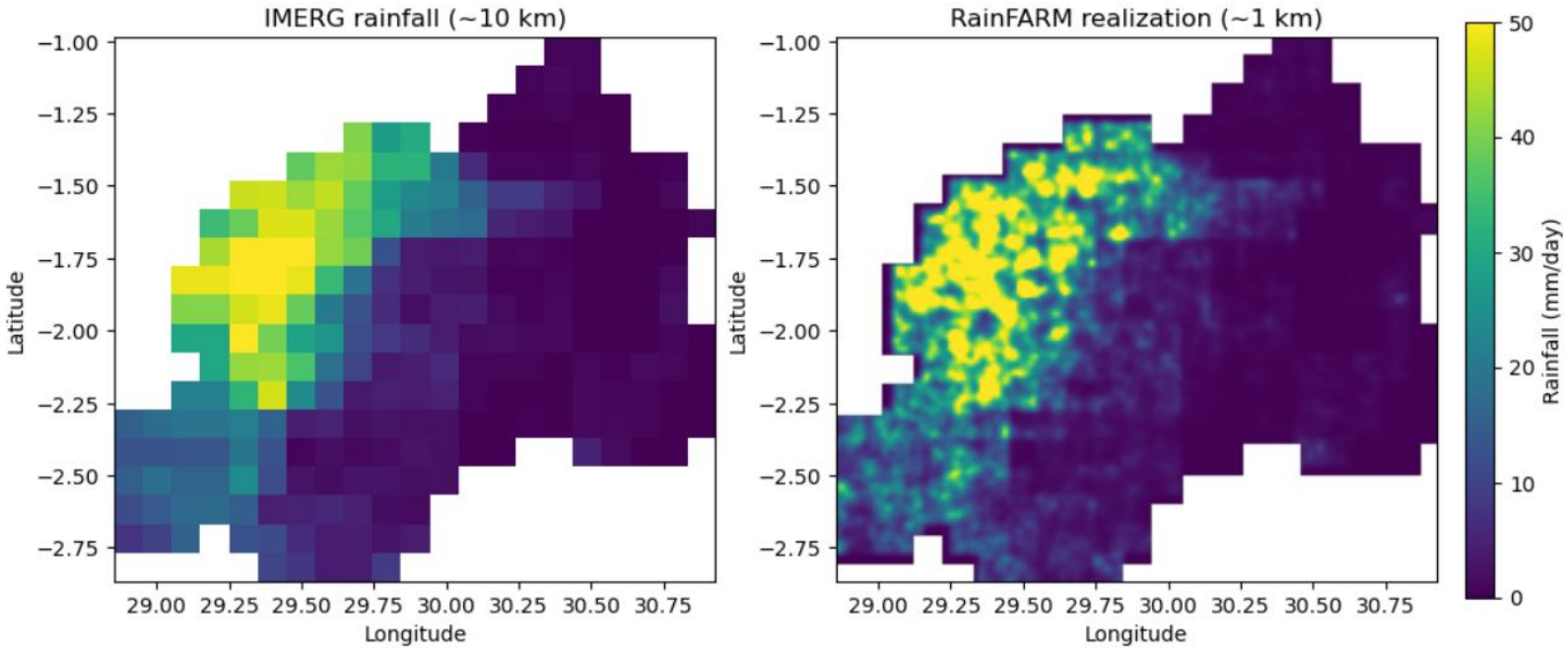
# Preliminary results




- **The landslide event distribution is consistent with the susceptibility classification**

# Preliminary results

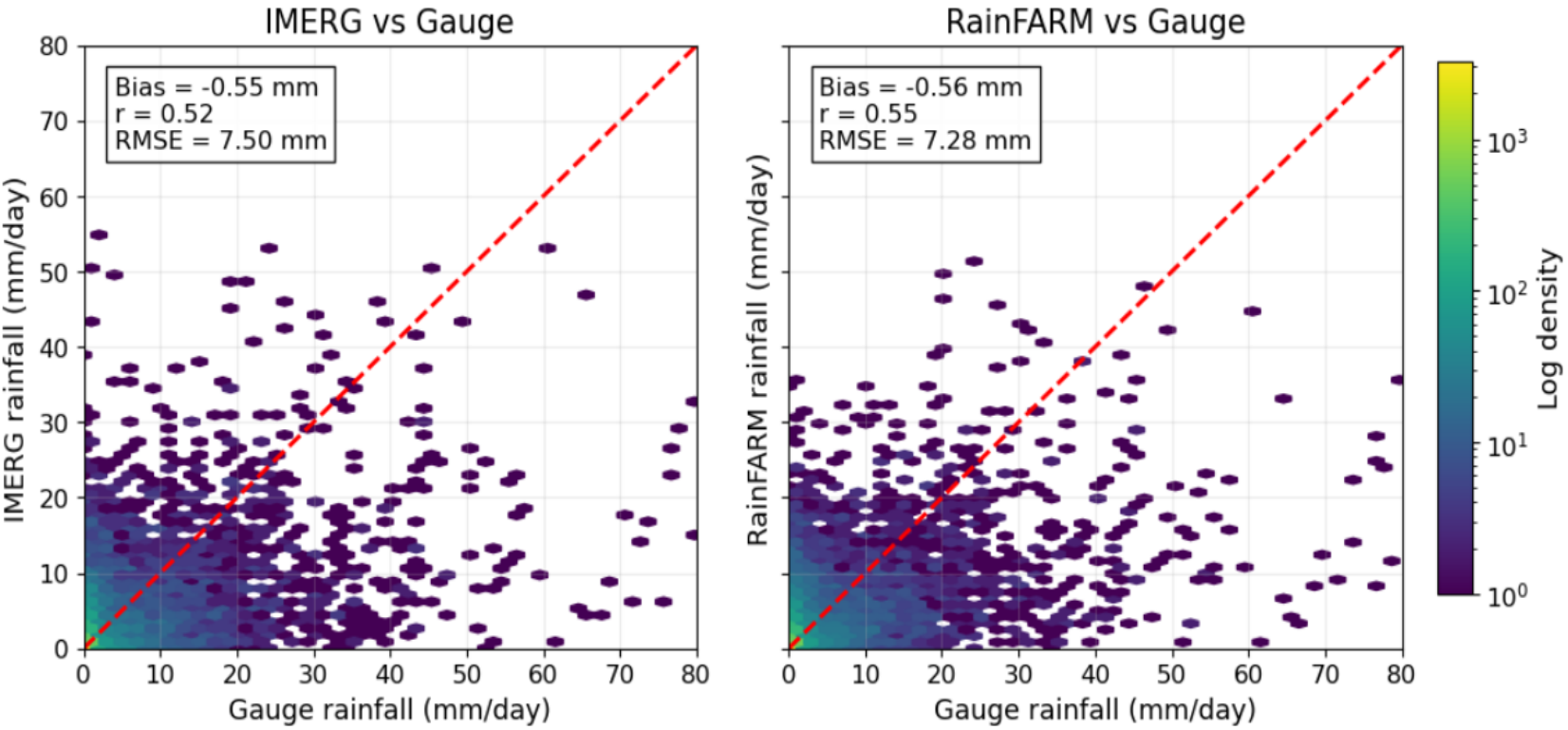



Event (2 May 2023): RainFARM reveals sub-grid variability

IMERG averages rainfall over large pixels, while RainFARM redistributes that rainfall into smaller-scale patterns, revealing local hotspots that are important for landslides

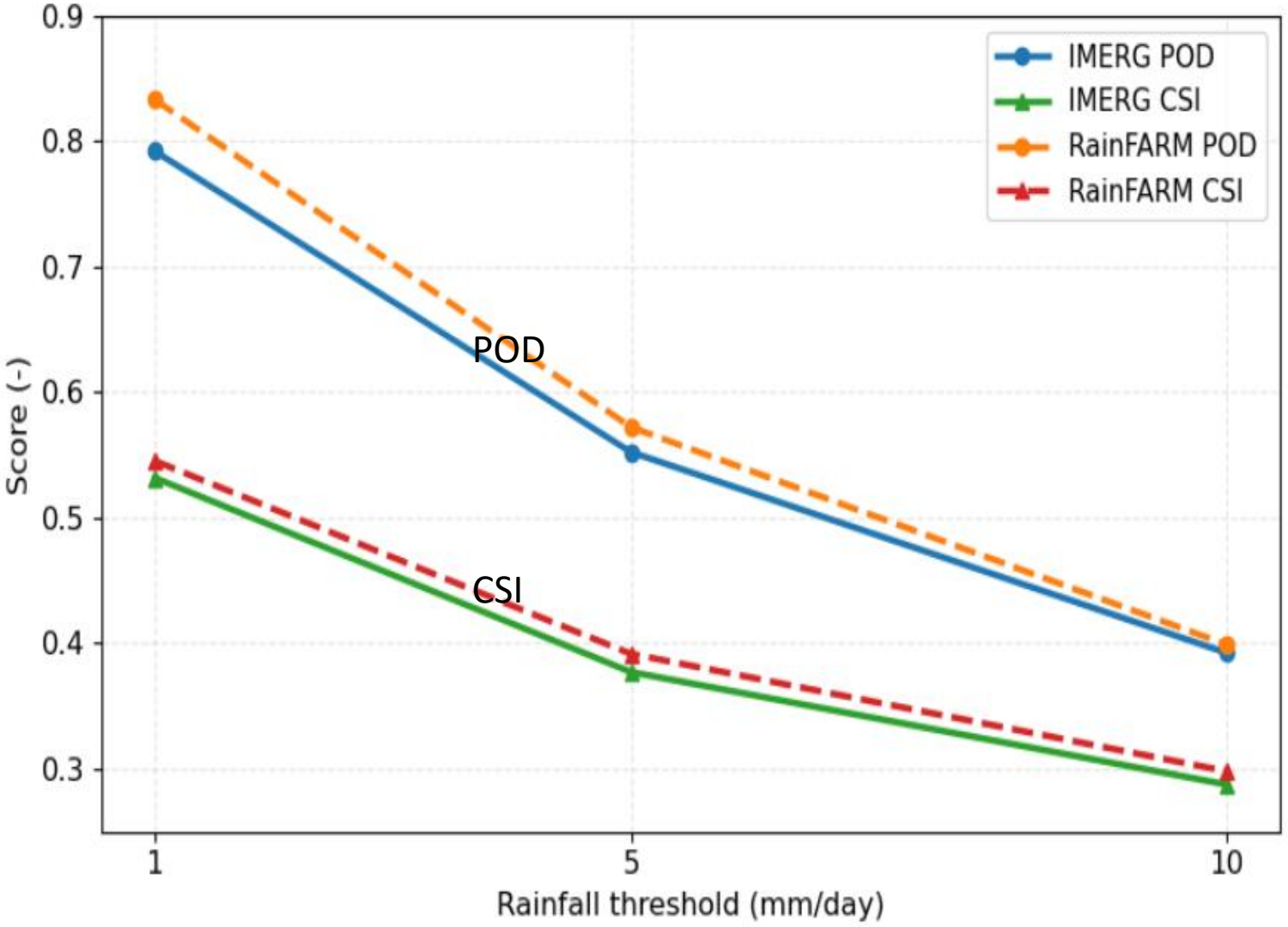
| Metric | IMERG | RainFARM |
|---|---|---|
| Std (mm/day) | 15.88 | 17.10 |
| P95 (mm/day) | 46.65 | 49.06 |
| P99 (mm/day) | 55.04 | 73.78 |

# Preliminary results




- Slight increase in correlation (~6%)
- Minor reduction in RMSE
- Bias remains unchanged

Comparison of IMERG and RainFARM with Gauge Observations (11 stations, 2022–2024)




POD and CSI across Rainfall Thresholds: IMERG vs RainFARM

# Preliminary results

- RainFARM increases Probability of Detection (POD) and Critical Success Index (CSI) at all thresholds
- Improvement is consistent but moderate

# Conclusion

- Our updated event inventory is in agreement with the regional susceptibility pattern
- RainFARM enhances spatial rainfall variability
- Detection skill improves slightly
- We move towards a susceptibility-informed framework integrating: susceptibility, soil moisture, and rainfall
- In future, incorporate event magnitude (number of landslides) and rainfall intensity in threshold derivation

# Thank you!

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