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O4.306: Impacts of heavy rainfall of July 2017 in mountainous watersheds in northern Kyûshû (Japan) on structural and process-based sediment connectivity

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How did the extreme event of 5-6 July 2017 influence the connectivity of these mountain watersheds?

Methods & data

Litterature review

- **Scientific papers**
- **Government and public sources** (reports, GIS/statistical data, photo/videos, etc.)
- **Technical sources** (geological and geotechnical investigation reports, etc.)
- **Private sources** (Photo et vidéo)

GIS / Remote sensing

- Multi-source photo-interpretation of landscape dynamics
- Validation of the landslides and flood areas mapping (GSI)
- Mapping of the Sabo system structures

Fieldwork (2022/2023/2024)

- **Observation of landslide areas**
- Confirmation of **Sabo dams inventory**
- **Geomorphological mapping**

Results

Monitoring of landscape changes

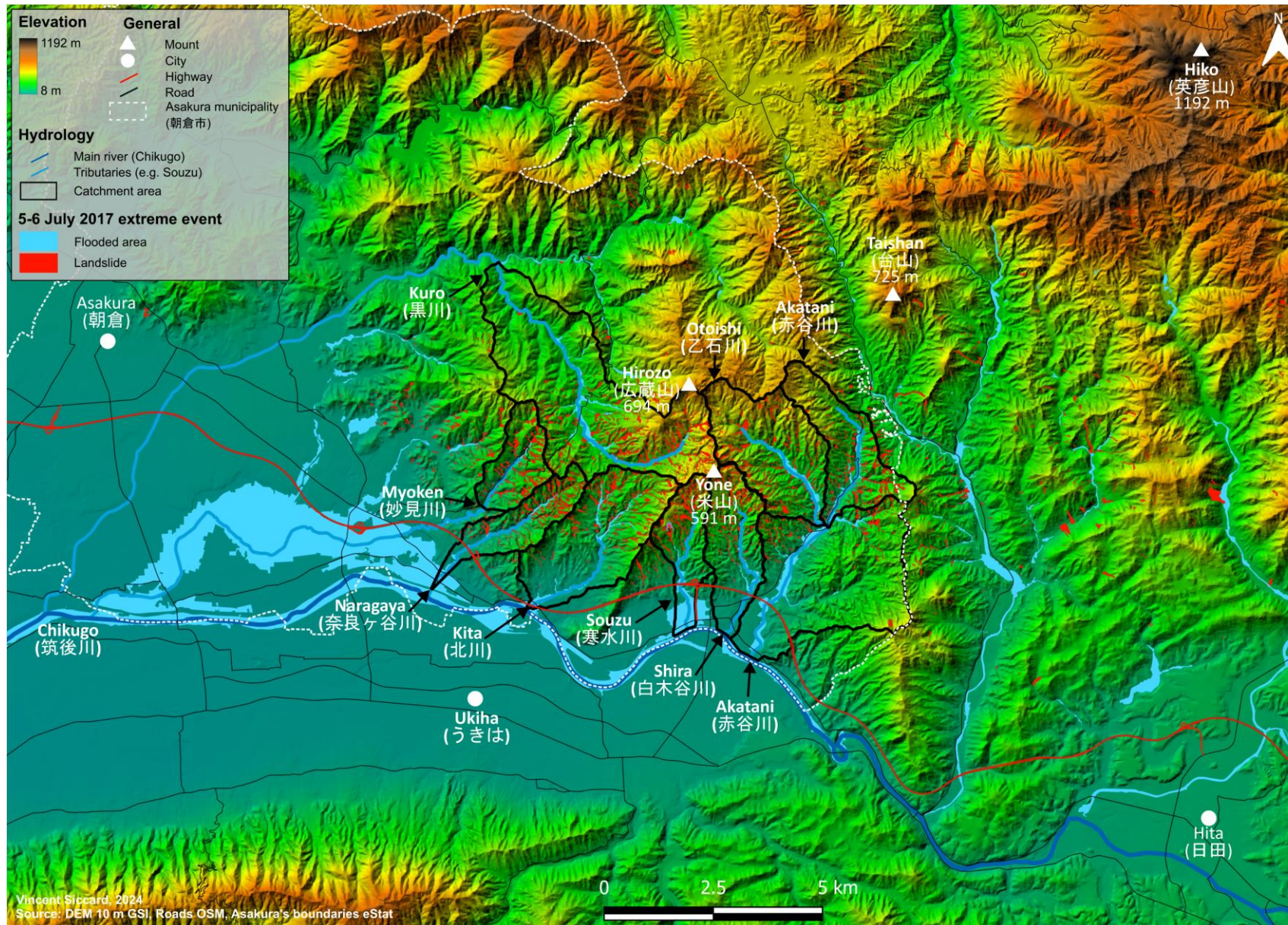
Inventory and typology of human-made structures

Presentation

1 Landscape metamorphosis

2 Erosion control with the Sabo system

3 *Post-event landscape dynamics*



General context:

- Chikugo watershed
 - Low mountains ($\approx 600\text{m}$); Steep slopes
 - Small size watershed ($< 5\text{km}^2$)
 - Rainy season from late may to september
- ⇒ **Rapid hydrological response**

July 2017 heavy rainfall:

- More frequent and intense heavy rainfall in a context of climate change
 - Cumulative rainfall between 600 and 800 mm over the event (4 to 7 July 2017).
 - **Asakura: 2 records** (Jiban, 2017)
 - Daily maximum = 516 mm
 - Hourly maximum = 129.5 mm
 - **Maximum cumulative rainfall over 3 hours: 281 mm.**
- ⇒ Hundreds of landslide triggered; floods and **42 victims**

Landslides concentration where 12-hour rainfall exceeds **400 mm** (MLIT, 2020).

Low Frequency / High Magnitude (LFHM) event. Estimated **probability of occurrence** greater than **1/200**. (Dumont et al., 2023 ; MLIT, 2017)

Deep landslide (>10m) in headwater with deeply weathered granodiorite and schist. (Jiban, 2017)

Large amount of Landslide deposit remain on site. (Jiban, 2017)



Significant landscape changes

Souzu watershed (2,8 km²): 1 victim

Before 2017 :

- **Landslide area = 0,08%** of the watershed

After July 2017 event:

- **Landslide area = 10,5 %** (294 725 m²)
- Flooded area = 17%

⇒ **Geomorphological changes** represent **28 %** of the watershed

Shira watershed (3,9 km²): 1 victim

Before 2017 :

- **Landslide area = 0,05%**

After July 2017 event:

- **Landslide area = 7,3 %** (284 576 m²)
- Flooded area = 4,7% contained by topography

⇒ **Geomorphological changes** represent **12 %** of the watershed

⇒ Fluvial metamorphosis (Chorley & Kennedy, 1971)

Before July 2017



After July 2017



Vincent Sicard, 2024
Source: Copernicus Post-2017, M.I.T., GSI.

Landscape metamorphosis caused by a wide range of hydro-gravitational processes

- Mostly Shallow landslides (0.5m to 2m); Few deeper landslide ; 2 Mega landslide (> 300k cubic meters)

⇒ Cascading effect / bank erosion and scouring

⇒ **Hundreds of sediment sources suddenly opened => sedimentary pulsation**

Sediment production at regional scale (MLIT, 2020):

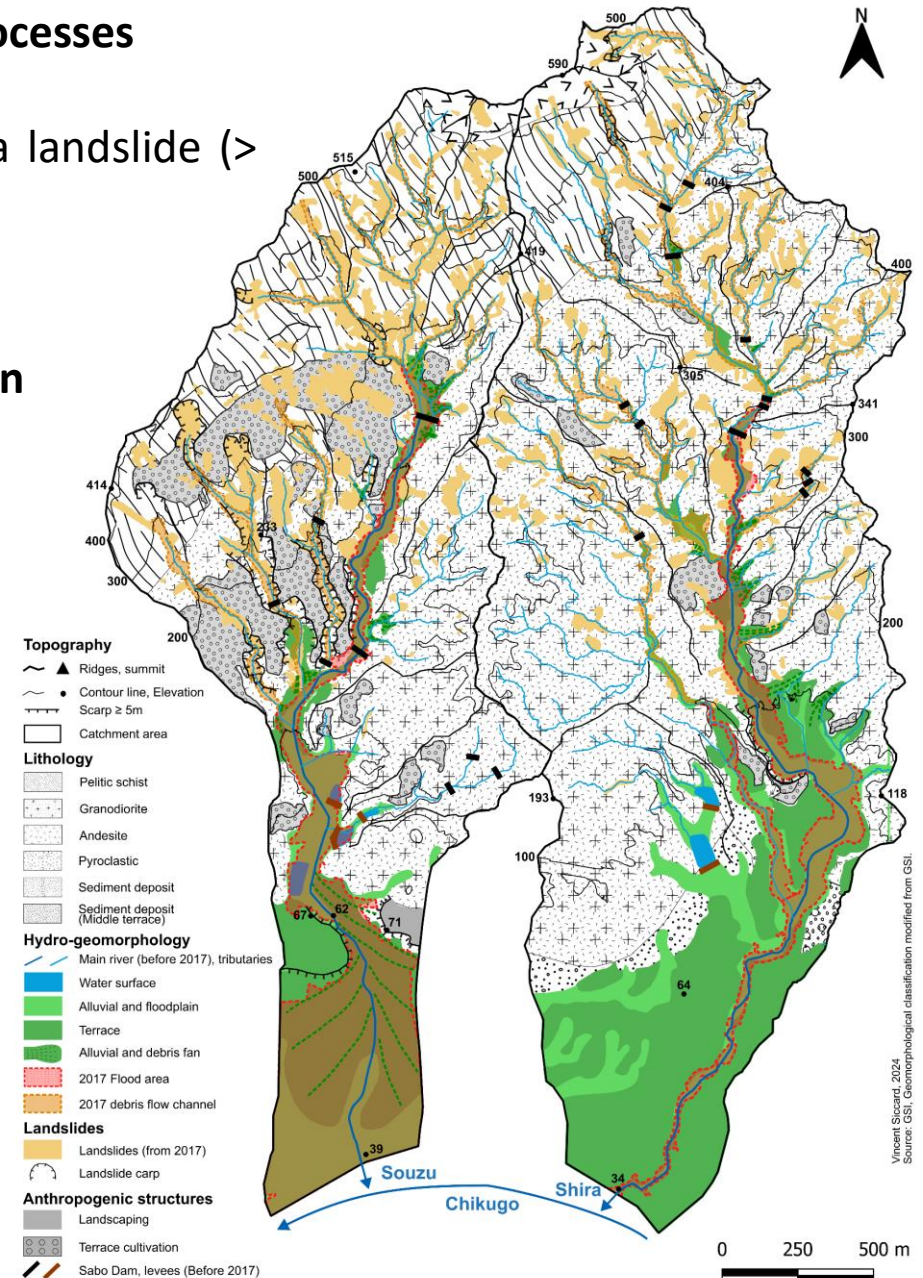
- Landslide area = 4.44 km²
- **Sediment production > 10 000 000 m³ => 2.25 m³ / m²**
- **Sediment discharge into Chikugo ≈ 2 000 000 m³**

Souzu watershed sediment production:

- ≈ 550 000 m³ (MLIT, 2020)
- ≈ 503 000 m³ (GIS estimation based on area and average depth of 1.5 m for shallow to 5 m for deeper landslide)

Shira watershed sediment production:

- ≈ 590 000 m³ (MLIT, 2020)
- ≈ 595 000 m³ (GIS estimation based on area and average depth of 2 m for shallow to 5 m for deeper landslide)



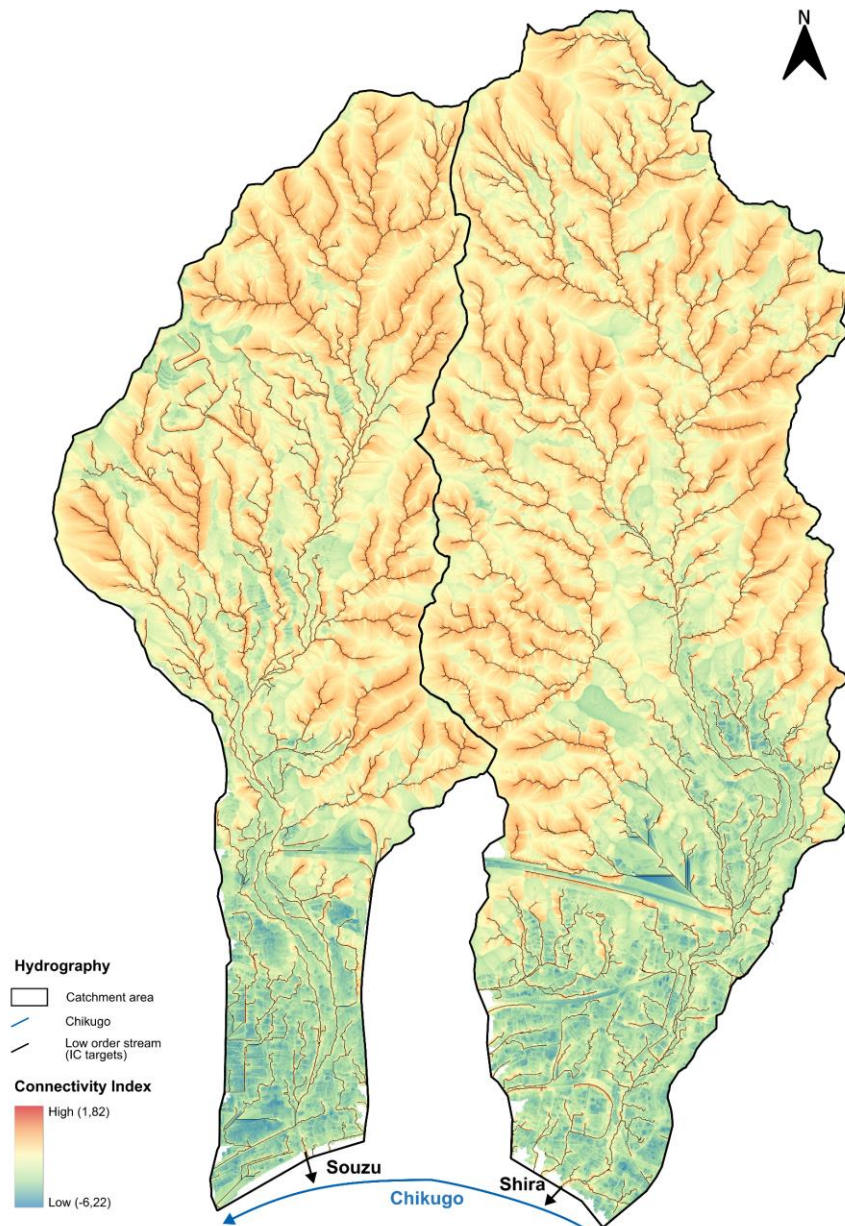
What about connectivity?

Structural connectivity:

- **Connectivity Index** with low order streams as targets (Cavalli et al., 2013)
- => **High lateral hillslope-channel connectivity** especially in low order catchment

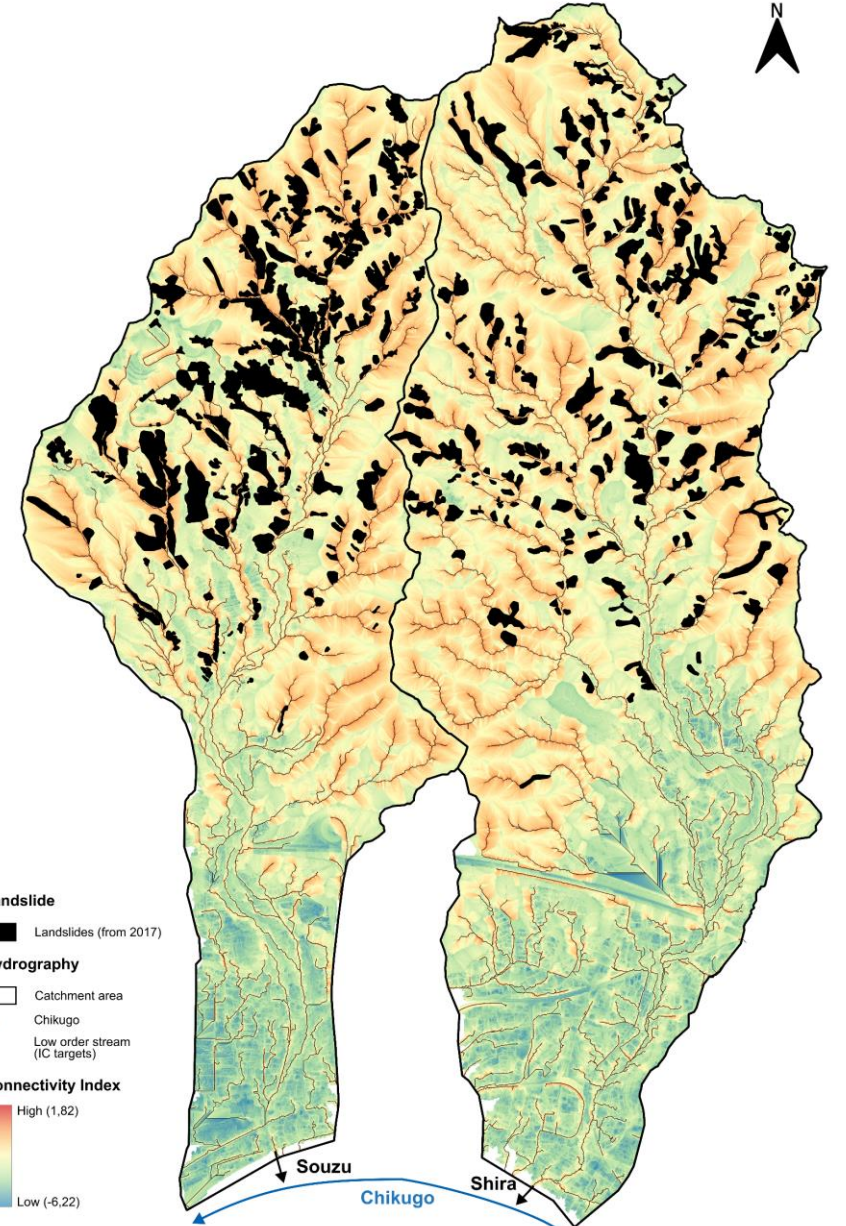
Process-based connectivity:

- **Cascading effect** => landslide to debris flow with bank erosion
- Mass movements concomitant with high energy sediment-water flow and debris flow
- Shallow landslide (low volume per landslide)
- Grain size



Vincent Sicard, 2024
Source: DEM 1m from MLIT

0 250 500 m



Vincent Sicard, 2024
Source: DEM 1m from MLIT

0 250 500 m

Concomitant sediment production from the slopes and high transport capacity

=> Flood and valley filling over 1-3 meters in Souzu watershed



High responsiveness and intervention post-event trough engineering

Sabo system: refers to the **system of countermeasures** designed to **manage erosion** and the **spread of sediment** from the **slopes** to the **river** and its outlet. It uses a wide range of management, prevention and warning methods. (Dumont et al., 2023 ; MLIT, 2009 ; Augendre, 2008)

=> **Modification of the sediment cascade, the structural and process-based connectivity**

Open Sabo dam: steel frame structure dam



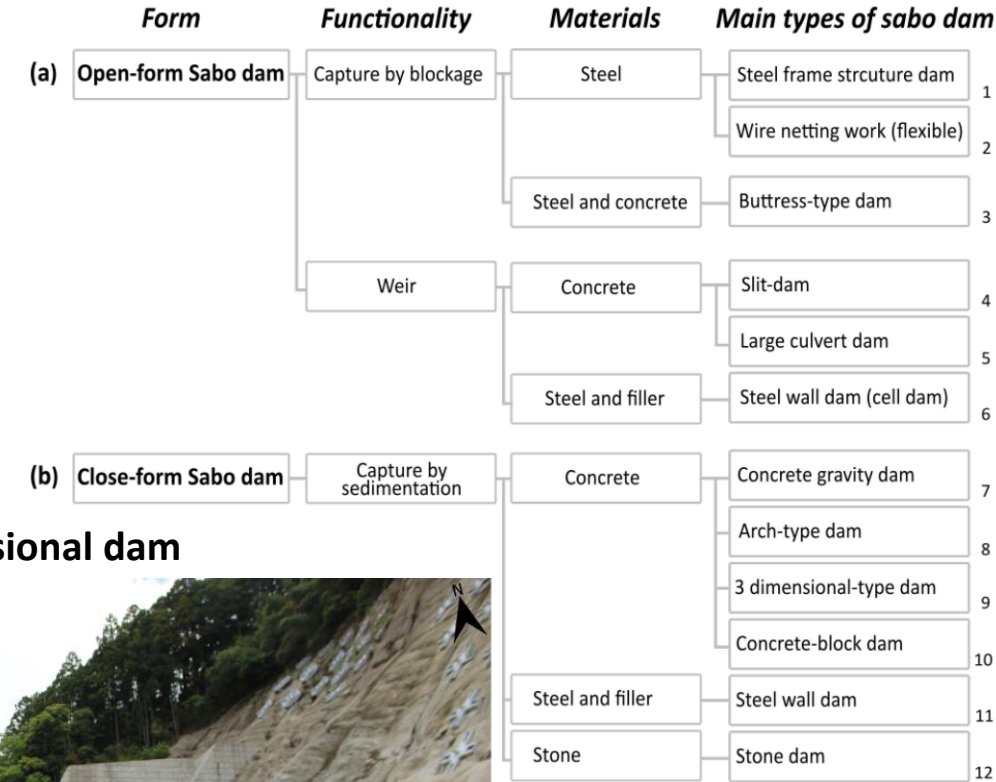
© V. Siccard, 2023

Close Sabo dam: 3 dimensional dam



© V. Siccard, 2023

Classification of Sabo dams according to the MLIT (Dumont et al., 2023)



Soft engineering

Medium engineering

Hard engineering

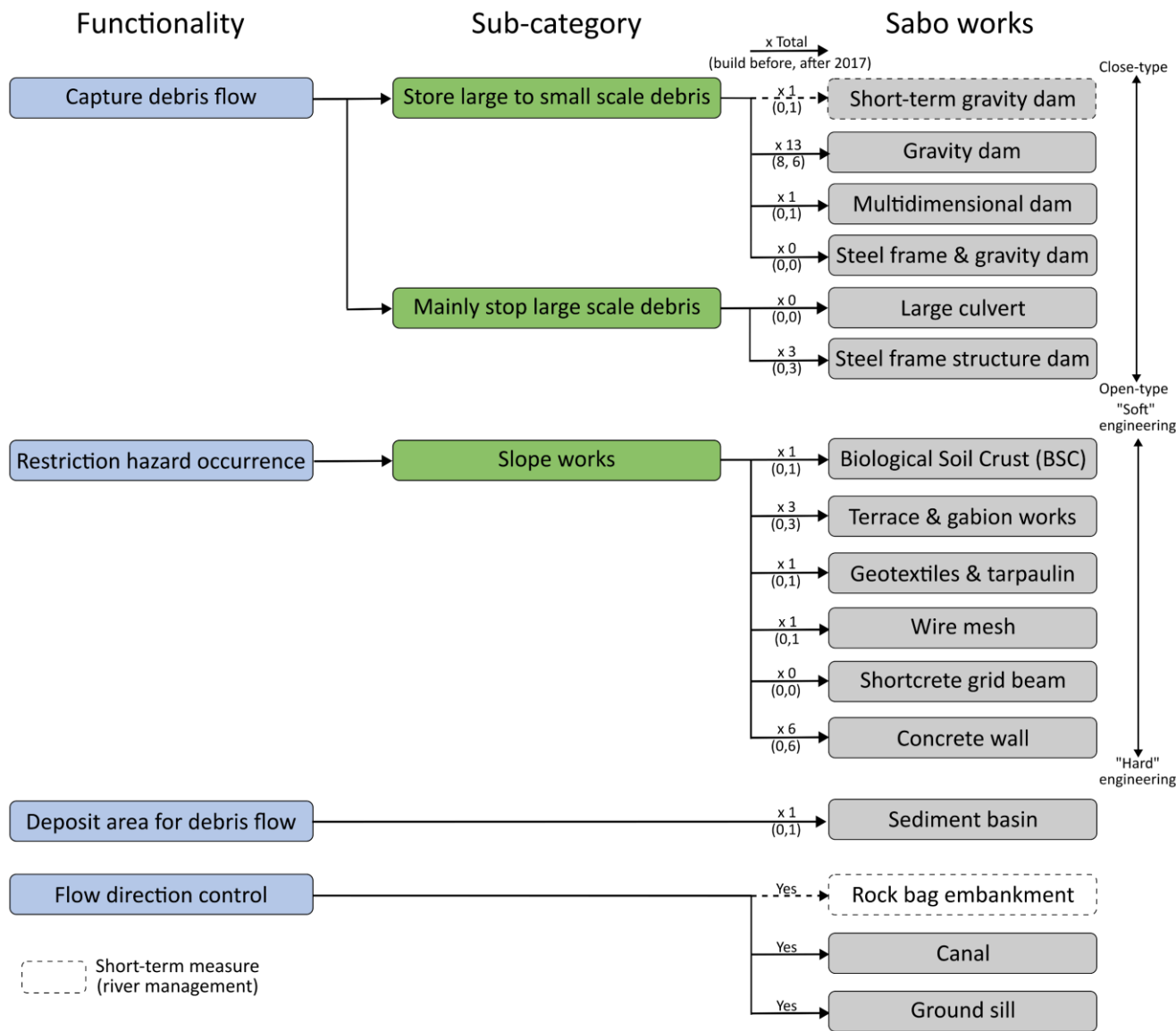


A wide range of slope works from soft to hard engineering:

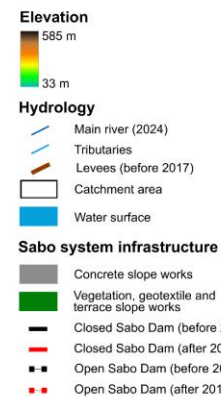
- Vegetation and Biological Soil Crust (BSC)
- Geotextile and Tarpaulin
- Terrace and gabion work
- Wire mesh
- Shortcrete grid beam
- Concrete cover
- Concrete cover with anchor and soil nailing



Sabo system in Souzu watershed: 11 dams built after 2017 (8 before) = massive response with engineering

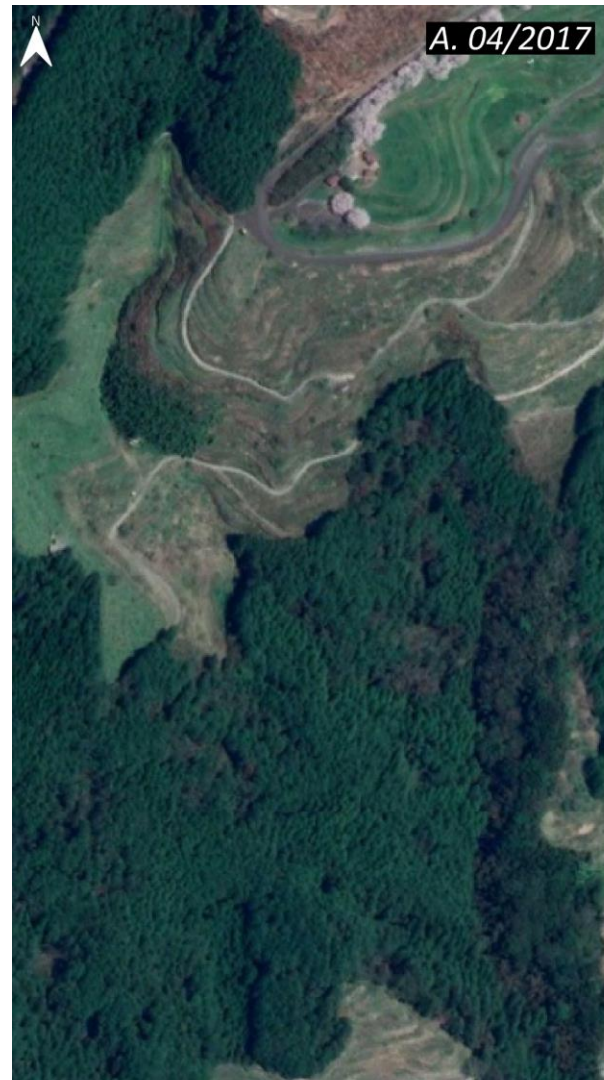


Souzu



Post-event landscape dynamics: radical change and rapid evolution once the breach has been open

=> Increased sensibility to lower magnitude event and runoff



A. 04/2017



B. 09/2017



C. 05/2023



D. 04/2024

0 50 100 m Source: Google Earth

0 50 100 m Source: GSI, MLIT

0 50 100 m Source: Google Earth

0 50 100 m Source: Pléiades © CNES 2024 (Distribution Airbus DS)

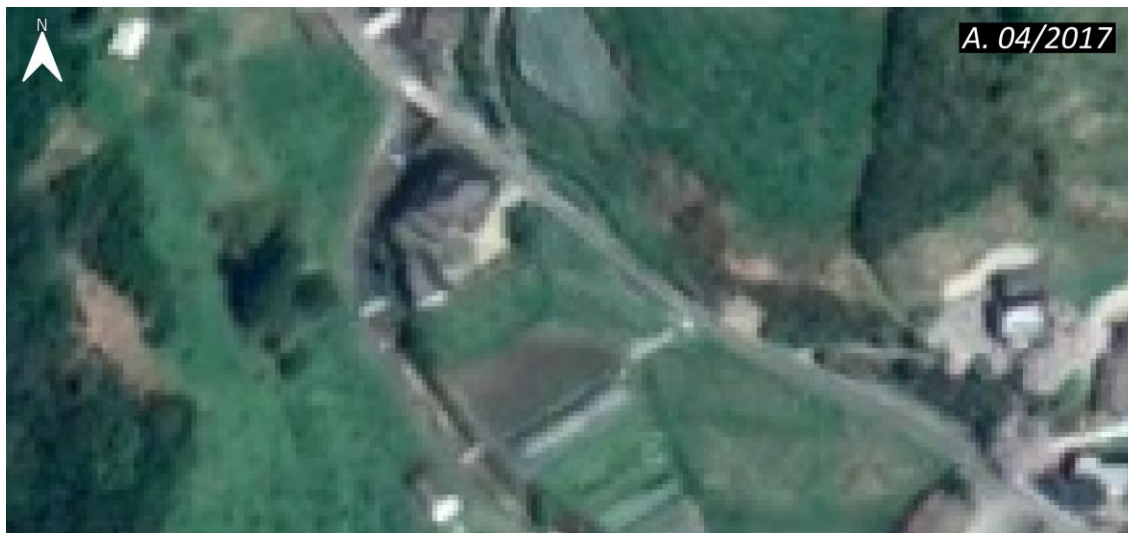
Steel frame structure dam filled after the heavy rainfall of 2023:



2023 heavy rainfall during rainy season:

- Section of approx. 150 m ; 3500 m² filled; 5 m height
- Thousands of cubic meters of sediment
- Probably more than 10 000-15 000 cubic meters

Slope works changes in reaction to the 2023 heavy rainfall:



A. 04/2017

Source: Google Earth



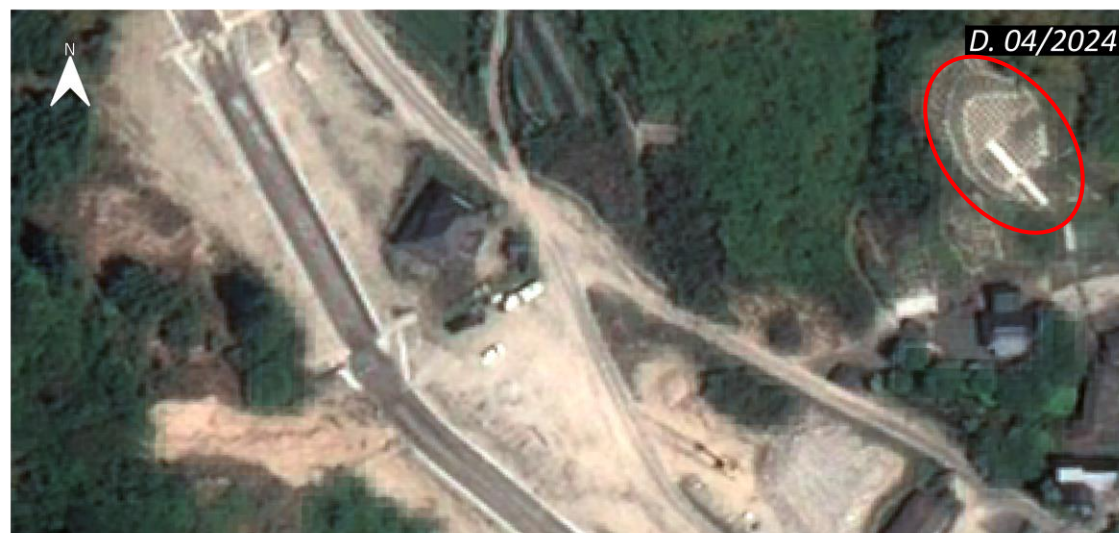
B. 09/2017

Source: GSI, MLIT



C. 05/2023

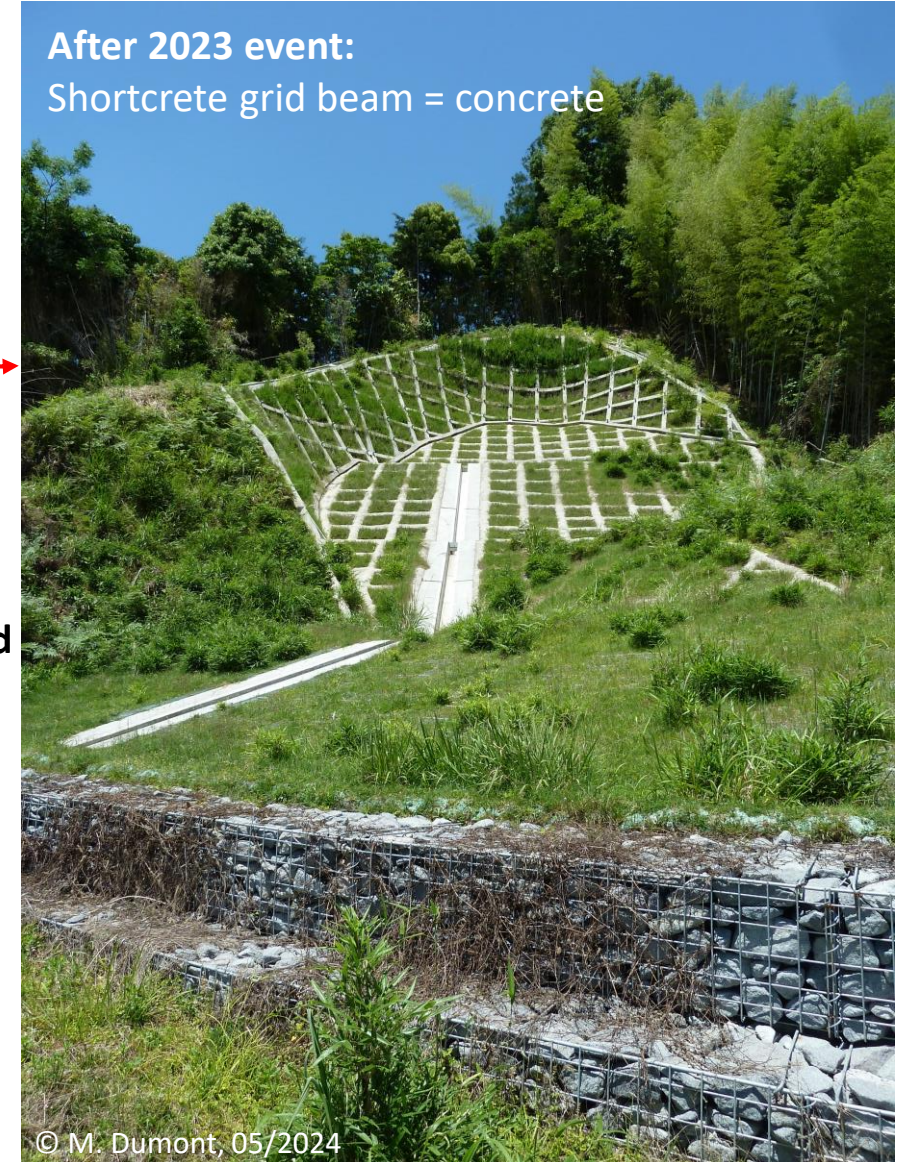
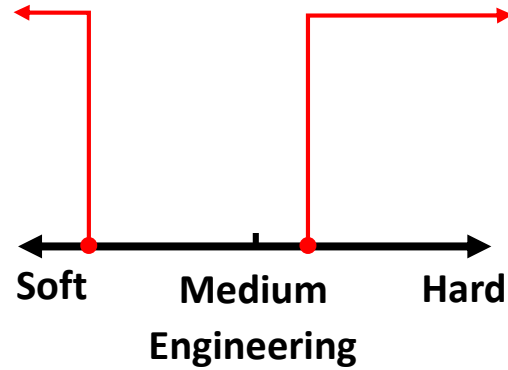
Source: Google Earth



D. 04/2024

Source: Pléiades © CNES 2024
(Distribution Airbus DS)

Different reactions from the slope works to the 2023 event



Mountains and heavy rainfall in climate change context

- Significant landscape changes due to hydro-gravitational processes and increased sensitivity to lower magnitude event
- Increase of extreme heavy rainfall in climate change context
- High structural and process-based connectivity

Sabo system for erosion control from hillslope to river

- High responsiveness and intervention
- Broad spectrum of slope stability and river technics and management; efficient but not foolproof
- High connectivity modification

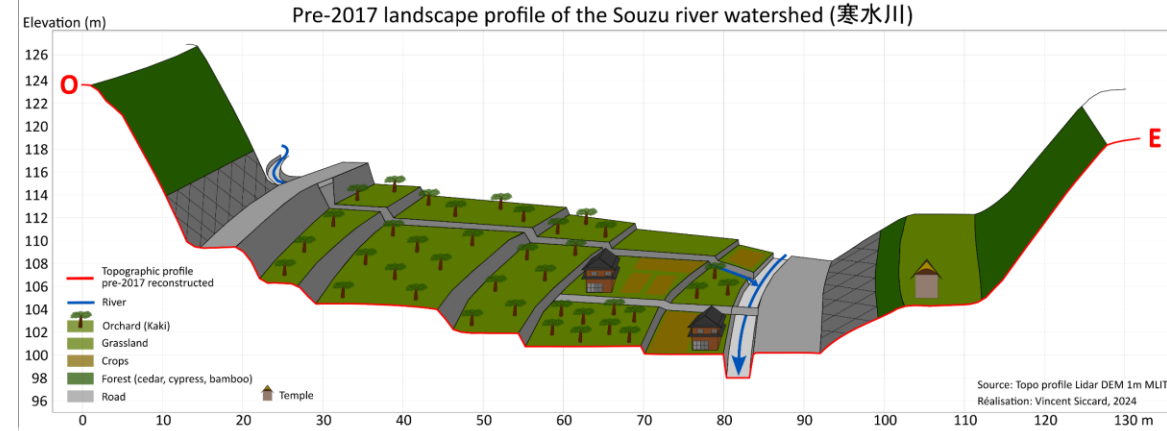
High modification of Satoyama* landscape post-event :

- (Hydro)-Geomorphological metamorphosis
 - Human intervention through the Sabo system
- ⇒ **New equilibrium, landscape metamorphosis.**

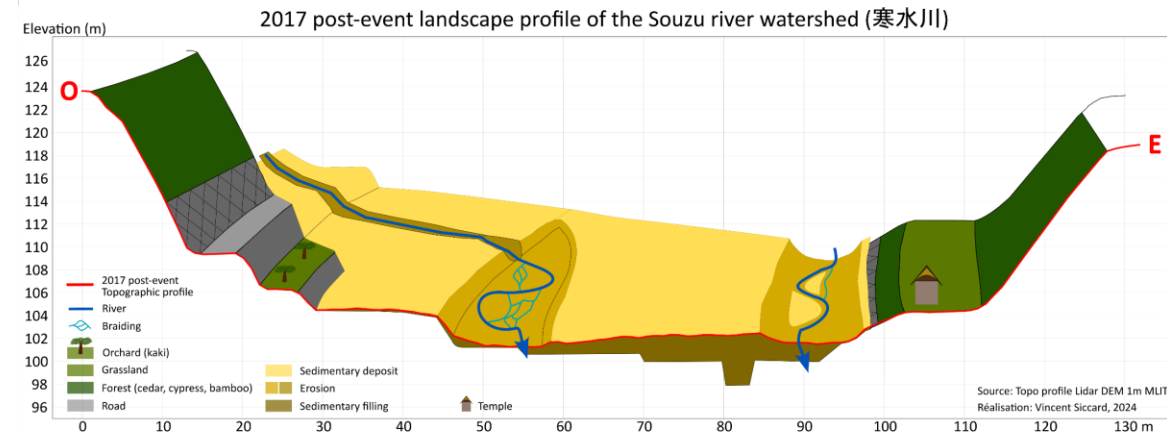
**Satoyama* (里山) : the village near the mountain (Dumont et al., 2023)

⇒ Socio-ecological system (Indrawan et al., 2014); Agroforestry practices and spatial organization; Management by local population

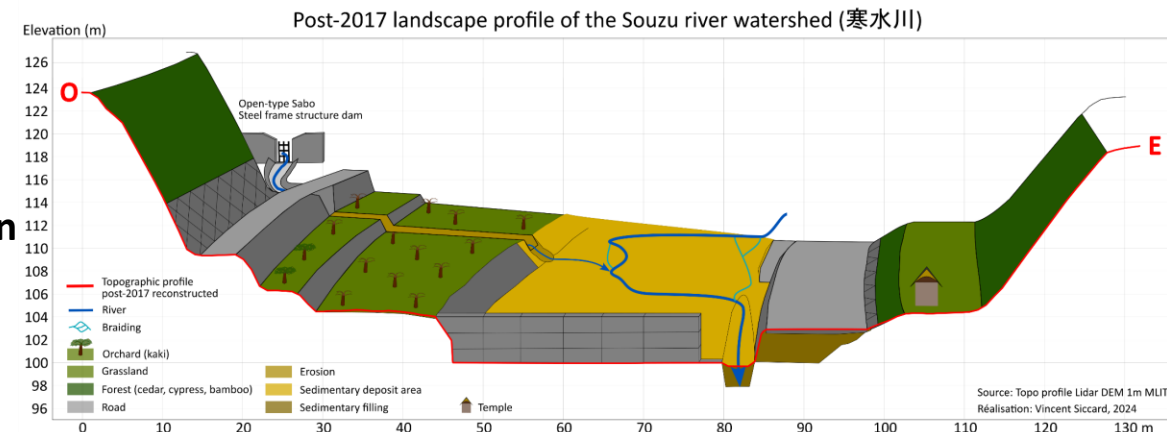
Before 2017



2017 post-event



Post 2017 reconstruction





Thank you!

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