Committee on Earth Observation Satellites

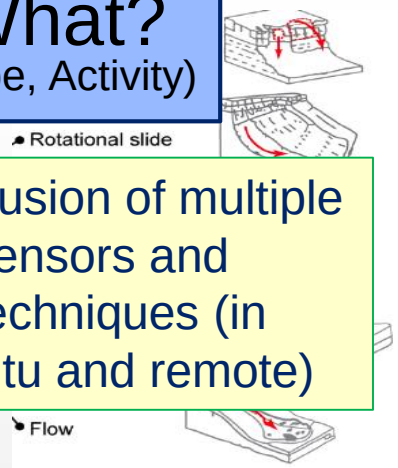
Landslide Pilot Working Group Presentation

September 1st, 2020

Integration of satellite platforms for understanding landslides

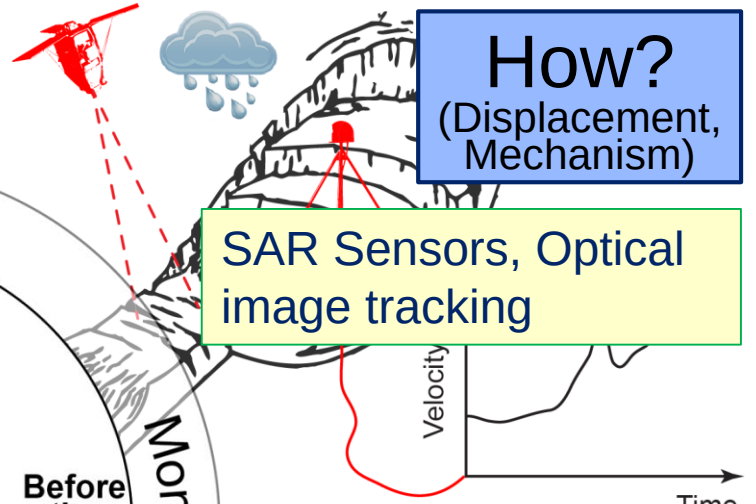
What?
(Type, Activity)

Fusion of multiple sensors and techniques (in situ and remote)



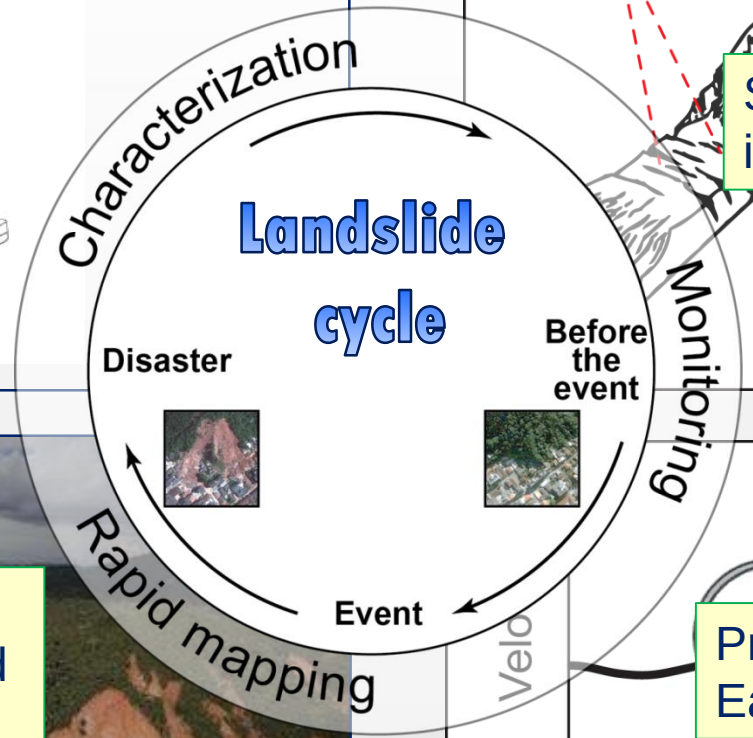
How?
(Displacement, Mechanism)

SAR Sensors, Optical image tracking

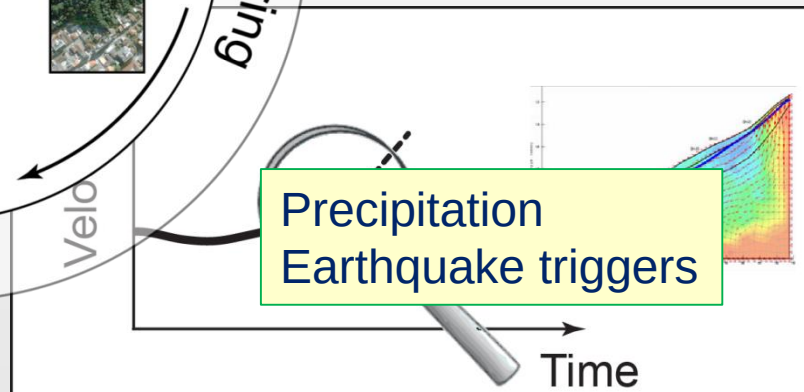


Optical data, Citizen Science and Inventory sharing

Where?
(Location)



Precipitation
Earthquake triggers



When?
(Forecast)

Regional study areas and leads

Region	*Regional Point of Contact*
Nepal	**Nick Rosser, Sigrid Roessner, Dalia Kirschbaum**
Pacific Northwest, US	**Jonathan Godt, Dalia Kirschbaum**
Eastern Africa	***Olivier Dewitte***
Caribbean (Cuba/Lesser Antilles)	***Georgina Bennett, Jean-Philippe Malet***
China	***Zeng-Guang Zhou***

Summary of data acquisitions for the pilot

Agency/Instrument	# of Acquisitions	Location(s)	Comments
DLR/TerraSAR-X	102	Nepal	Acquisition ended
ASI/COSMO-SkyMed	144	Nepal	Acquisition ended
ASI/COSMO-SkyMed	120	PNW, USA	Acquisition ended
ASI/COSMO-SkyMed	84	Africa	Acquisition ended
CNES/Pleiades	22542 Km^2	Nepal	Acquisition possible based on remaining area
CNES/Pleiades	8140 km^2	PNW, USA	Acquisition possible based on remaining area
CNES/Pleiades	56 km^2	Caribbean	Acquisition possible based on remaining area

Nepal Study Sites: Recent Results

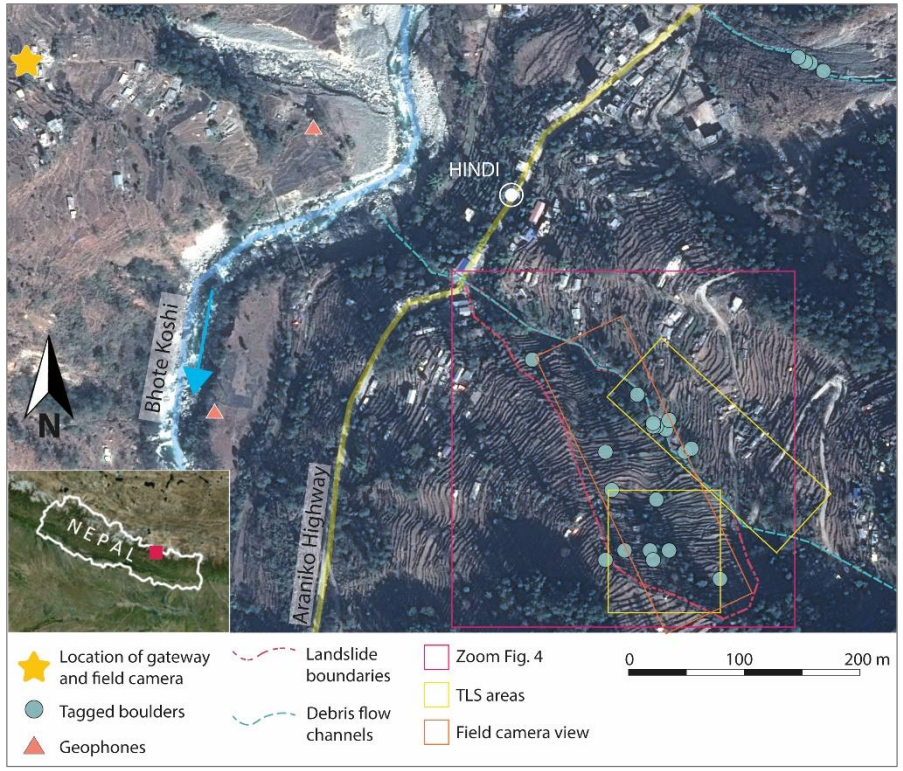
BOULDER: Accounting for BOUlders in Landslide-flood hazard Disaster Evaluation and Resilience

Benedetta Dini, Georgina L. Bennett, Aldina M. Franco, Michael R. Z. Whitworth, Kristen L. Cook, Andreas Senn, John Reynolds

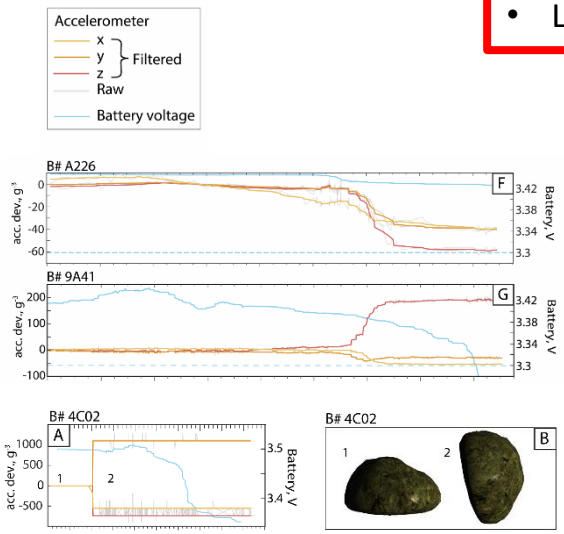
Objectives:

- Develop boulder tracking system
- Understand controls on boulder production on hillslopes
- Towards an early warning system
- Improve resilience through hazard assessment

May 2019: installation of the network
Bhote Koshi, Nepal



- 23 boulders tagged
- 9 show movement in accelerometer data

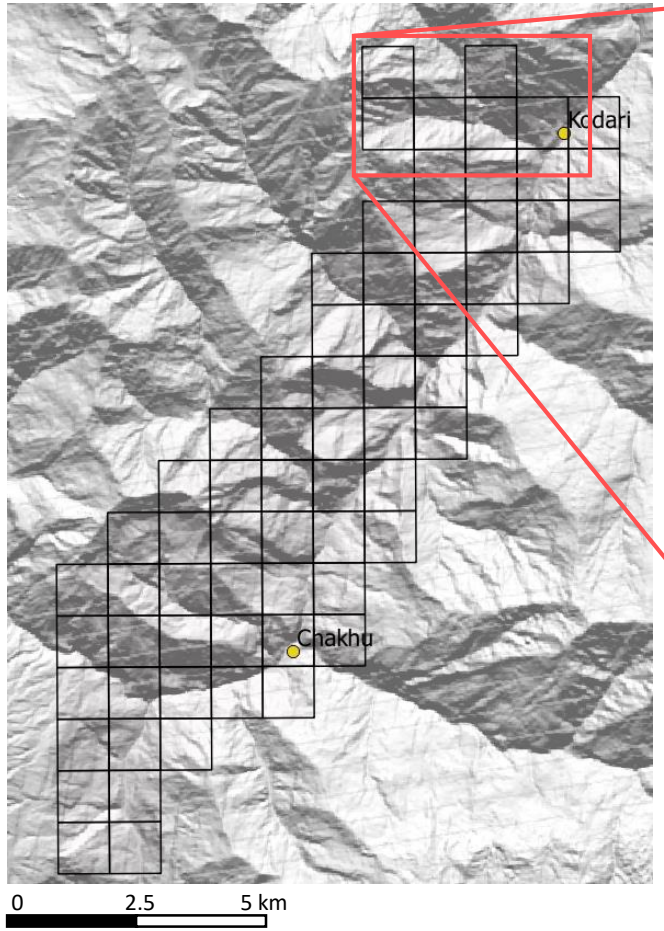


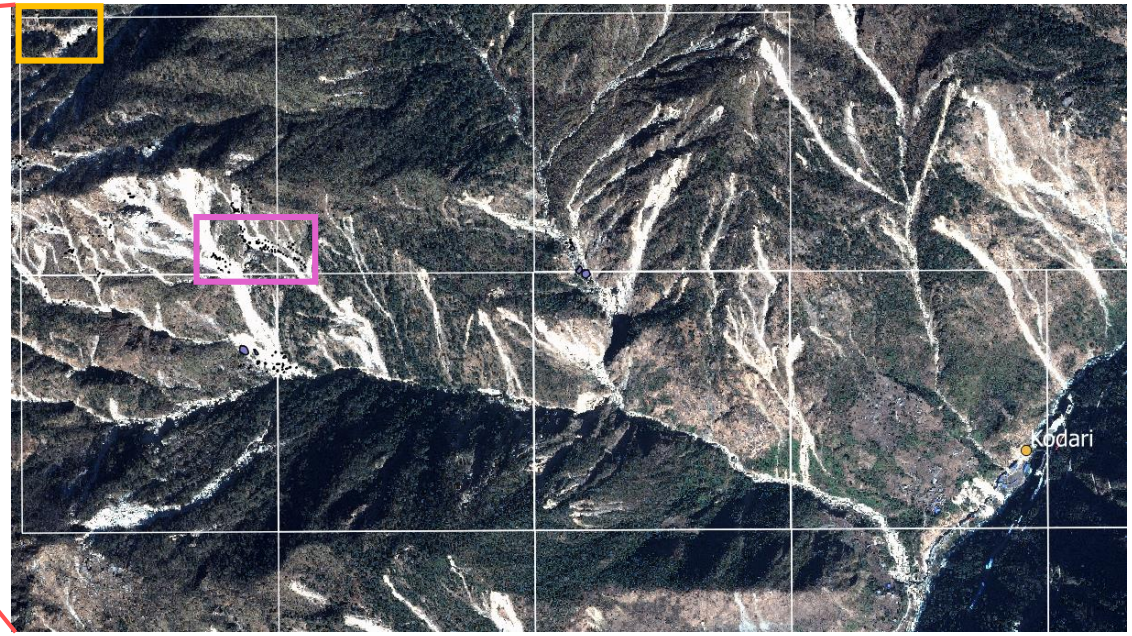
Dini, Bennett et al., 2020, in prep.

CURRENT ANALYSIS

- What controls large boulder presence?
- Structures (intersections, spacing, persistence)?
- Lithology?

Boulder mapping

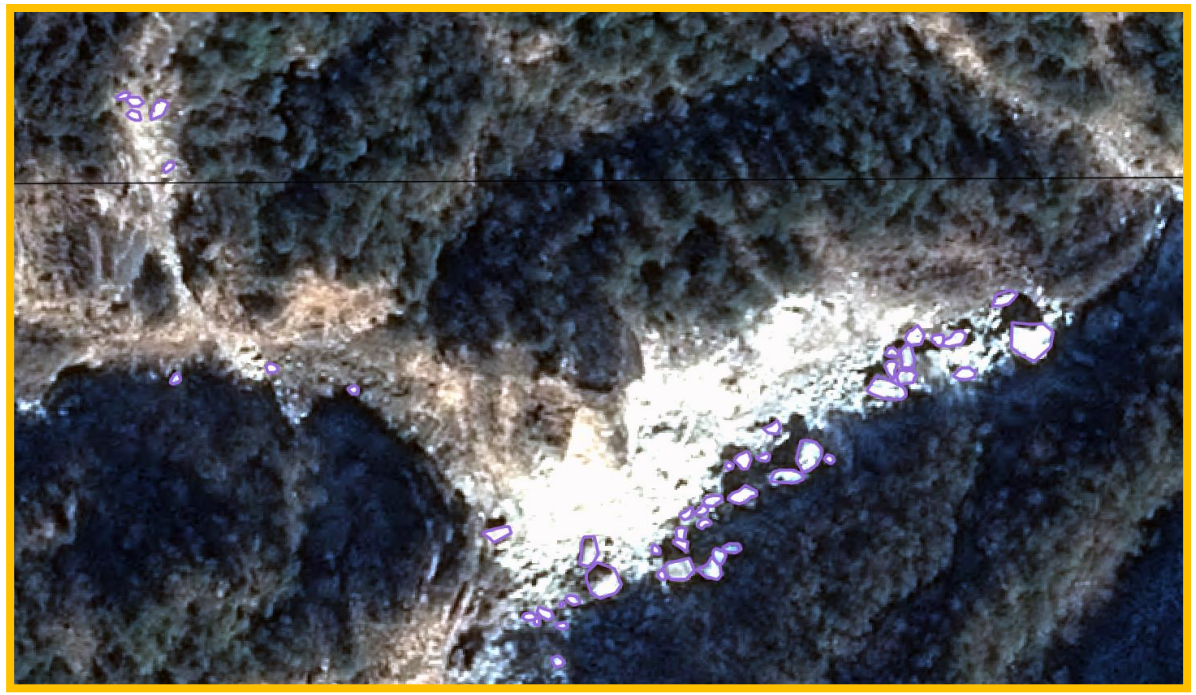




- Systematic mapping of large boulders (~2m +)
- Visual boulder recognition on Pleiades image and Google Earth

Examples in next slides

Mapping on Pleiades imagery



- High resolution allows for precise polygon boundaries
- Many deposits are not well captured (high exposure?) – see next slide

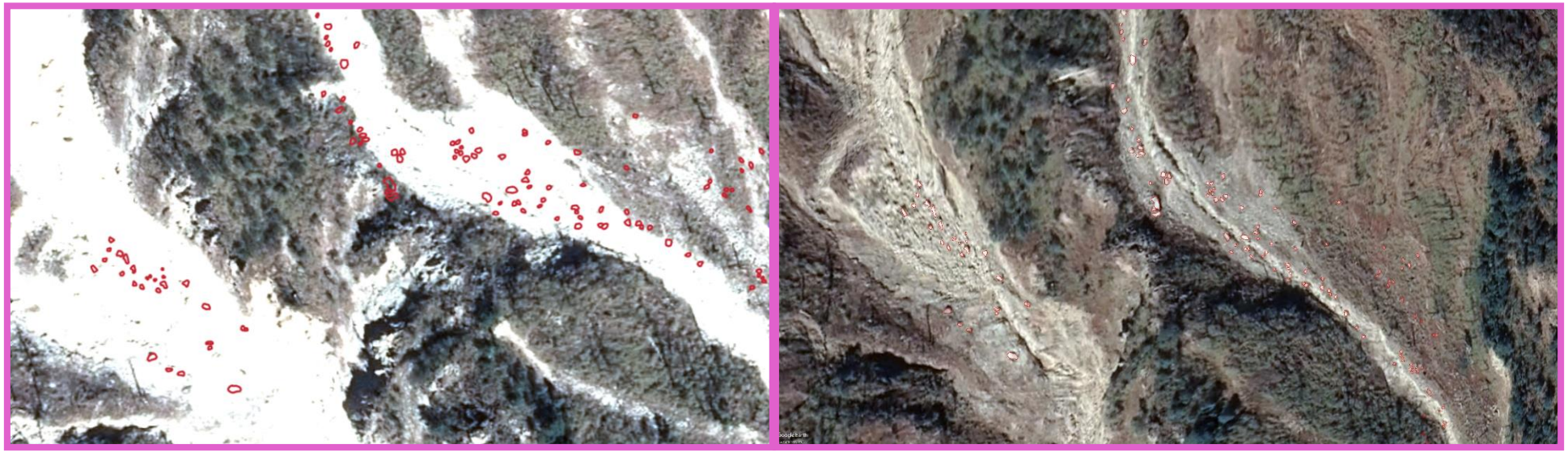
Boulders mapped on Pleiades

Mapping on Google Earth

- Often significant shifts between images acquired at different times and between GE images and Pleiades – difficulties in placing precise boundaries

- Often better visibility of the deposits - in the example below, the boulders mapped are not visible in Pleiades

Boulders mapped on Google Earth



Pleiades

Google Earth

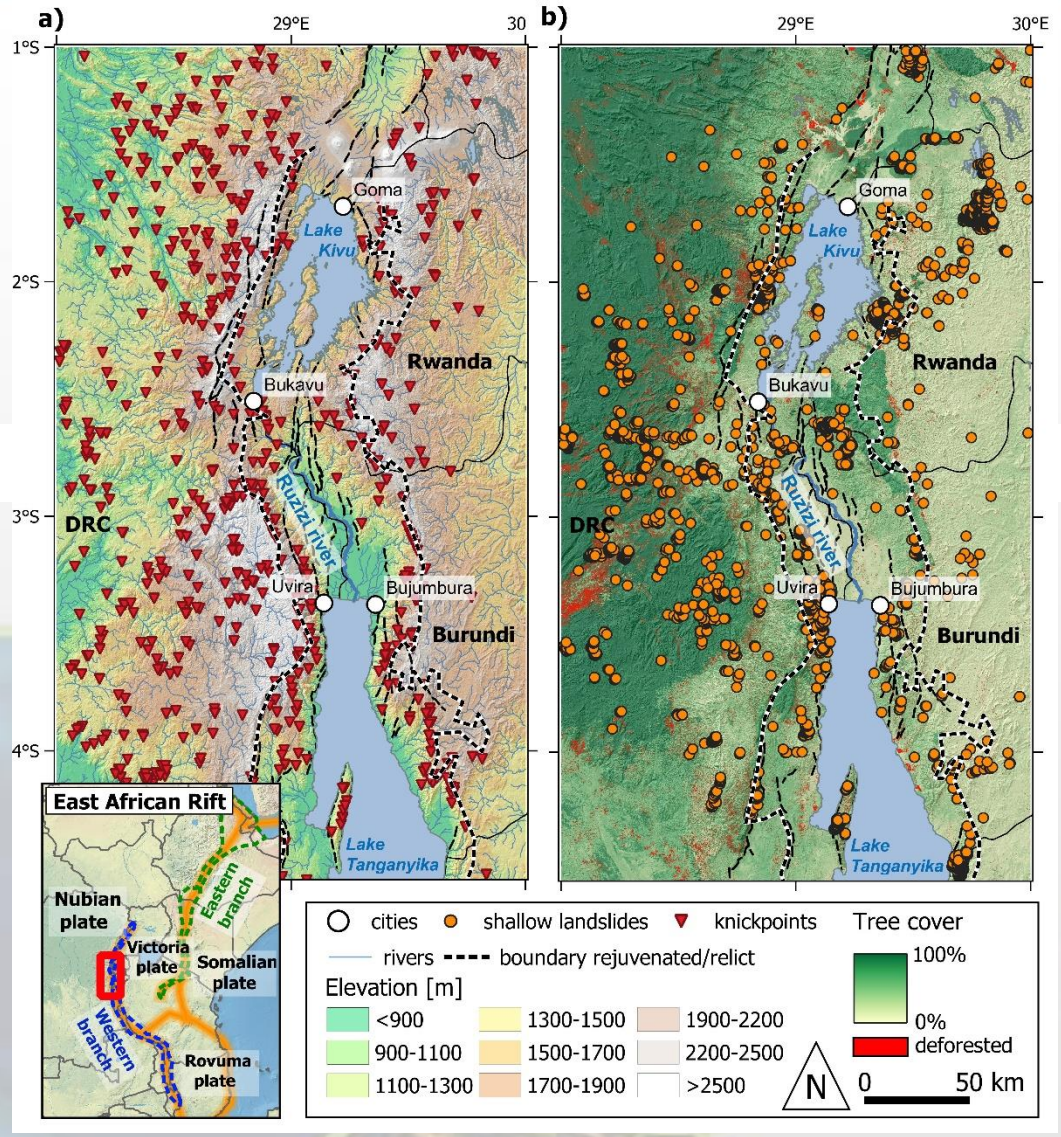
Africa Study Site: Preliminary Results

Olivier Dewitte, Arthur Depicker, Antoine Dille, Elise Monsieurs

Royal Museum for Central Africa, Department of Earth Sciences, Tervuren, Belgium

AFRICA museum

Landslides rates, deforestation and rifting

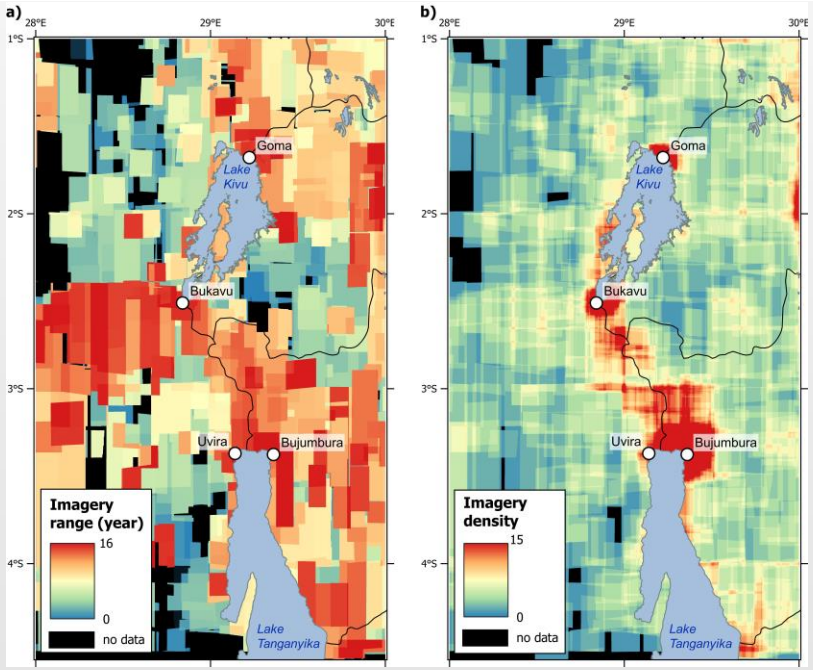


1) Shallow landslide inventory from **Google Earth imagery**

2 Landslide rates are computed considering imagery density and range

3) Rates are analysed with regard to river incision patterns, geology and rift tectonics

→ **We find that deforestation initiates a landslide peak that lasts 15 years. The deforestation response is different according to the long-term landscape evolution patterns of the rift**

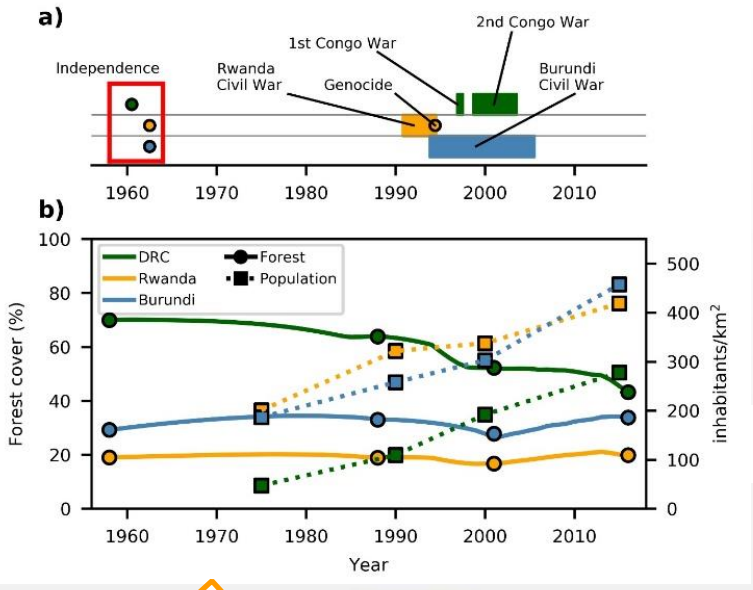


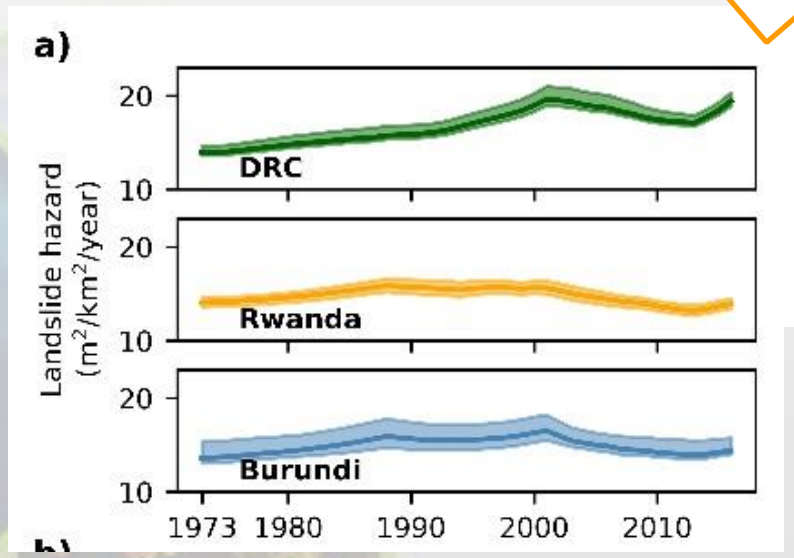
AFRICA museum

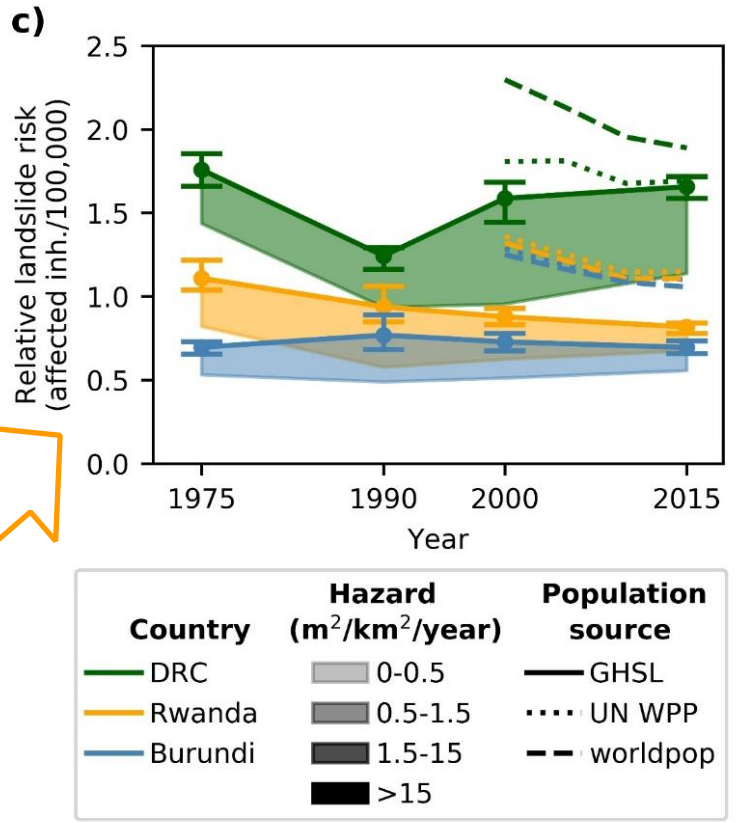
KU LEUVEN

Depicker et al., to be submitted.

Forest management and landslide hazard and risk trajectories







1) Based on the results of landslide rates and recent deforestation (former slide)

2) 70 years of forest dynamics reconstructed from historical photos and **Landsat and Sentinel-2 images**

3) Forest patterns from photos are extracted with deep-learning approaches (Mboga et al., 2020)

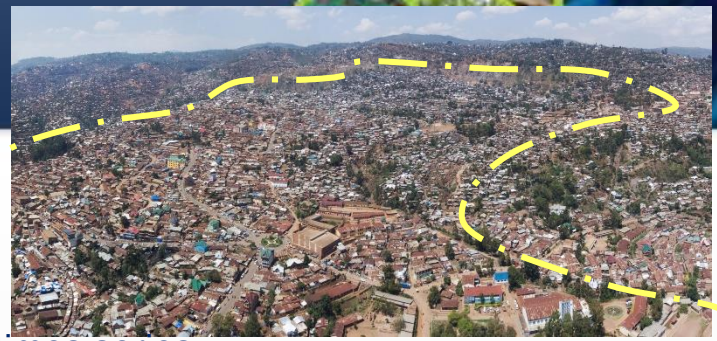
4) Forest dynamics is analysed for three countries separately in relation to key management drivers

5) Forest dynamics is linked to deforestation response patterns (slide 1) to compute hazard evolution

6) Hazard evolution is linked to population dynamics to assess the relative landslide risk.

Depicker et al., in prep.

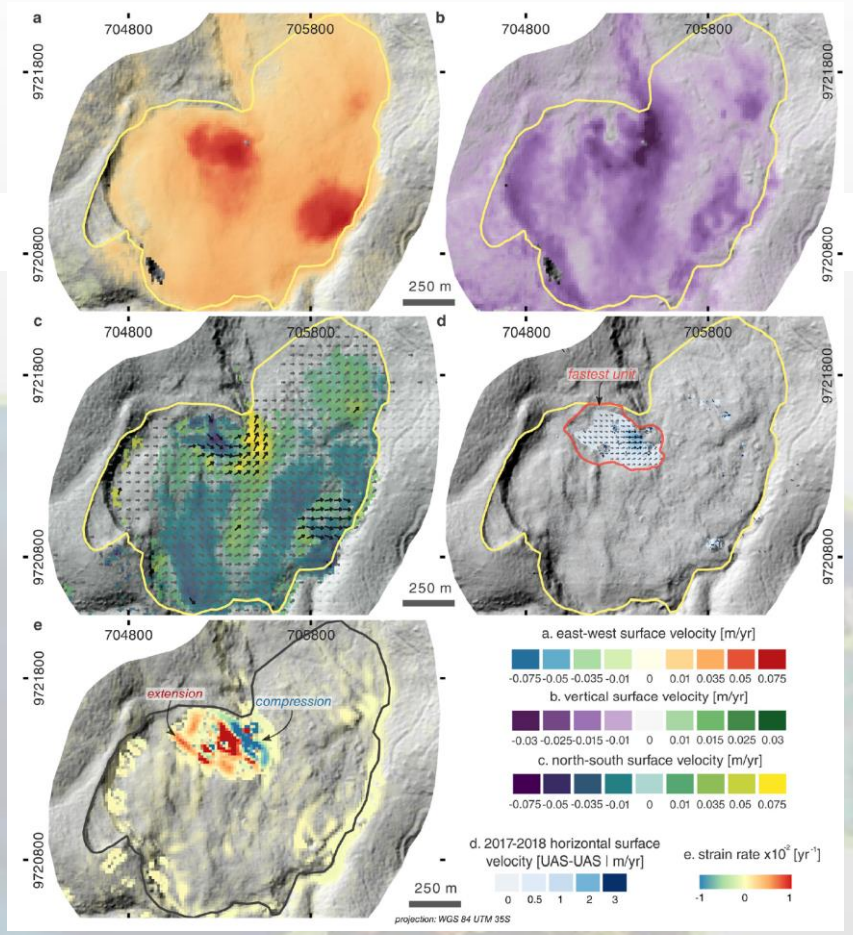
Unravelling landslide dynamics using SAR interferometry: Bukavu



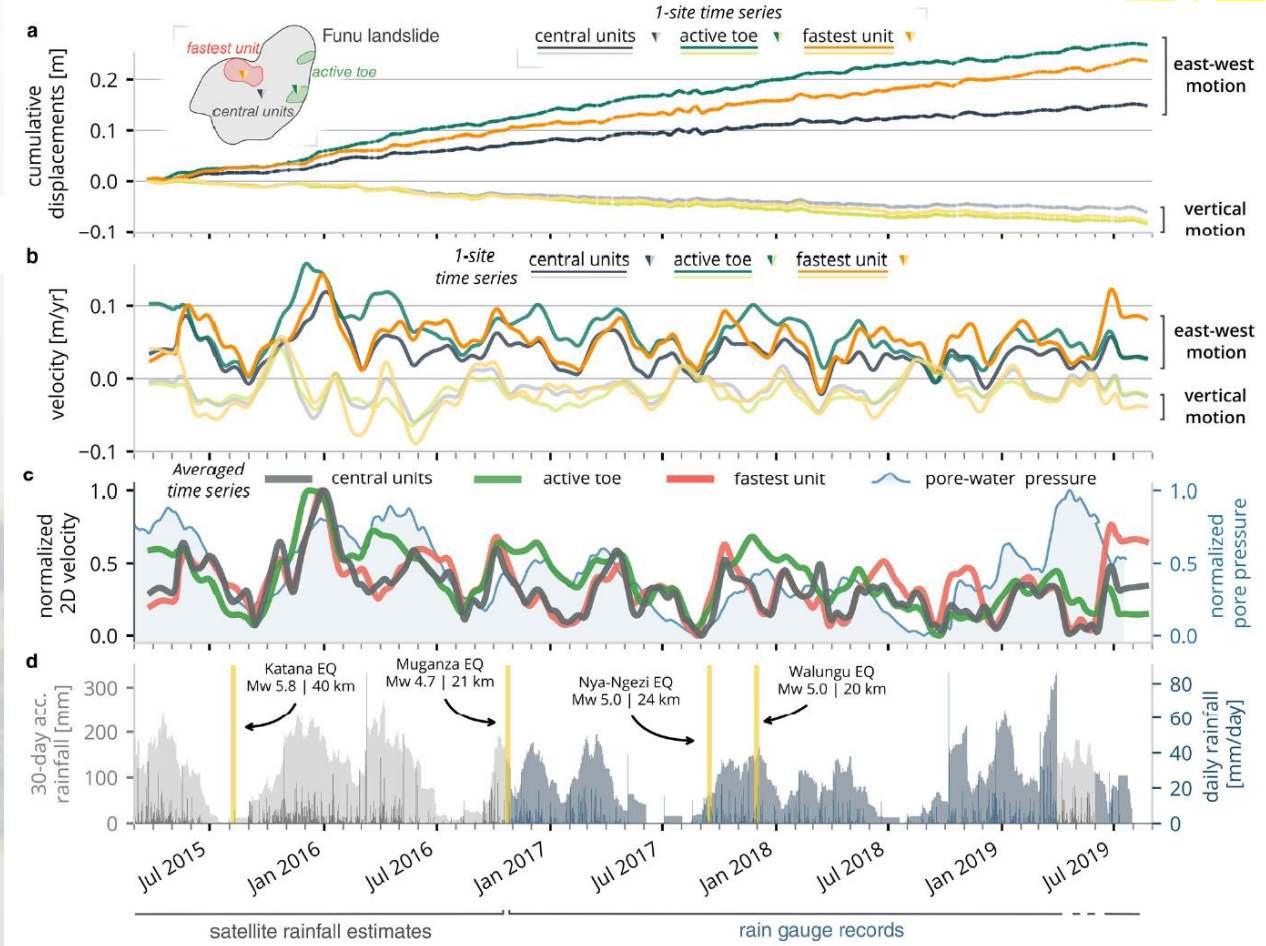
Data: 590 Sentinel 1 & CSK; Pléaides, UAS, IMERG. 4.5 year time series

Method: SAR interferometry (MSBAS) + a new method (MSBAS 3D) (Samsonov et al.,2020, Eng. Gel.) Pore-water pressure (modelled using Handwerger et al. 2013 solution)

Landslide motion and surface strains



Landslide displacement, pore pressure and rainfall times series

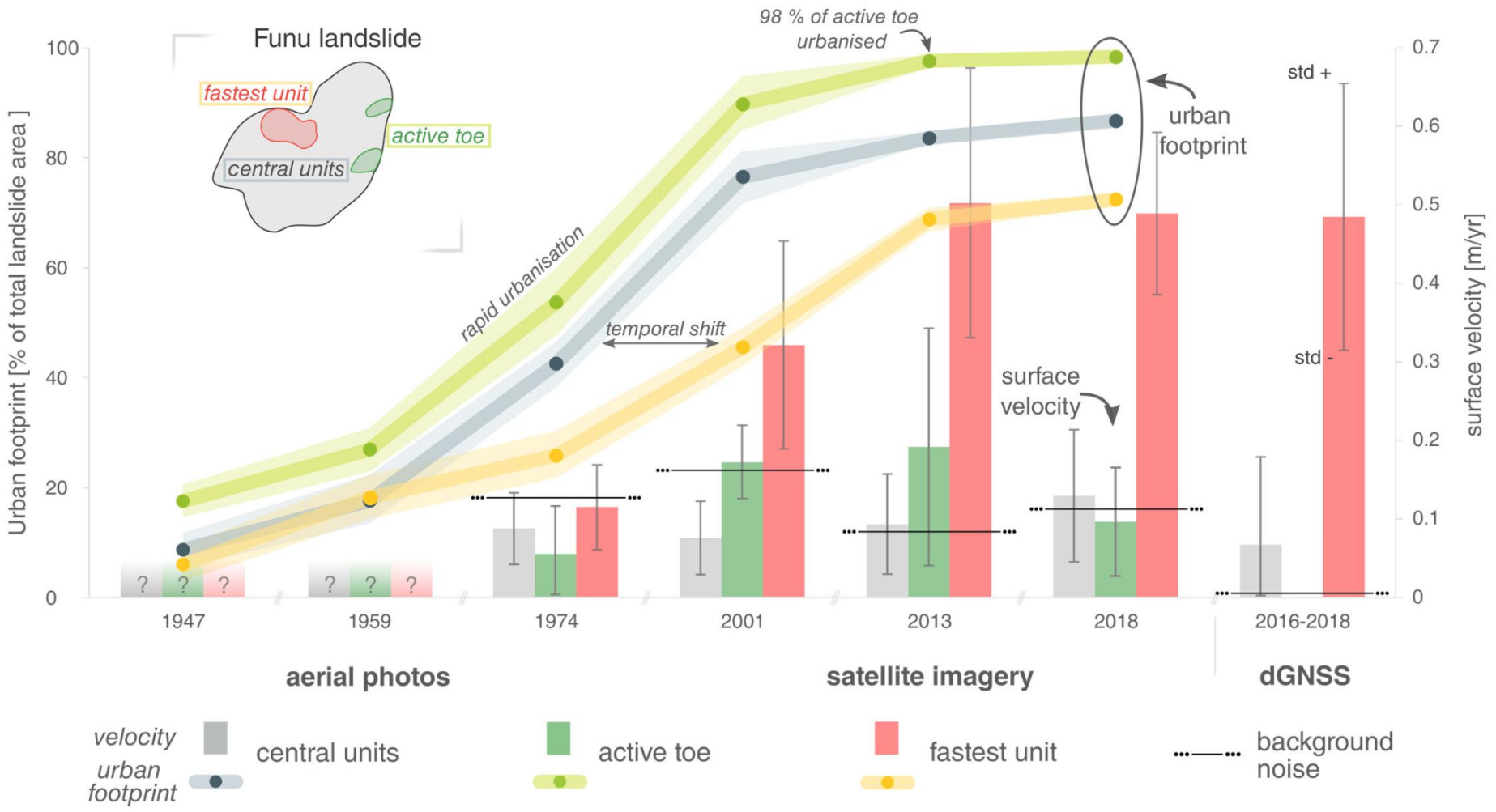


AFRICA museum

Funu: an urban landslide

Dille et al., in review

Unravelling landslide dynamics using historical data



Data: **Historical aerial photos, Ikonos, Pléiades, UAS**. 70 year time series

Method: Image-correlation, SfM

Dille et al., in review

Global Work

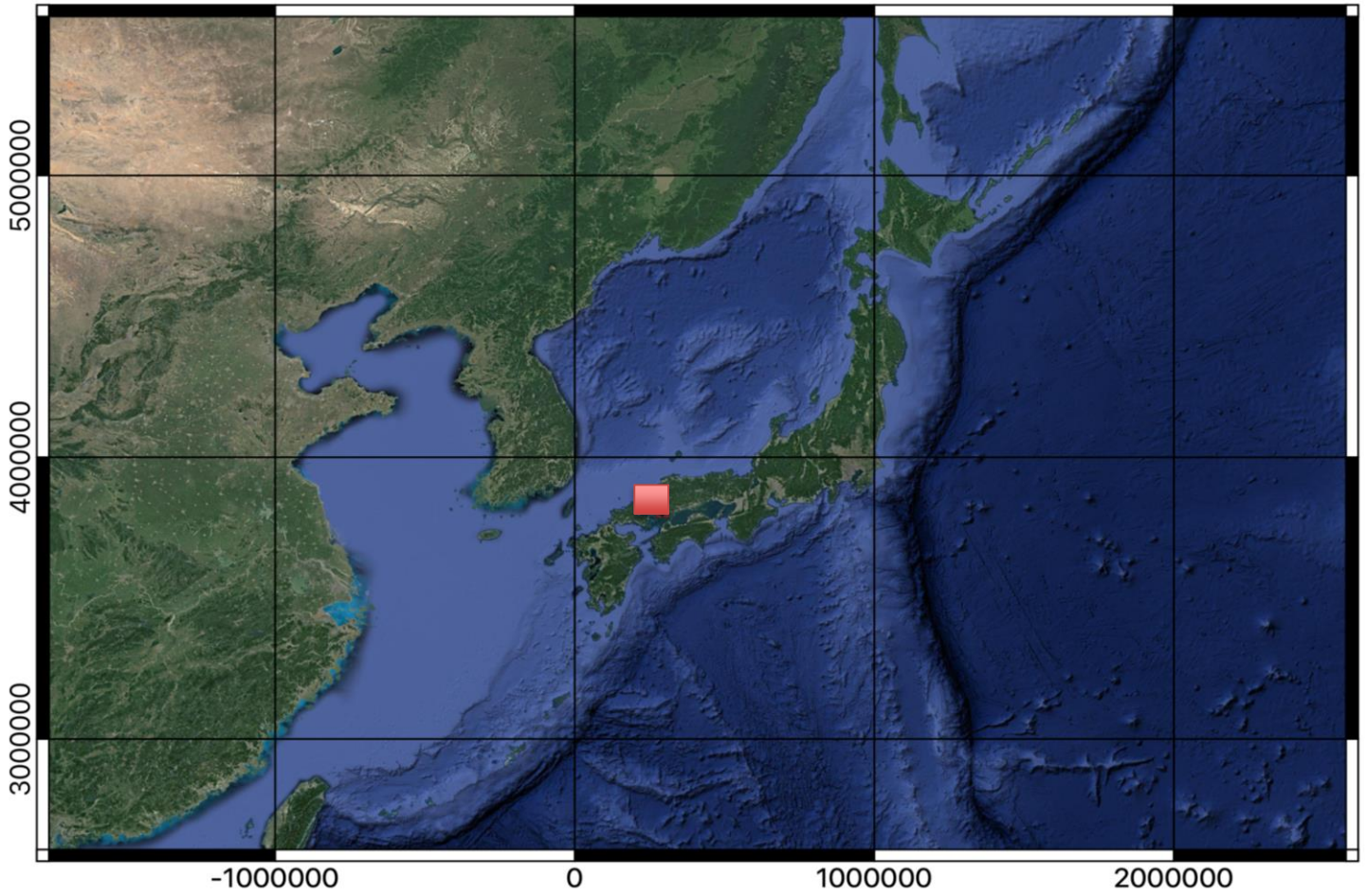
Landslide Detection from Sentinel-2 imagery

Testing of machine learning based detection algorithms

SALaD (NASA) vs. ALADIM (CNRS/EOST) vs. ImCLASS (CNRS/EOST)

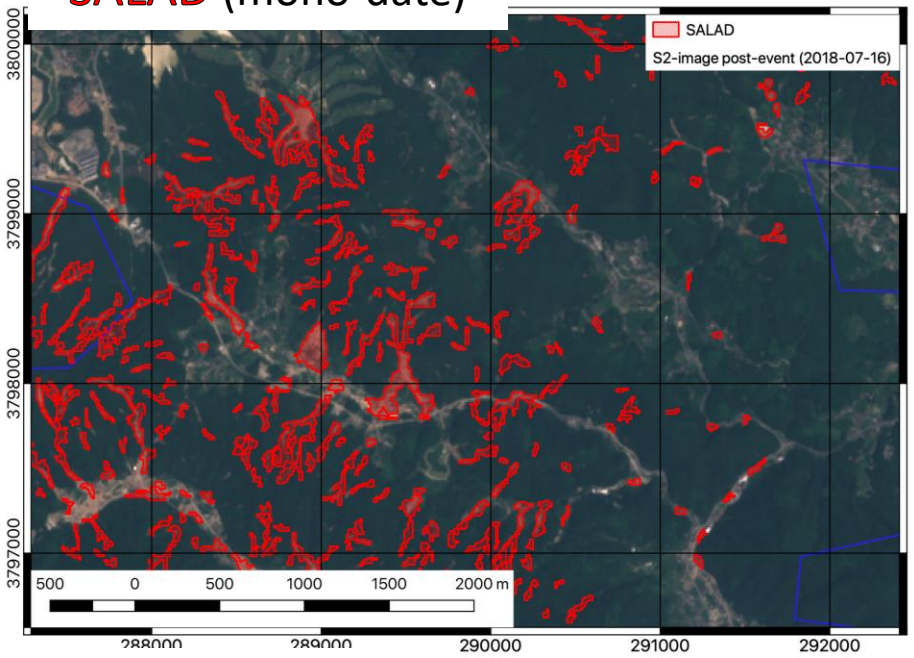
Use case: Hiroshima Torrential Rains of July 2018

Test AOI of 182 km^2

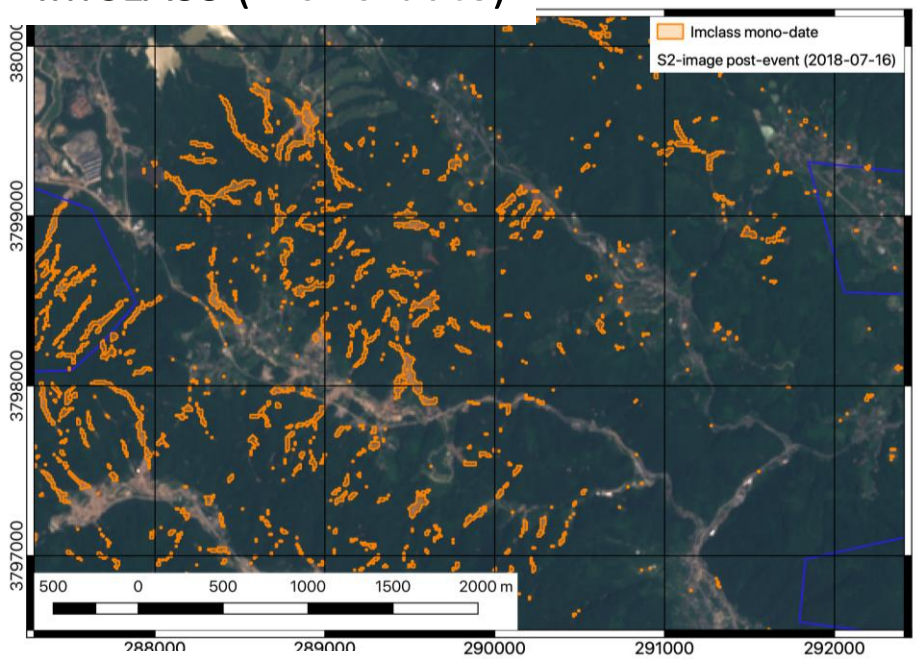


Université de Strasbourg

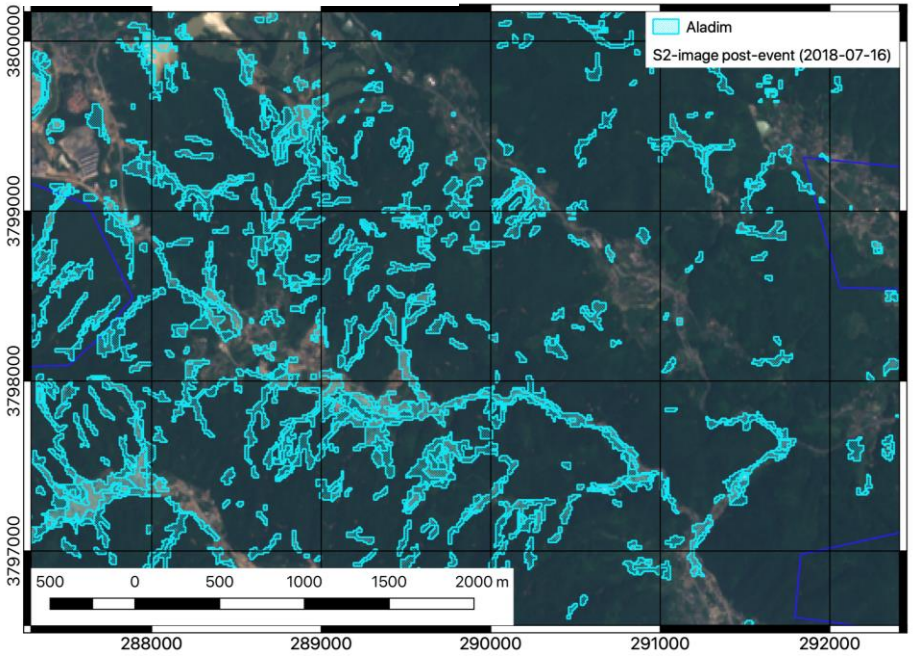
SALAD (mono-date)



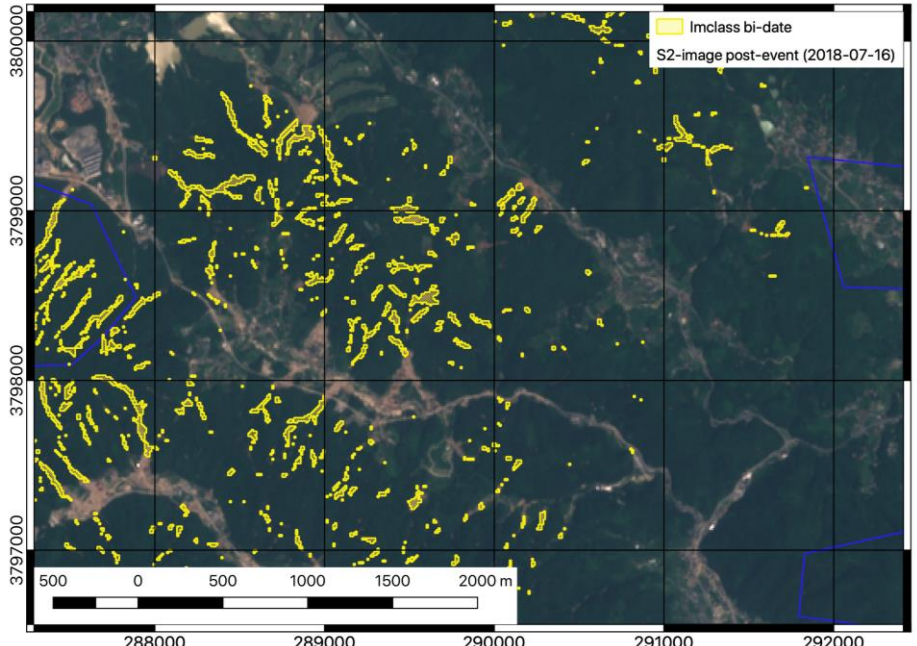
ImCLASS (mono-date)



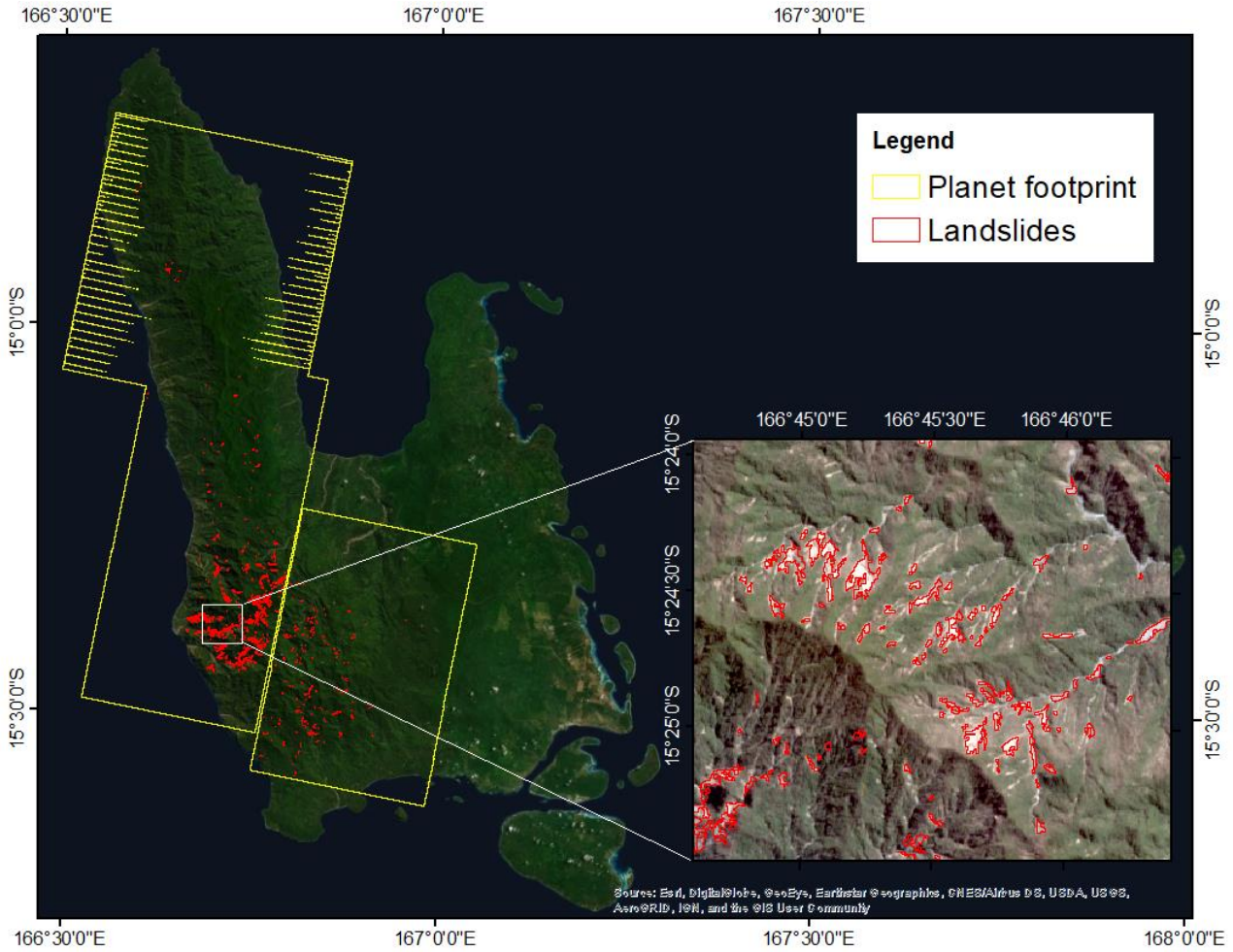
ALADIM (bi-date)



ImCLASS (bi-date)



Cyclone Harold landslides, Sanma Province, Vanuatu



Number of landslides mapped: 1484 (includes earlier landslides as well)

Source: Planet (3m)

Date: 04/12/2019

Method: Semi-Automatic Landslide Detection (SALaD) system (Amatya et al. 2019 a,b)

Credits: Pukar Amatya (USRA), Dalia Kirschbaum (NASA), Thomas Stanley (USRA), Robert Emberson (USRA) and Planet Team

References:

Amatya P, Kirschbaum D, Stanley T (2019a) Use of very high-resolution imagery to create multi-temporal landslide inventories along key highway corridors in Nepal. In: EGU General Assembly Conference Abstracts 21, 10243

Amatya P, Kirschbaum D, Stanley T (2019b) Use of Very High-Resolution Optical Data for Landslide Mapping and Susceptibility Analysis along the Karnali Highway, Nepal. Remote Sens 11:2284

https://maps.disasters.nasa.gov/arcgis/home/item.html?id=b6598e9b92bf4979a76e8fccee741ed2

Landslide Demonstrator

Landslide Demonstrator Proposal
Lead: CNRS & NASA

- Showcase satellite tailored services and products for the 3 thematic applications over relevant areas of interest for the 2021-2023 period;
- Document the data and services with the creation of on-line demonstration/dissemination materials in order to extend the use of the data and services to a larger partnership of *landslide DRM stakeholders* for regular use of satellite imagery, on-line processing services and derived products;
- Engage and expand multi-sectorial partnership by providing timely support (in best effort mode) to the 3 thematic applications and facilitating the provision of satellite-derived products, access, and support for use of services.

Landslide Demonstrator Applications:

Application 1: Use satellite data for landslide disaster assessment and mitigation along **transportation and pipeline corridors**, with goal of establishing local monitoring of areas of possible danger with regularity and consistency of observation, and of facilitating the assessment of the future evolution of these slopes.

Application 2: Use of satellite data for establishing landslide risk financing products (country or region risk profiles, hazard and risk maps) in full complementarity with the World Bank Disaster Risk Financing and Insurance Program (DRFIP).

Application 3: Demonstrate the usefulness of satellite data for *landslide science* at global scale, with the systematic documentation of large landslide disasters triggered by intense rainfall and/or high magnitude earthquakes in terms of standardized inventories of different complexity.

Landslide Demonstrator: Application 1

Application 1: A demonstrator for the operational landslide monitoring of traffic and pipeline corridors (China, Alps, France, US, Scandinavia, maybe UK)

Demonstrator Leads: Jean-Philippe Malet (CNRS/ EOST) and Corey Froese (BGC, to be contacted)

Industry Participants: Highway/Train companies, Pipelines companies, Engineering Geology Bureau x, State offices, BP

Methodologies

- Use of InSAR-PSI techniques to monitor slow-moving deformation patterns
- Use of optical derived techniques to monitor fast-moving deformation patterns
- The definition of procedures to propose permanent monitoring services over the uses cases as demonstrator

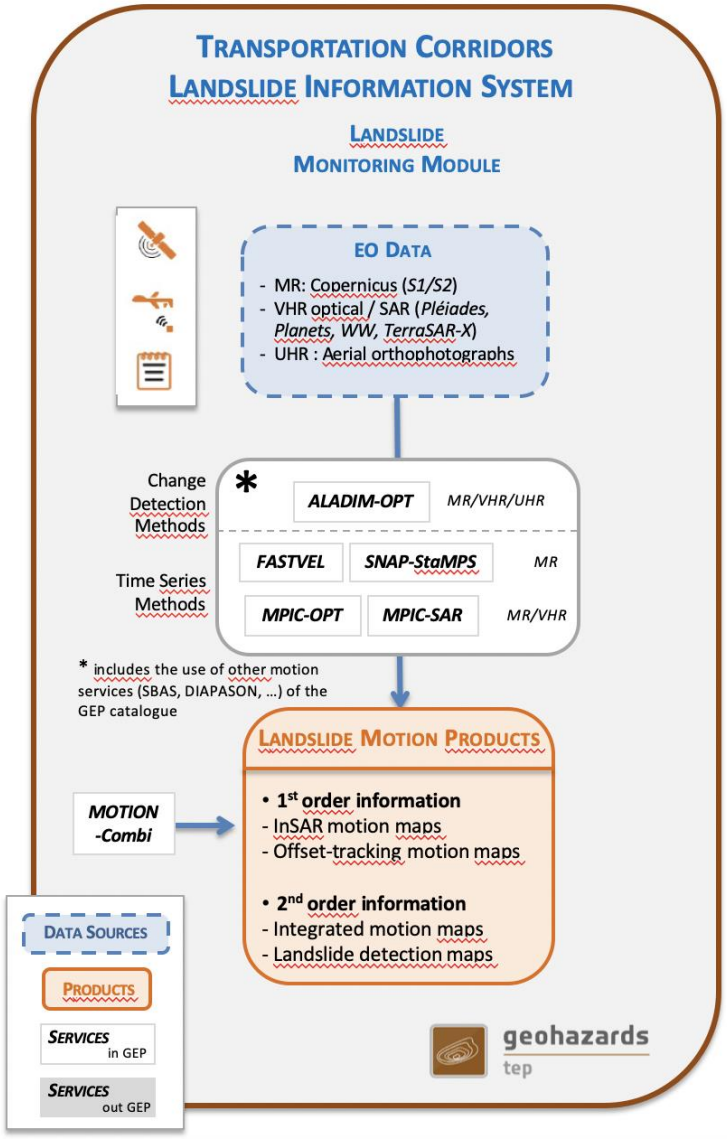
East France – March 2020 – landslide on high speed train TGV

This goal is to collaborate amongst researchers and the operational community to develop end-user oriented landslide monitoring and share best practices, methodologies and applications to meet the needs of engineers, geologists, infrastructure managers, and planners in companies, country and state organizations (BGC, SAGE, BP and SNCF RESEAU (French Railway network), among others) in charge of landslide monitoring and mitigation at local scales.

Elkhorn city (Kentucky, US) – February 2020 – shallow landslide / mudflow

Landslide Demonstrator: Application 1

Outline of a possible LANDSLIDE CORRIDOR MONITORING Information System
(e.g. based on current GEP services)



Landslide-induced pipeline failure (Georgia/Caucasus) – July 2020

Landslide-induced train derailment at Carmont (UK/Scotland) – August 2020

Interested stakeholders (partnership to consolidate)

BGC

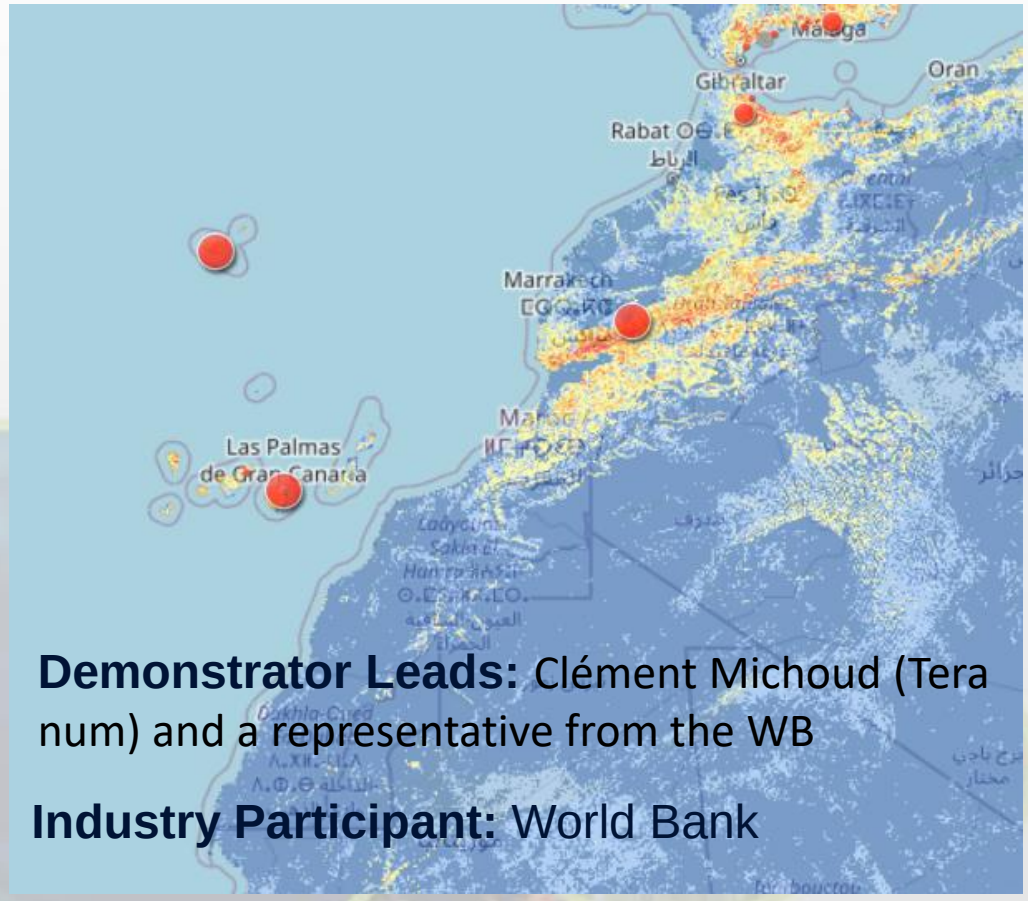
SAGE INGENIERIE

SNCF RÉSEAU

TRL THE FUTURE OF TRANSPORT

Landslide Demonstrator: Application 2

Application 2: Operational Landslide EO Products for Disaster Risk Financing and Insurance Program (World Bank)



Demonstrator Leads: Clément Michoud (Terranum) and a representative from the WB

Industry Participant: World Bank

In cooperation with World Bank and FSEC/Morocco, this application will propose a methodological concept and the access to a processing platform prototype to respond to incipient likely landslide events (in Near-Real Time, NRT) in order to provide estimates of parameters suitable to inform parametric insurance calculations. The activity will concentrate on the development of services and products over a pilot use case in Morocco, but all the development will be generic to be easily transferred to other countries and risk situations.

Methodology

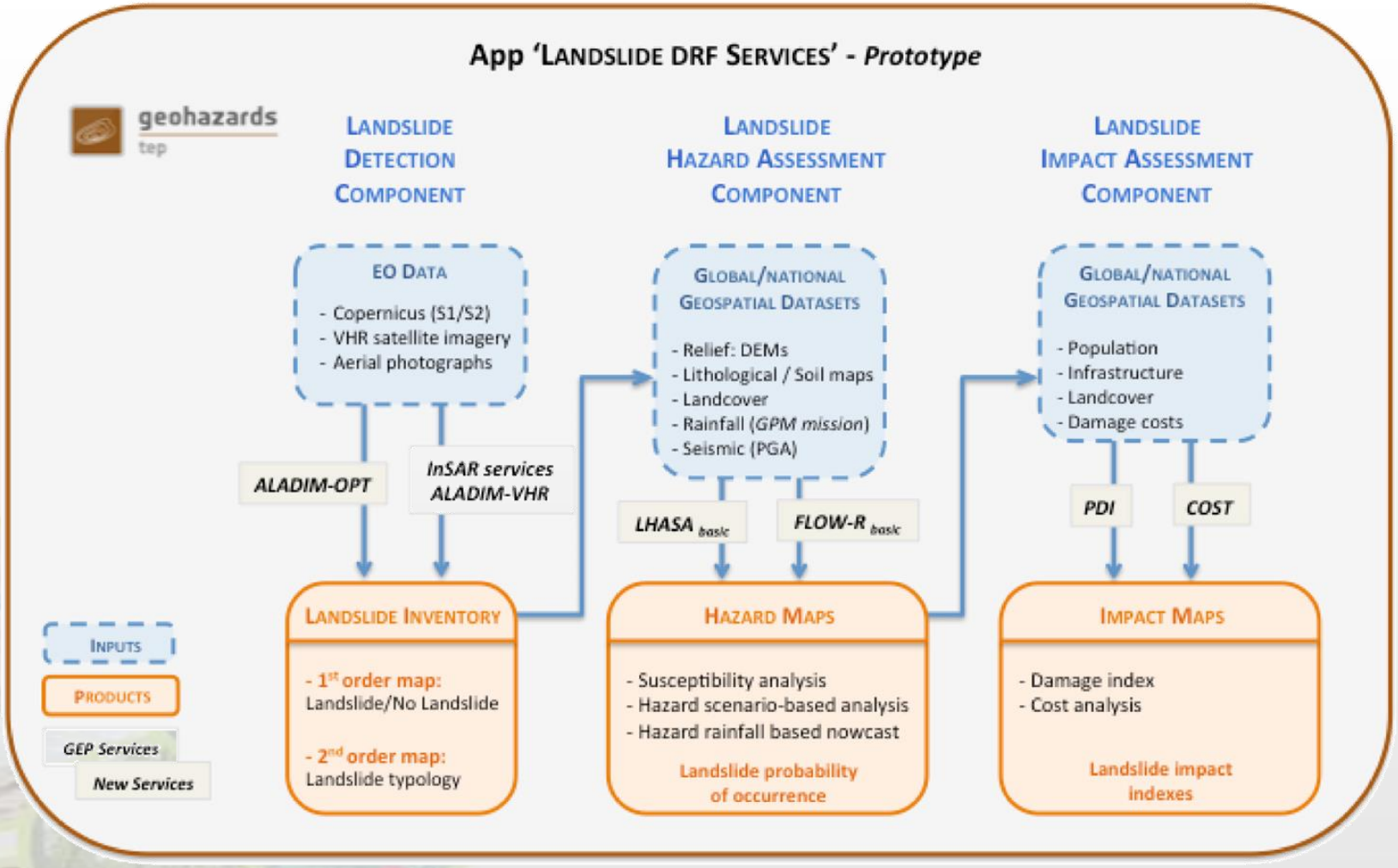
Use GEP infrastructure. Will base analyses on medium and VHR data (S2, Pléiades; S1, TSX).

Linking CNRS and NASA algorithms and models in a coherent system

- Engage with the stakeholders in Morocco (FSEC and to determine specific needs

Project to be started in October 2020

Landslide Demonstrator: Application 2



Outline of the LANDSLIDE DRF Information System to be deployed on GEP for NRT landslide product modelling

Landslide Demonstrator: Application 3

Application 3: Advancing EO-based landslide inventories for extreme forcing events (heavy rains, high-magnitude earthquakes)

The goal of this application is to coordinate and share methodologies for the establishment of landslide inventories acsross different geologic and morphologic zones. In this activity we will proose standard for creating and publishing EO-based landslides inventories, with the goal of develoing an online open system to share algorithms and inventories using SAR and optical methodologies. This work will be done in coordination with the newly formed LandAware consortium's Data Working Group, with EGS (EuroGeoSurveys) and with JRC

Methodologies

→ Inventories

- Methods to fuse InSAR-based inventories and optical-based inventories. Definition of quality criteria for validating EO-based inventory and store the information, data standards
- A system to store and disseminate the inventory on-line (including data from past events)

→ Models

Comparison and sharing of models that provide automatic mapping capabilities and calculation of advanced statistics from the EO database. Establish correlation with triggers (thresholds, scaling laws) for benchmark inventories.

Demonstrator Leads: Dalia Kirschbaum, Jean-Philippe Malet (CNRS/EOST) and Olivier Dewitte (RMCA, to be contacted).

Industry Participants: LandAware Consortium, World Landslide Forum, USGS, EuroGeoSurveys, JRC and other geological mapping agencies

Demonstrator Timeline

Writing of Demonstrator Proposal: End September 2020

- **Year 1 (January 2021 – December 2021):**
  - Definition of landslide services and products requirements for the three applications.
  - EO-satellite database creation for the geographical use cases.
  - Consolidation of resources (persons, data, IT processing).

- **Year 2 (January 2022 – December 2022):**
  - Demonstration of the landslide services for some use cases and reporting;
  - Concept of the prototype demonstration App on GEP for the three applications.

- **Year 3 (January 2023 – December 2023):**
  - Implementation of the prototype demonstration App on GEP for the three applications;
  - Training and dissemination on-line user-oriented material for the three applications.
  - Final Demonstrator reporting

Deliverables and Stakeholder Engagement

- **Key pilot outputs/deliverables:**
  - Guidelines of landslide services and products for transportation corridor monitoring from satellite imagery.
  - Guidelines of landslide services and products for risk financing products creation from satellite imagery.
  - Lessons-learned and sustainable plan for uptake of the Demonstrator outcomes for other users.
- **Stakeholder groups**
  - **Geological Surveys** and **Environmental Agencies** in charge of landslide DRM and tasked to operate landslide inventories and to provide hazard assessments at regional/national scales.
  - **Engineering Geology and Risk Analysis companies** which support local and regional authorities for the operational management of landslide risks, providing specialized consultancies in the geological, geomatics, geotechnical and civil engineering fields with the aim to provide to their end-users clients the necessary information for risk mitigation purposes;
  - **Governmental authorities** in charge of landslide risk management, which consist of administrations with several roles: public operators responsible for natural hazard regulation whose job is to prepare land-use regulatory documents, civil protection, relief and emergency services, whose job is to prepare contingency plans, c) public/private operators responsible for facility (building, critical infrastructure) planning and management whose task is to draft regulations/codes of practice for construction ensuring that adequate protection is provided at minimum cost.
  - **Insurance and re-insurance companies** in charge of disaster risk financing and developing risk models for landslide hazards

Demonstrator EO Data Requests

Requests

- [Application 1] and [Application 2]: archive and new regular acquisitions over relevant AOIs, time intervals and time period in Morocco [Application 1], and Swiss/Italy/France, UK/Scotland, Canada, and China (??) for [Application 2];

- [Application 3] access to archived and new acquisitions of pre/post disaster imagery at global scales for relevant landslide disaster. The team will define criteria to select landslide disaster to analyze for this application. If possible, the disaster might be similar to those used for response by the International Disaster Charter, the Copernicus EMS Rapid Mapping, the CNES CIEST2 Activation program, or any other relevant initiatives.

Requirements

- The EO satellite data must be provided both at **Level 1C and at Level "analysis ready" for optimal use** of the landslide processing services, and easy integration into user systems. The derived products will be designed with open standards to encourage transmission and sharing across organizations and regions. The EO data requirements include both archived and new image data from the satellite missions of CEOS member agencies (e.g., Radarsat-2 and RCM, COSMO-SkyMed, TerraSAR-X, TanDEM-X DSM, Landsat-8, Pléiades, SPOT-6/7, Sentinel-1 and 2, and others).

→ Landslide Demonstrator Leads will now engage (Sept. 2020) with space agencies to discuss their interest

Wrap-up

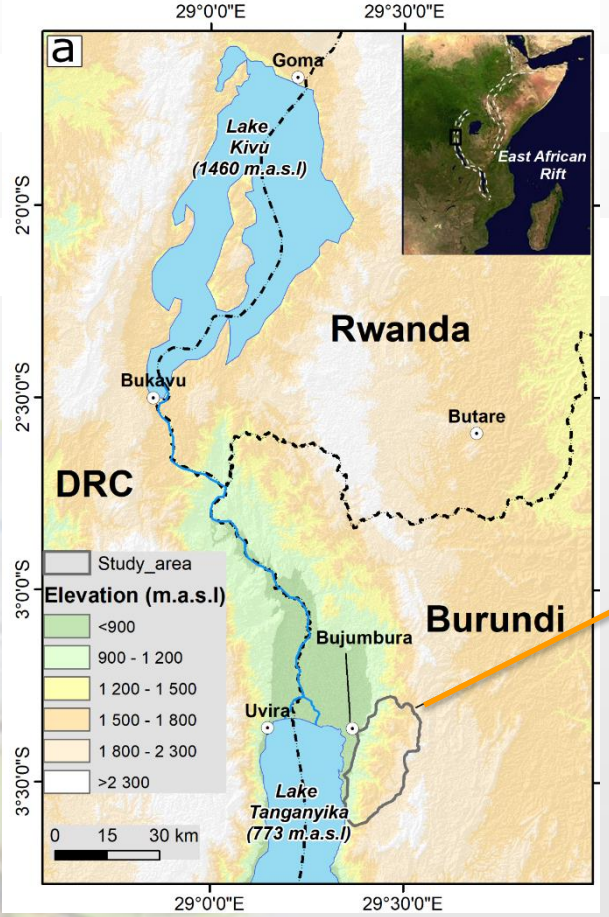
- **Achievements in the Pilot**
  - Case studies that demonstrate the following:
    - EO satellite data can effectively support the estimation of relevant landslide parameters (location, size, velocity, triggers) over large spatial domains;
    - the combination of Synthetic Aperture Radar (SAR), multispectral and microwave satellite data can improve classical landslide modelling approaches;
    - EO satellite data can provide first order estimates of landslide hazard where local ground-based observation capacity is limited, making it highly suitable for applications in developing countries.
- **Goals for the Demonstrator**
  - Demonstrate the usefulness of satellite data for *operational applications of landslide disaster risk management (DRM)* with the ultimate goal to increase resilience against landslide disasters.
    - Use EO data to engage the railway, transportation and pipeline sector on monitoring of hazards that may affect their operations and planning
    - Develop an operational platform to conduct and evaluate landslide risk financing products
    - Coordinate and expand the use of EO data for landslide inventory generation, particularly after major triggering events, create a repository for data and code sharing on this topic.

Extra Slides

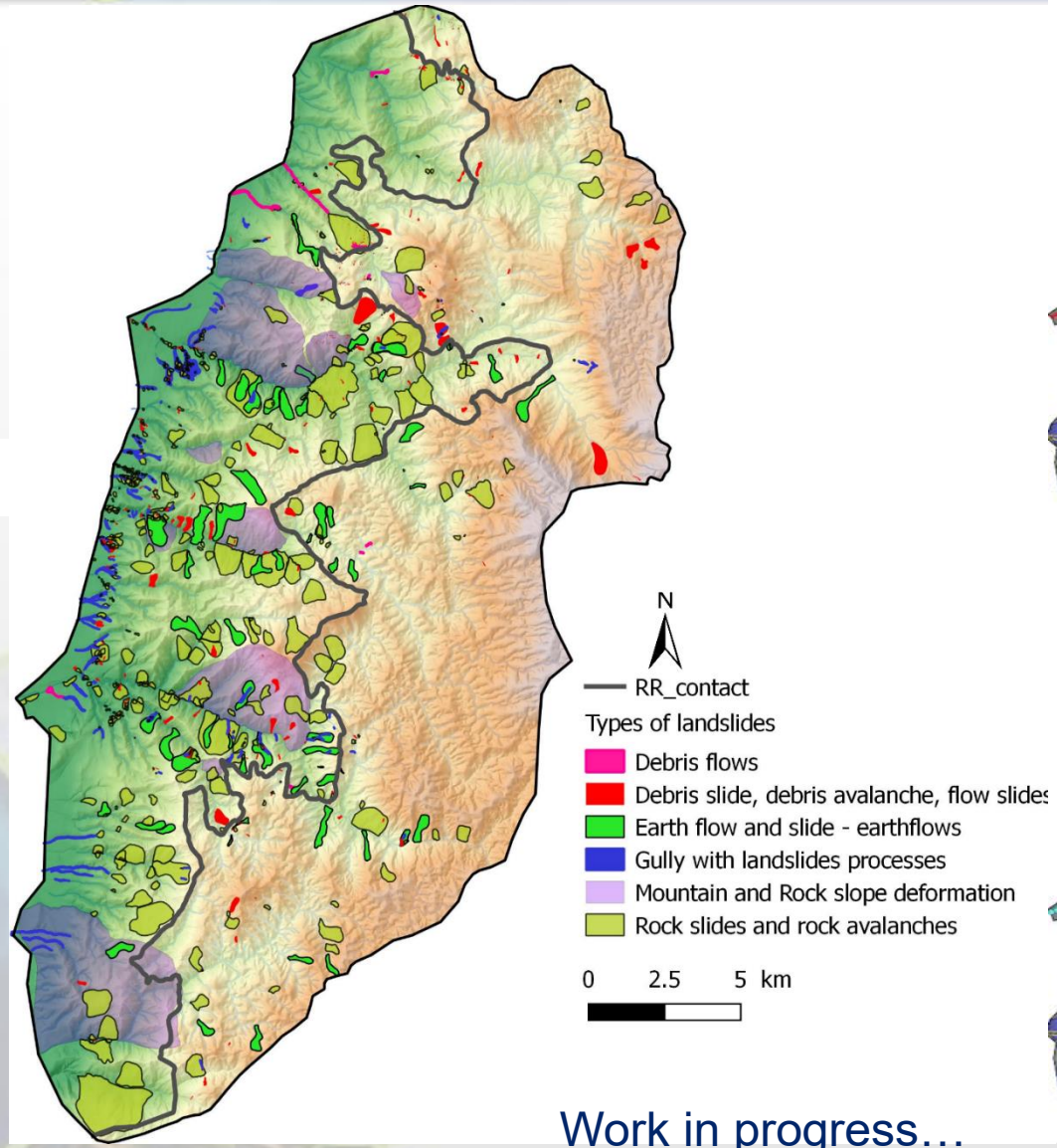
Landslide types, rates and controls in the populated hillslopes of the city of Bujumbura (Burundi) – first step: landslide inventory

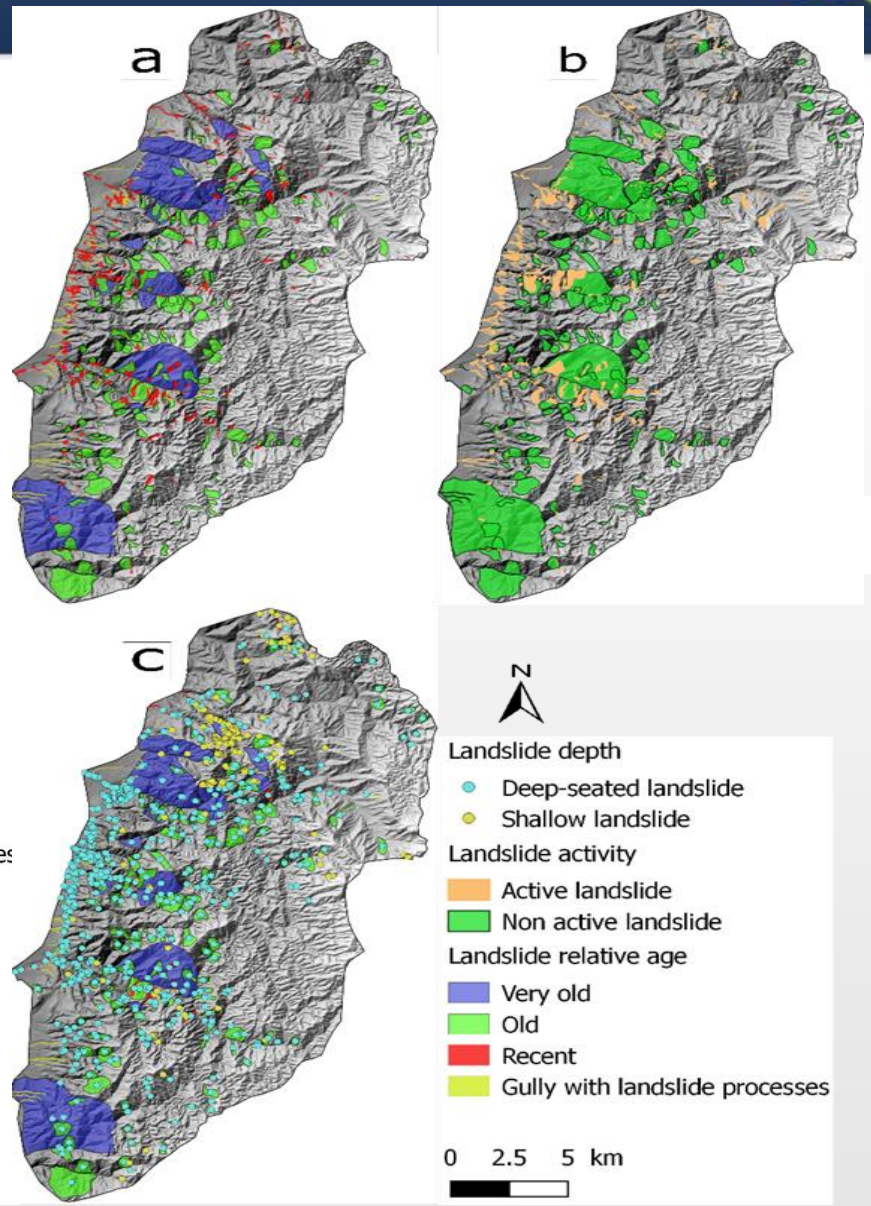
Data: Historical aerial photos, Pléiades Tri-Stereo DEM, Google Earth. 70 year time series

Method: Photogrammetry, visual analysis, field investigation



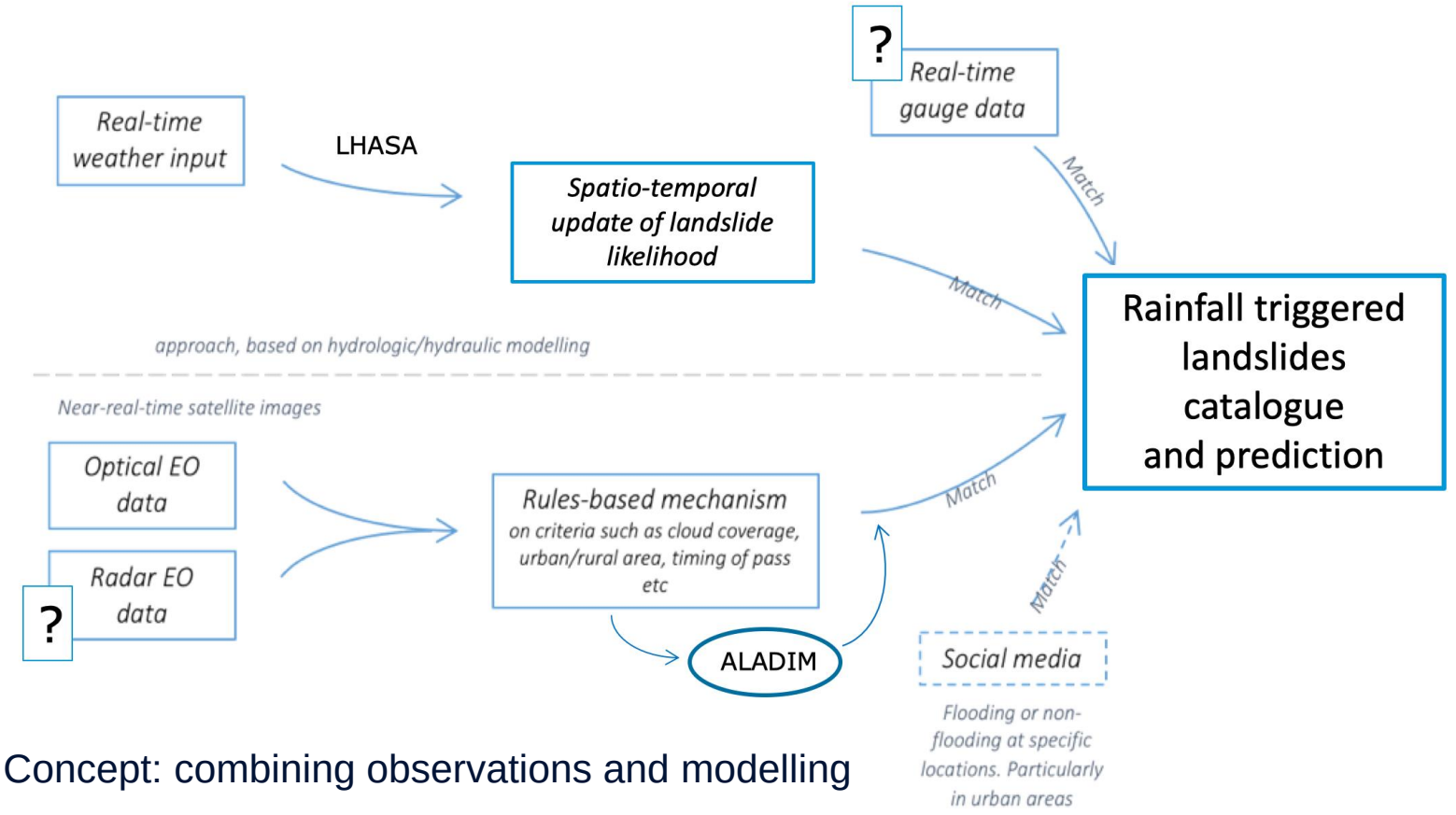
Landslide types, rates and controls in the populated hillslopes of the city of Bujumbura (Burundi) - first step: landslide inventory



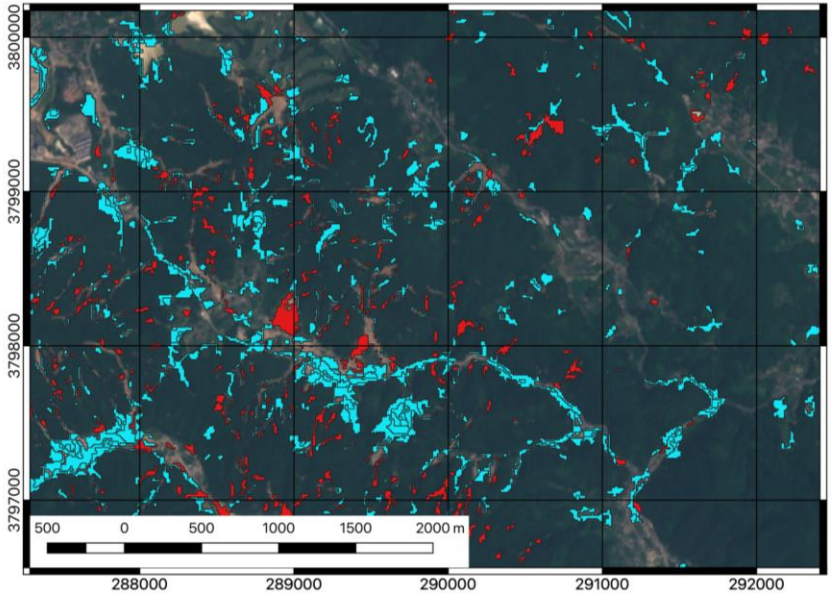


Work in progress…

LANDSLIDE DEMONSTRATOR

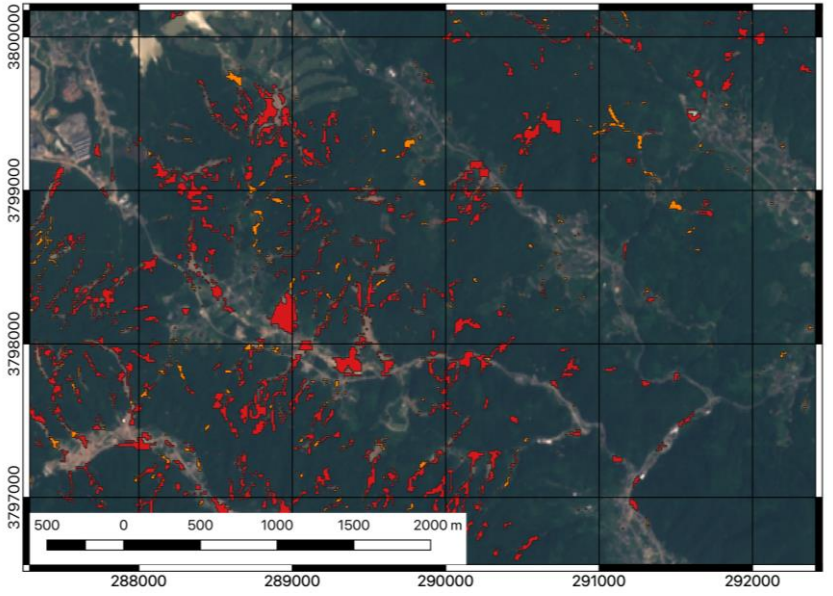


Concept: combining observations and modelling



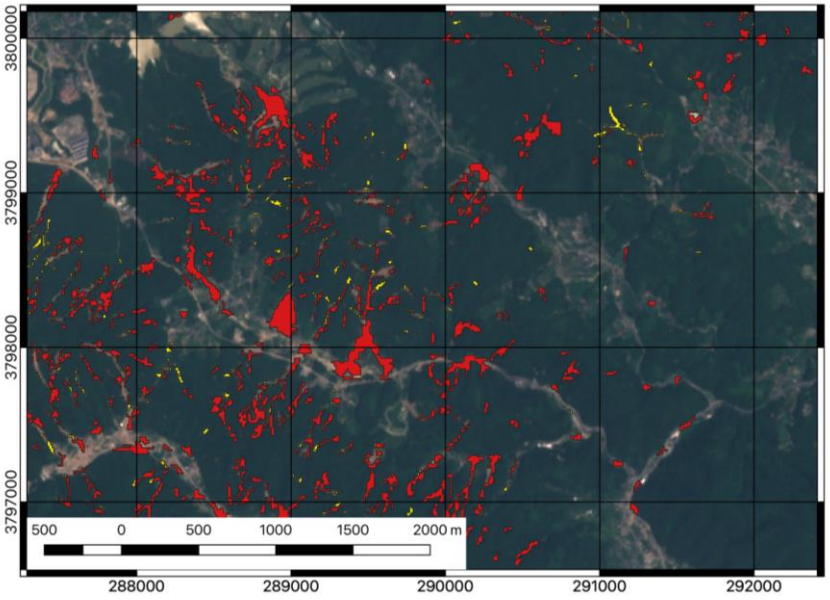
In ALADIM & not in Salad

In Salad & not in ALADIM



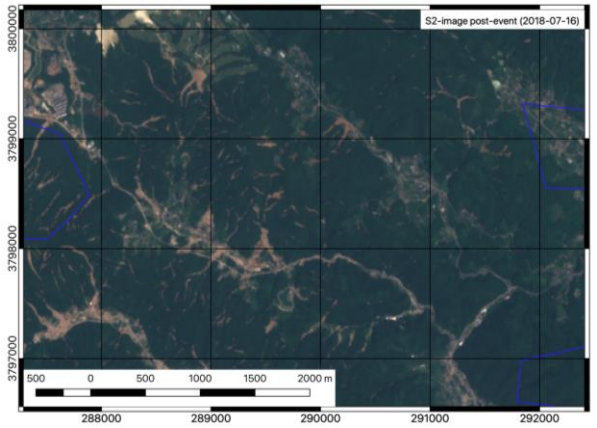
In ImCLASS-mono & not in Salad

In Salad & not in ImCLASS-mono



In ImCLASS-bi & not in Salad

In Salad & not in ImCLASS-bi



Landslide Demonstrator

Policy cover

Design of the insurance for the clients' needs.

Assessment

Create a **reliable index** on which to trigger the policy.
Based on historical data.

Recovery

Pre-agreed payment structure: triggered based on event parameter

Monitoring/Triggering

Monitoring of the parameter and automatic or semi-automatic triggering of the payment

Payment