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EGU25-12564: Landscape coevolution of human-geomorphic system in northern Kyûshû (Japan) induced by the July 2017 heavy rainfall

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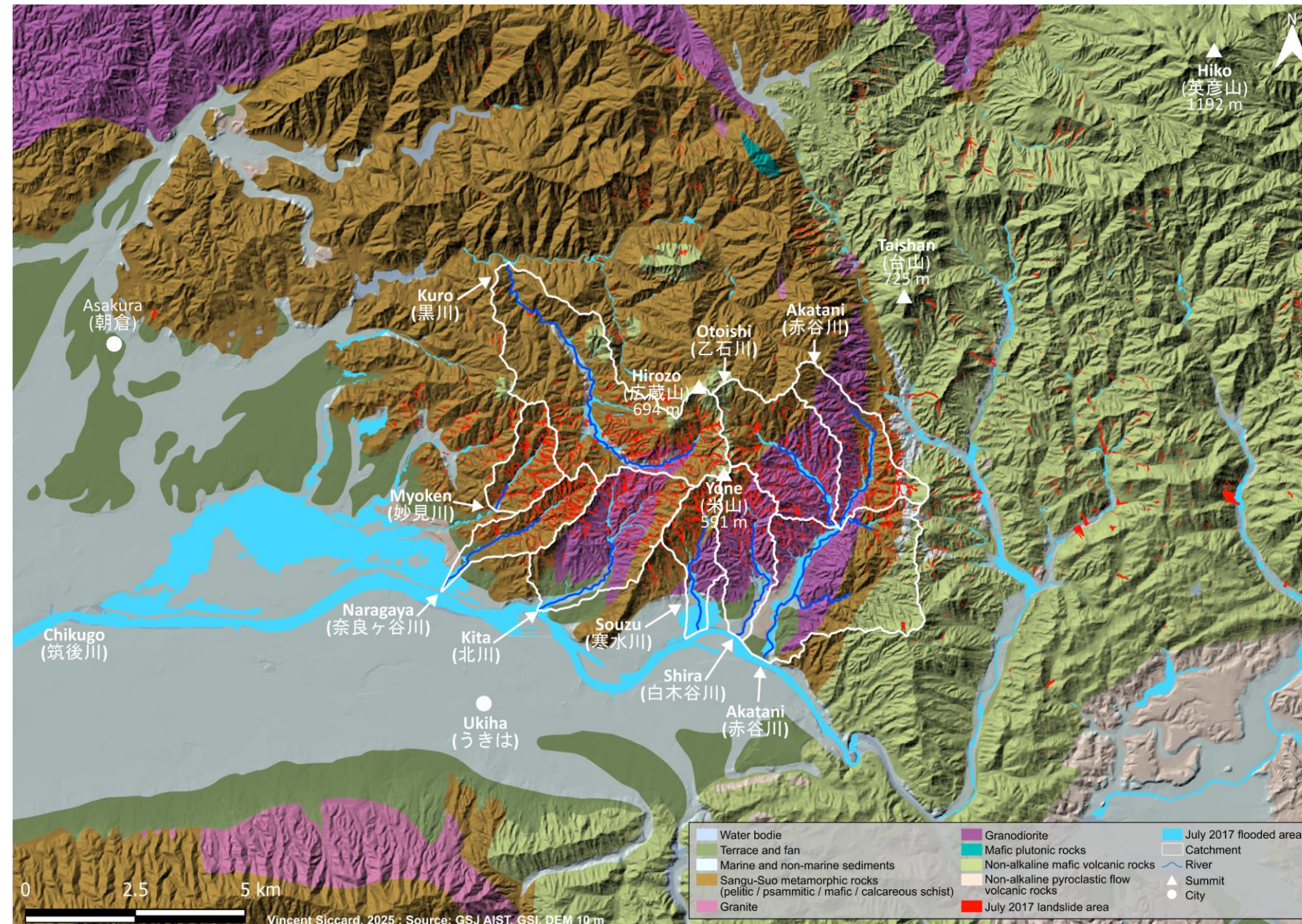
Gilles Arnaud-Fassetta, *Université Paris Cité, PRODIG UMR 8586 (France)*



Location :

- Northern Kyûshû (South Japan)
- Municipality of Asakura
- Chikugo watershed
- Souzu and Shira subcatchments





Topography:

- Low mountain area
- Small size watershed (< 4 km²)

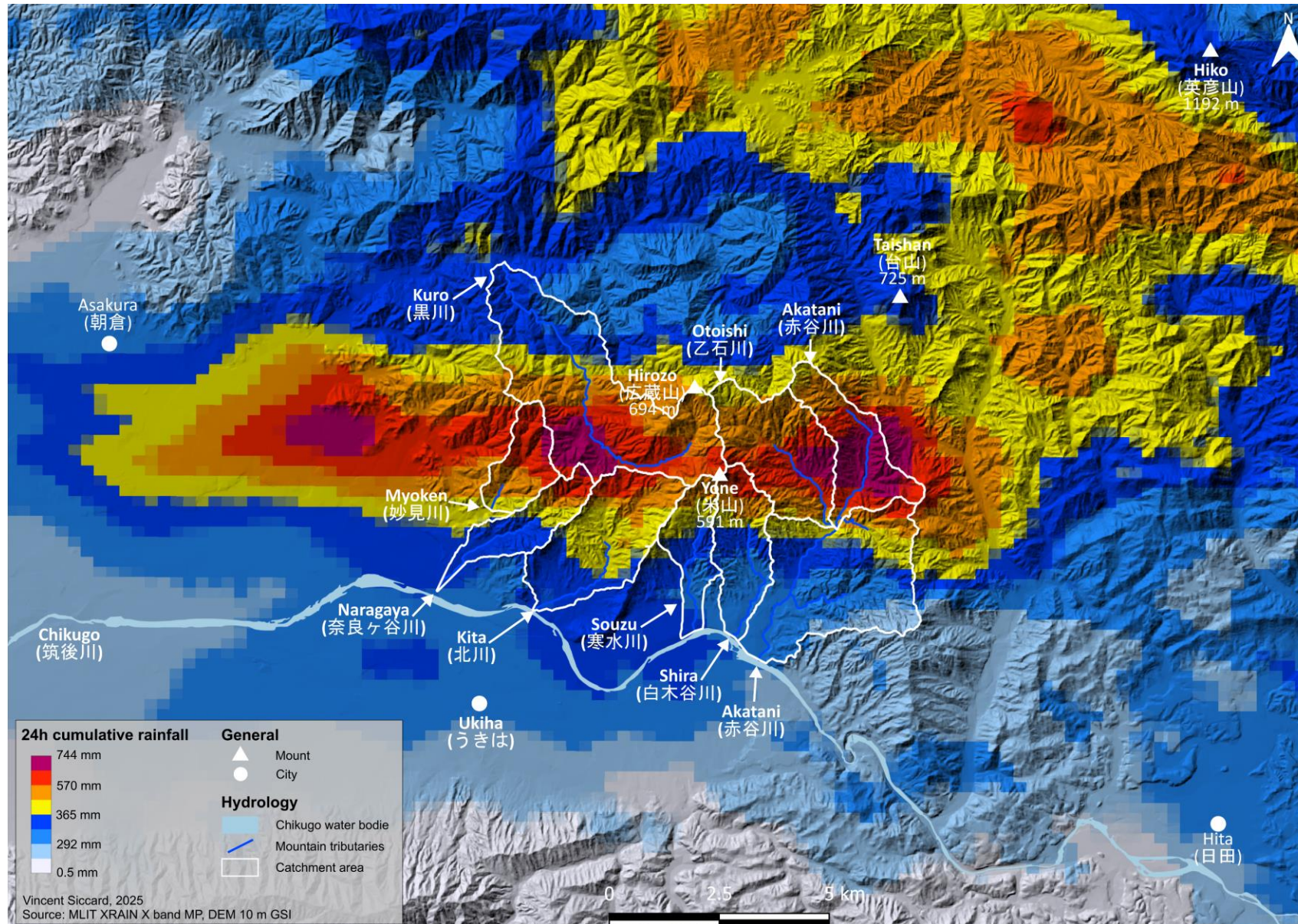
Study area geology:

- **Sangu-Suo Metamorphic rocks (schist)**
 - Souzu = 56%
 - Shira = 13%
- **Granodiorite**
 - Souzu = 27%
 - Shira = 65%

Regional geological setting:

- Non-alkaline mafic volcanic rocks (30%)
- Sangu-Suo Metamorphic rocks (Schist = 26%)
- Marine and non-marine sediments (22%)
- Terrace and fan (7%)
- Granodiorite (7%)
- Non-alkaline pyroclastic flow volcanic rocks (5%)
- Granite (1,5%)

1.1) Localized heavy rainfall



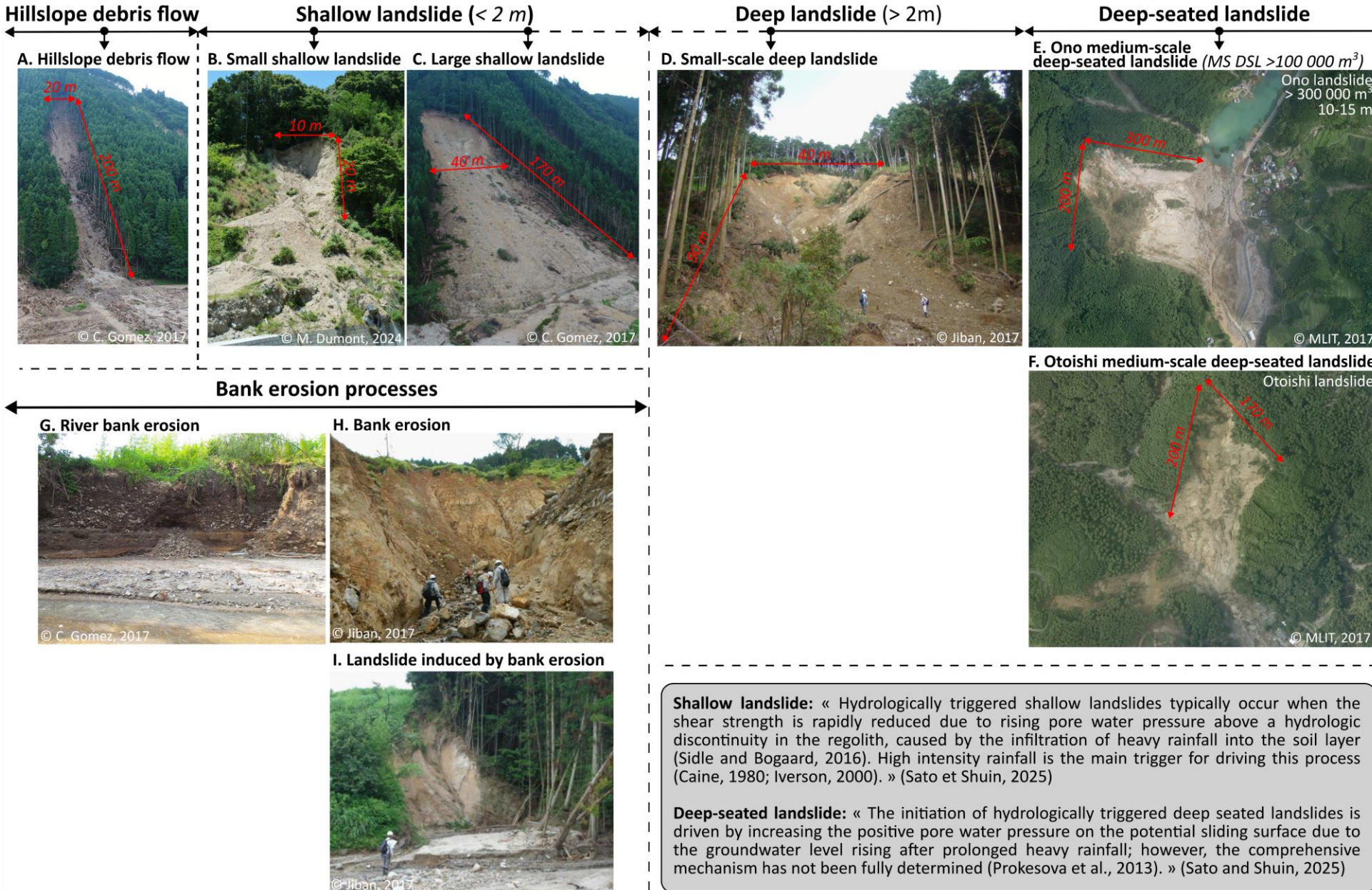
5-6 July 2017 :

- Stationary front during the rainy season
- **Asakura's station in lowland: 24h cumulative rainfall: 516 mm; 1h rainfall intensity 129.5 mm/h**
- Hundreds of landslides
- 42 casualties
- More frequent and intense heavy rainfall in a climate change context (MEXT et JMA, 2020 ; MLIT, 2020)

Estimated probability of occurrence greater than **1/200**. (Dumont et al., 2023 ; MLIT, 2017)

- **Low Frequency / High Magnitude (LFHM) event.**

1.2) Hundreds of landslides triggered



Mostly Shallow landslide

Few deeper landslide often in headwater with deeply weathered granodiorite and schist. (Jiban, 2017)

2 deep-seated landslide

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

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

⇒ Cascading effect / bank erosion and scouring

⇒ **Hundreds of sediment sources suddenly opened**

⇒ **Sedimentary pulsation**

2.1) Significant landscape changes

Souzu watershed (2,8 km²): 1 casualty

Before 2017 :

- Landslide area = 0,08% of the watershed

After July 2017 event:

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

Shira watershed (3,9 km²): 1 casualty

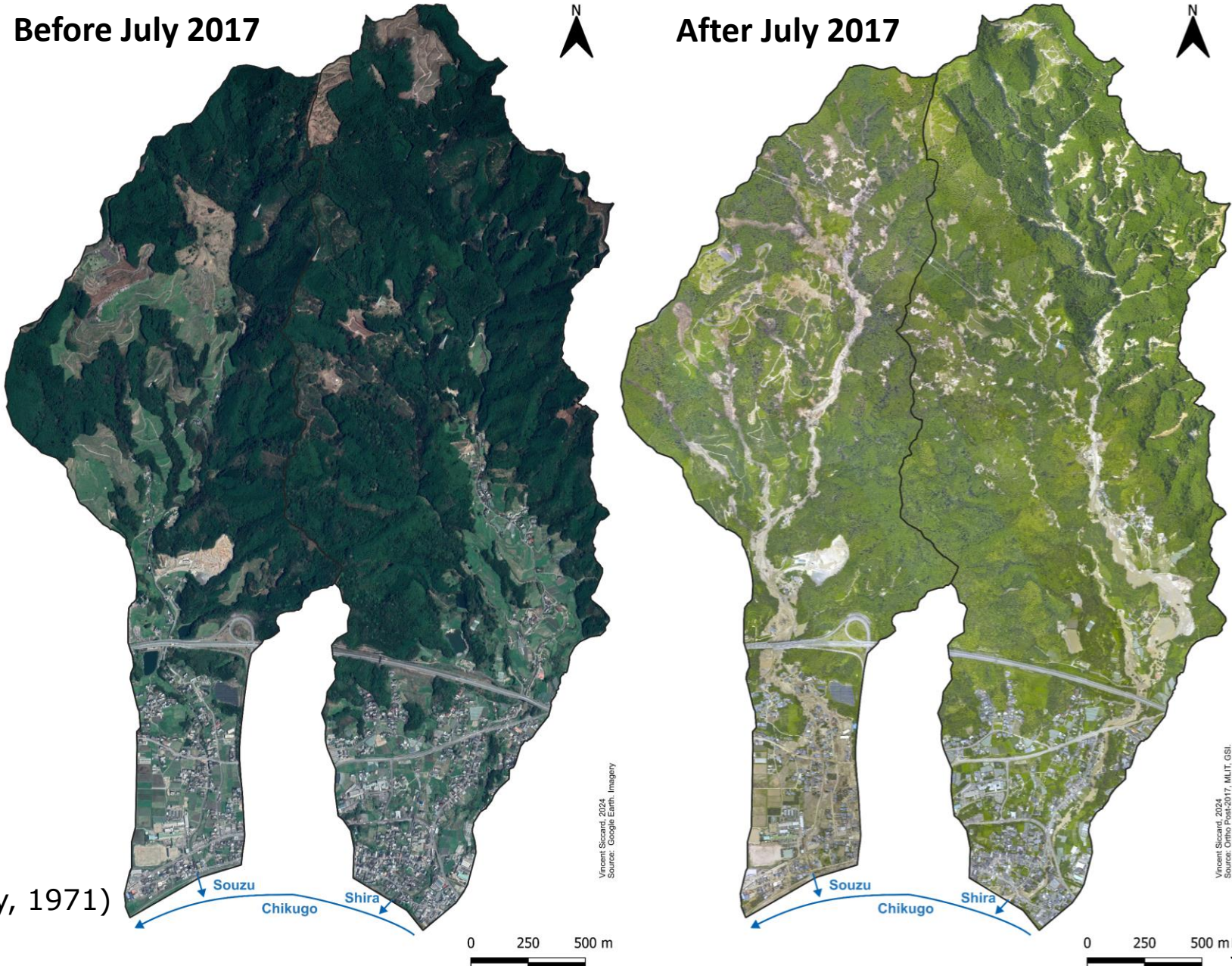
Before 2017 :

- Landslide area = 0,05%

After July 2017 event:

- Landslide area = 7,3 % (284 576 m²)
- Flooded area = 4,7%

⇒ Fluvial metamorphosis (Chorley & Kennedy, 1971)



2.2) High sediment production

Sediment production at regional scale (MLIT, 2020):

- ⇒ Landslide area = 4.44 km²
- ⇒ Sediment production > 10 000 000 m³
- ⇒ Sediment discharge into Chikugo ≈ 2 000 000 m³

Souzu watershed sediment production:

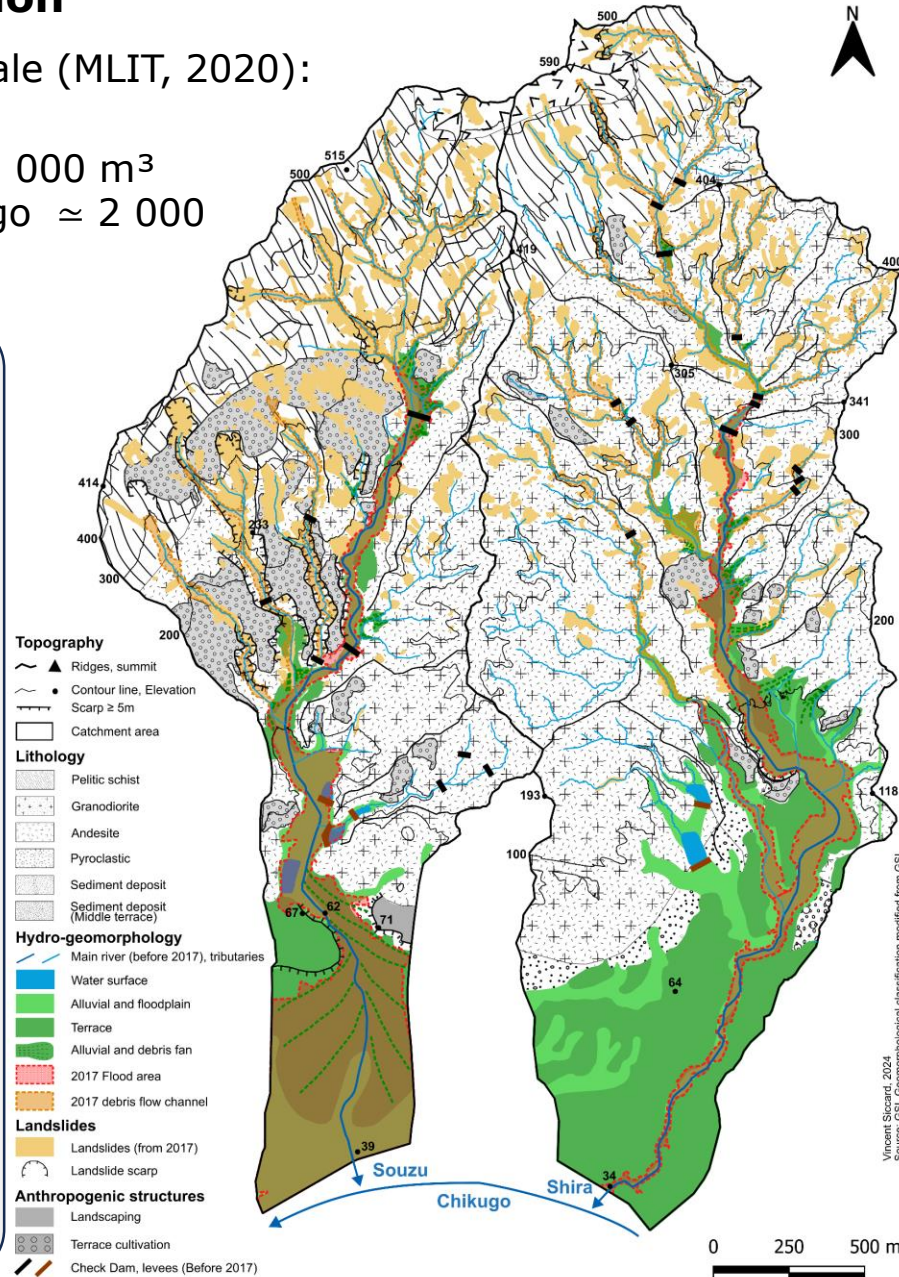
≈ 550 000 m³ (MLIT, 2020);
 ≈ 503 000 m³
 (GIS Based estimation)

⇒ ≈ 196 000 m³/km²
 ⇒ Sediment deposits in valley > 389 000 m³ (measured on 2/3 of the main valley)
 (Komuro et al., 2018)

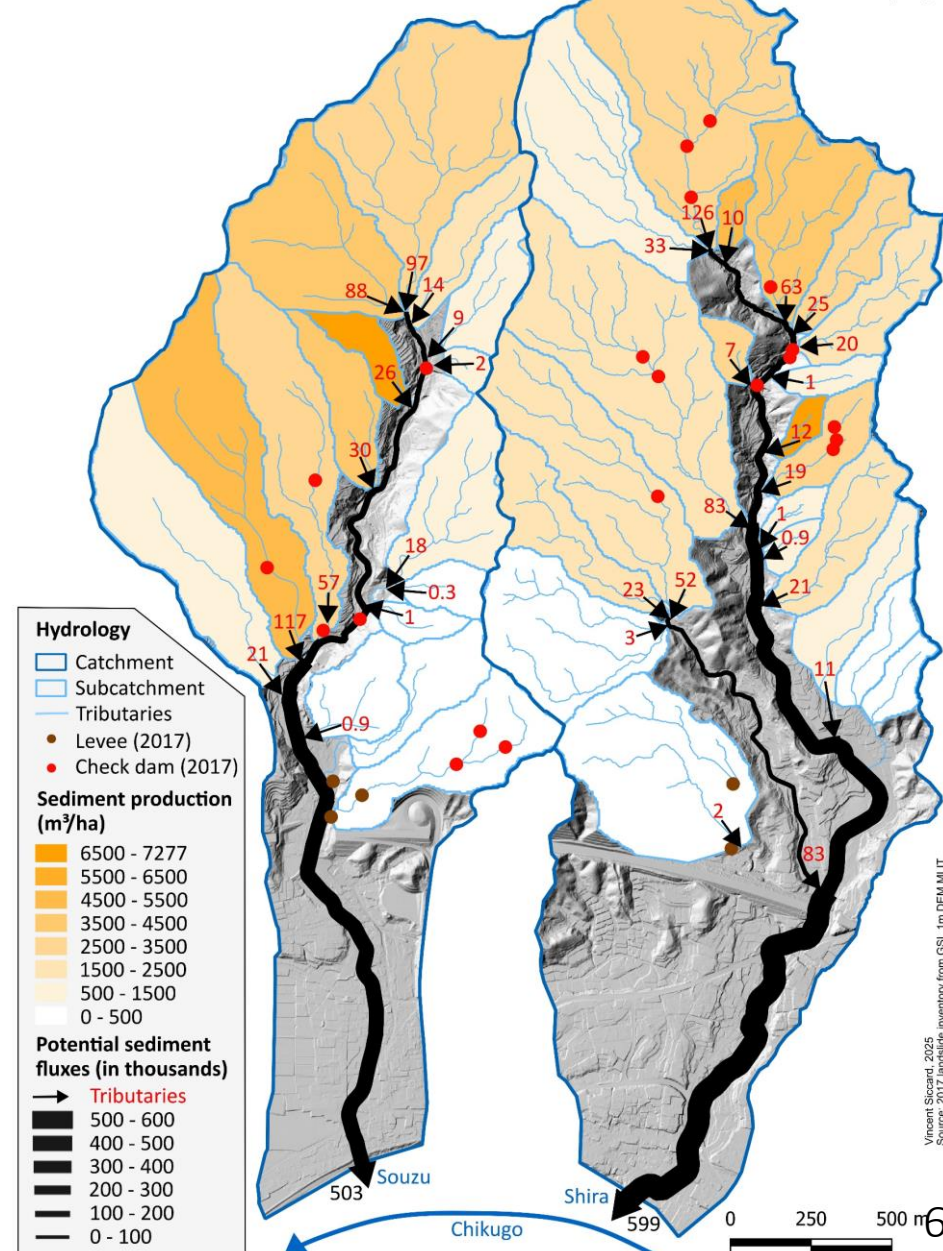
Shira watershed sediment production:

≈ 590 000 m³ (MLIT, 2020) ;
 ≈ 599 000 m³
 (GIS Based estimation)

⇒ ≈ 151 000 m³/km²



Sediment production and potential sediment fluxes during the LFHM event on 5 July 2017



2.3) High sediment fluxes generated by concomitant heavy rainfall and sediment production

Souzu watershed: sediment fluxes have reinforced flooding by clogging the channelized river

- **Lower valley pre-2017:** inhabited places and agricultural production
- **Lower valley post-2017:** sediment filling over 1-3m; destroyed houses



3.1) Removal of sediment deposits in valley floors: exemple of Souzu watershed

Post 2017



Post 2017



Post sediment removal



Post sediment removal

**Souzu watershed:**➤ **Sediment production:**

- ≈ 550 000 m³ (MLIT, 2020) ;
- ≈ 503 000 m³ (GIS Based estimation)
- ≈ **196 000 m³/km²**

➤ **Sediment deposits in valley floor:**

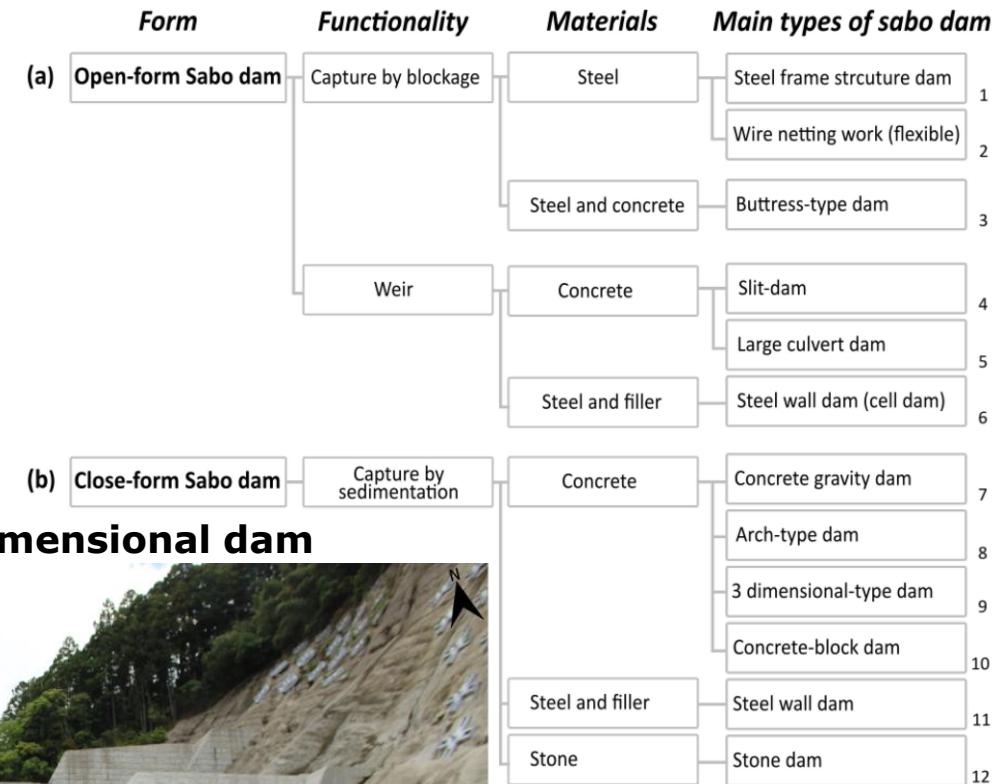
- **> 389 000 m³**
(Komuro et al., 2018)
- Measured on 2/3 of the main valley

⇒ removal of hundreds of thousands of m³ of sediment deposits

⇒ Partially reused in reconstruction work

3.2.1) High responsiveness and intervention post-event through engineering: check dam system

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



- **Sabo system:** when designed by the Japanese Ministry of Land Infrastructure and Transport (MLIT)
 - **Check dam system:** for similar objects not built by MLIT
- ⇒ **System of structural countermeasures** to mitigate sediment production from hillslopes to transport in rivers
- ⇒ **Modification of the sediment cascade**, the structural and process-based connectivity

Open check dam: steel frame structure dam



Close check dam: 3 dimensional dam



3.2.2) High responsiveness and intervention post-event through engineering: slope works

Soft engineering

Medium engineering

Hard engineering



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

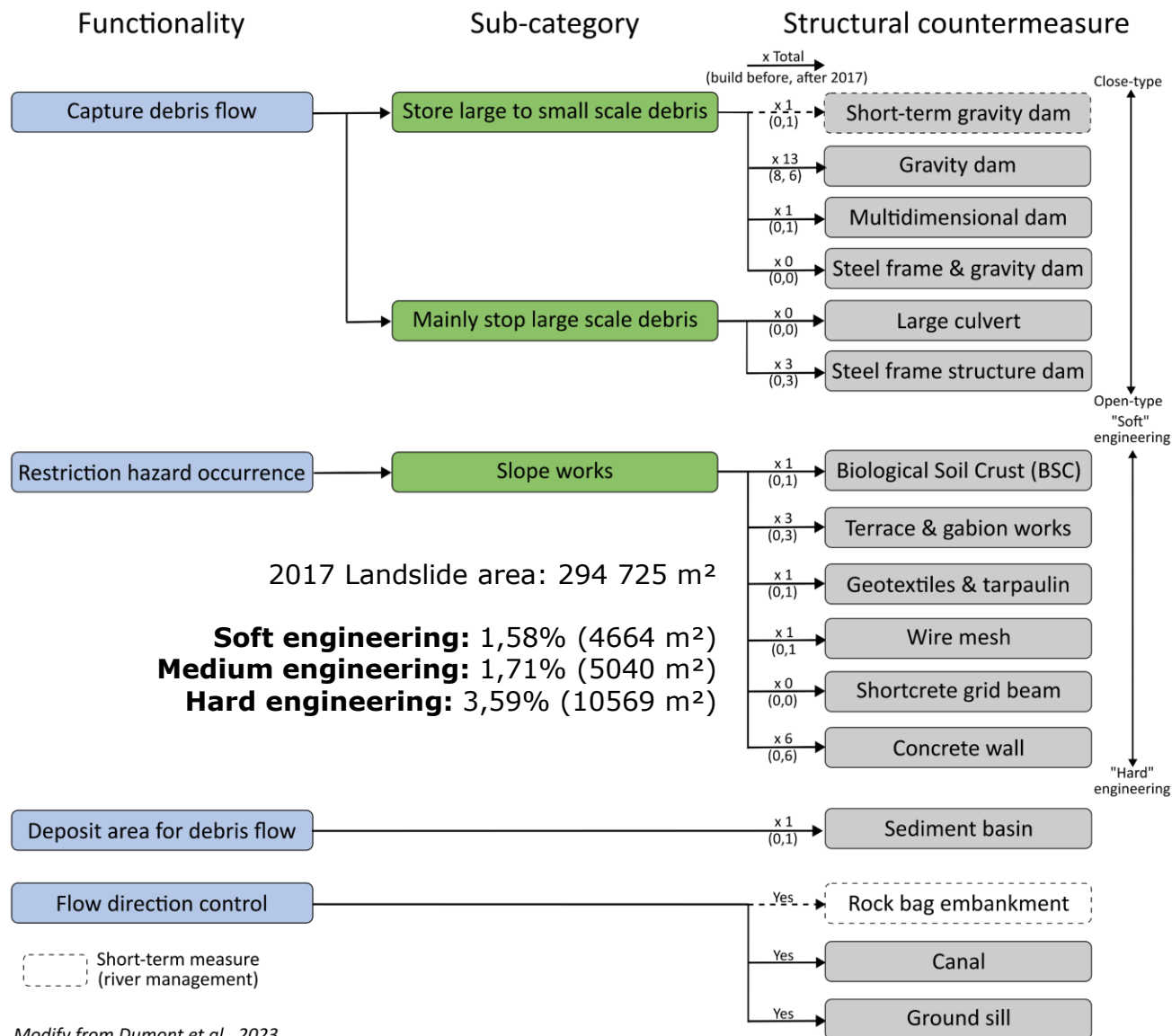
- Vegetation and Biological Soil Crust (BSC)
- Geotextile and Tarpaulin
- Terrace and gabion work
- Wire mesh
- Shortcrete grid beam
- Concrete cover
- Concrete cover with anchor and soil nailing



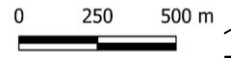
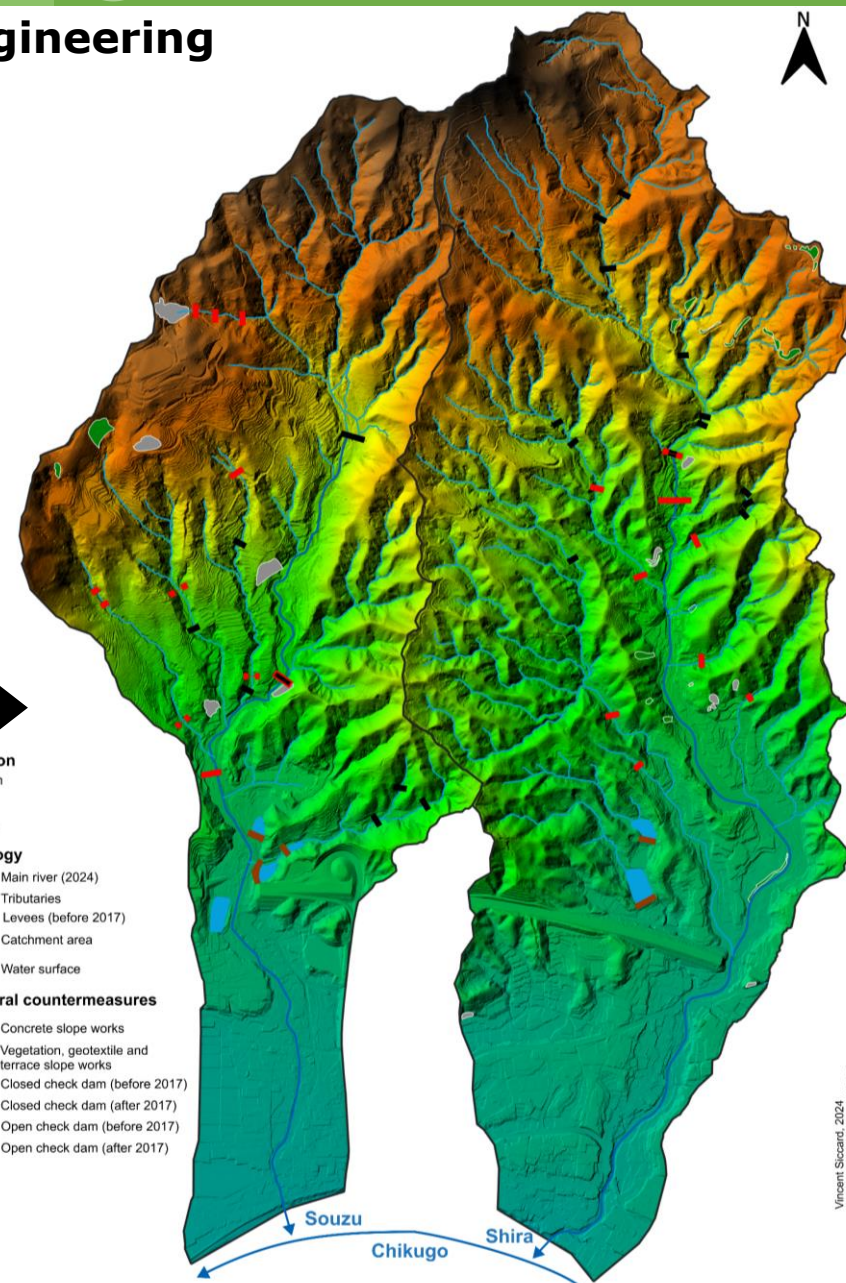
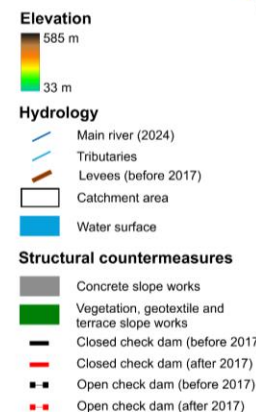
3.2.3) High responsiveness and intervention post-event through engineering

Check dam system in Souzu watershed: 11 dams built after 2017 (8 before 2017)

Slope works: mainly hard engineering



Souzu



Modify from Dumont et al., 2023

Vincent Siccard, 2024
 Source: DEM 1 m GSI, MLIT

3.2.3) High responsiveness and intervention post-event through engineering

Check dam system of Souzu watershed during 2023 rainy season

Sediment production + remobilisation of older deposit

Funasoko check dam N°2 => $\approx 20\,000\text{ m}^3$ of $59\,000\text{ m}^3$ (upstream erosion)

Efficiency of the sediment capture countermeasures but higher sediment fluxes production => Dam maintenance is crucial for maximum efficiency

Funasoko check dam N°2

Pre 2023

Upstream Funasoko check dam N°2

Pre 2023



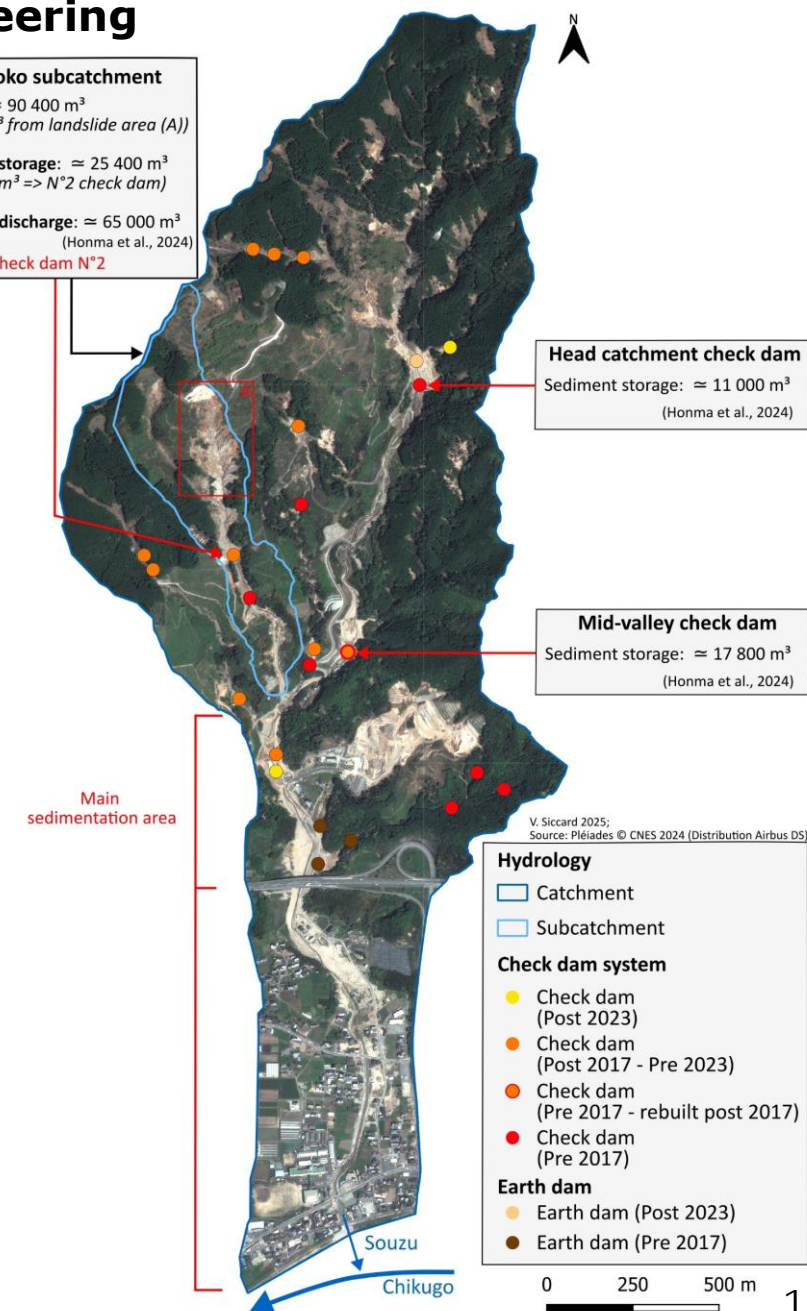
© Miyase M., Miyagi A., 2024

Post 2023

© V. Siccard, 04/2023



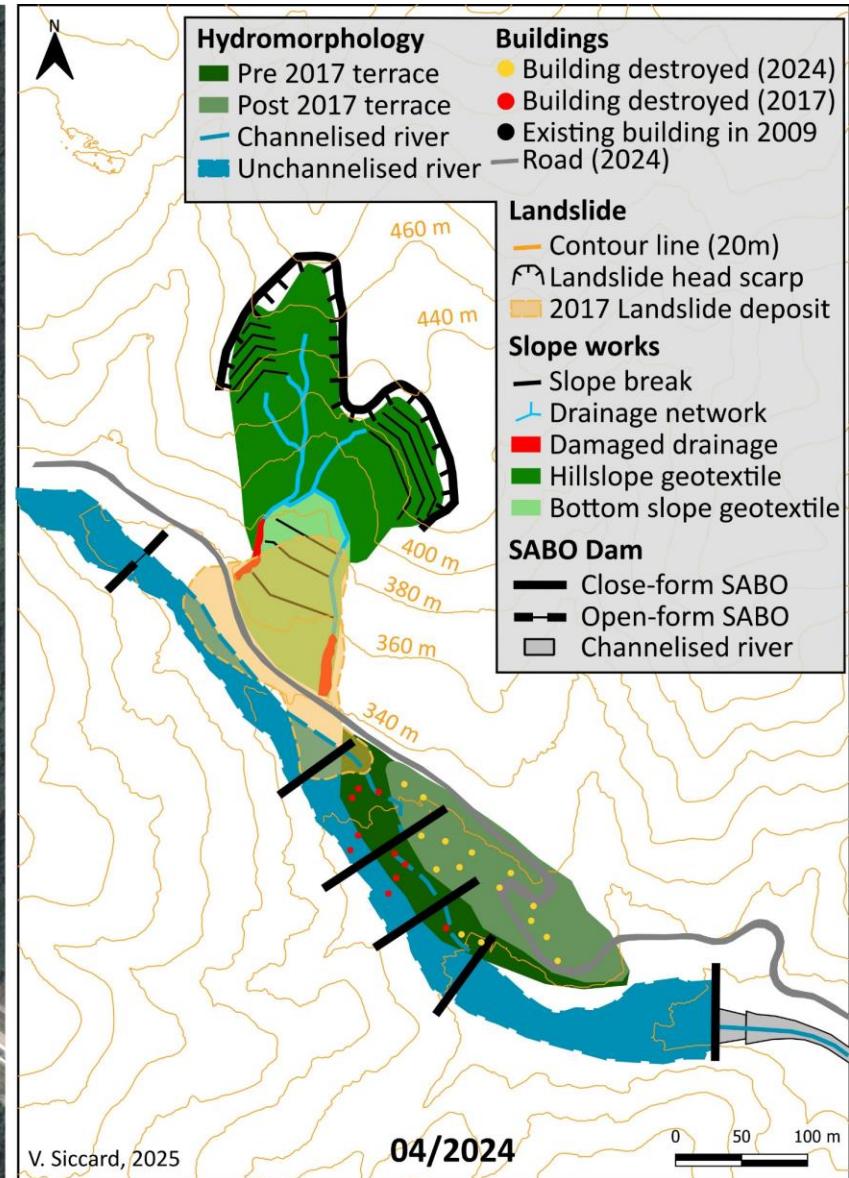
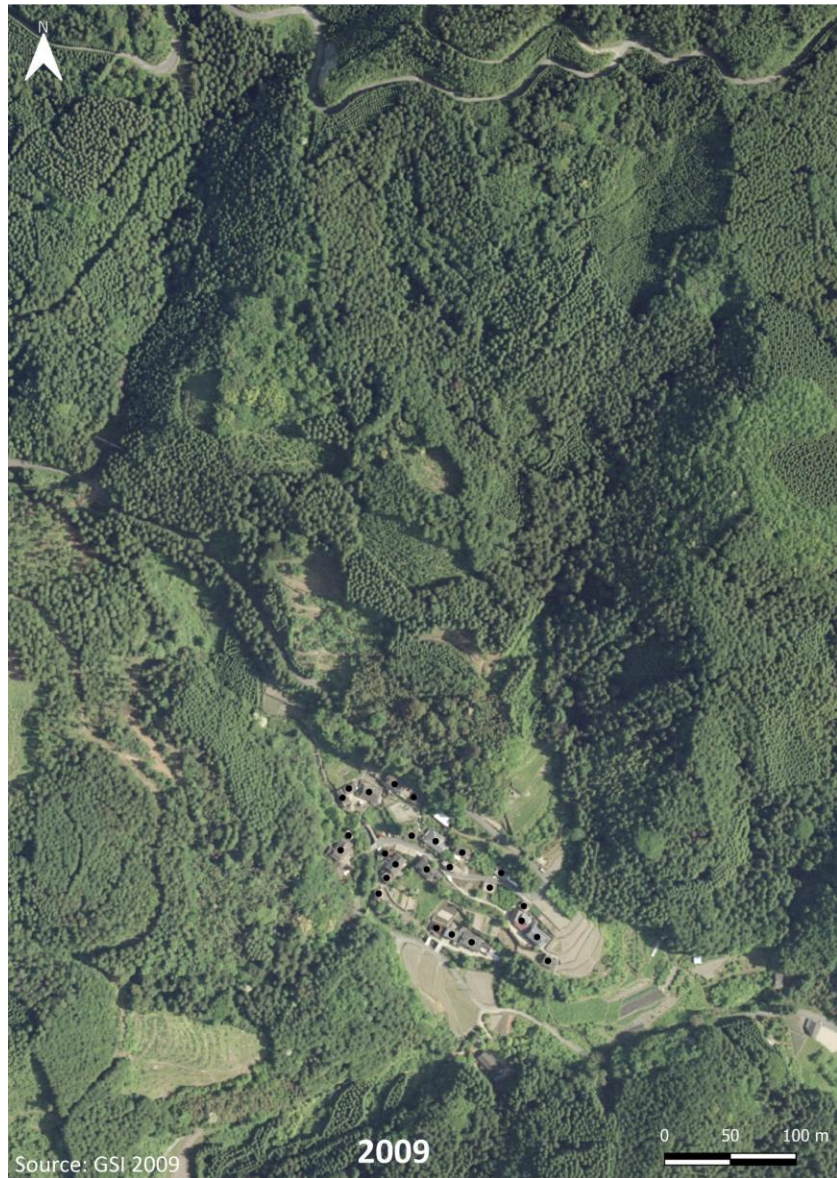
Funasoko subcatchment
 Erosion: $\approx 90\,400\text{ m}^3$
 (59 000 m³ from landslide area (A))
 Sediment storage: $\approx 25\,400\text{ m}^3$
 ($\approx 20\,000\text{ m}^3$ => N°2 check dam)
 Sediment discharge: $\approx 65\,000\text{ m}^3$
 (Honma et al., 2024)
 Funasoko check dam N°2



3.3) Dismantling of deep-seated landslide and land use changes in Otoishi watershed



3.3) Dismantling of deep-seated landslide and land use changes in Otoishi watershed



Landscape (co)evolution due to a serie of feedbacks in those coupled human-geomorphic system

Before 2017: Satoyama (里山) landscape

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

2017 post-event: radical changes in the Satoyama landscape linked to the propagation of hydro-sedimentary fluxes

- Flooding and fluvial metamorphosis
- Destruction of buildings and infrastructure
- Structural and process-based changes of the sediment cascade and connectivity

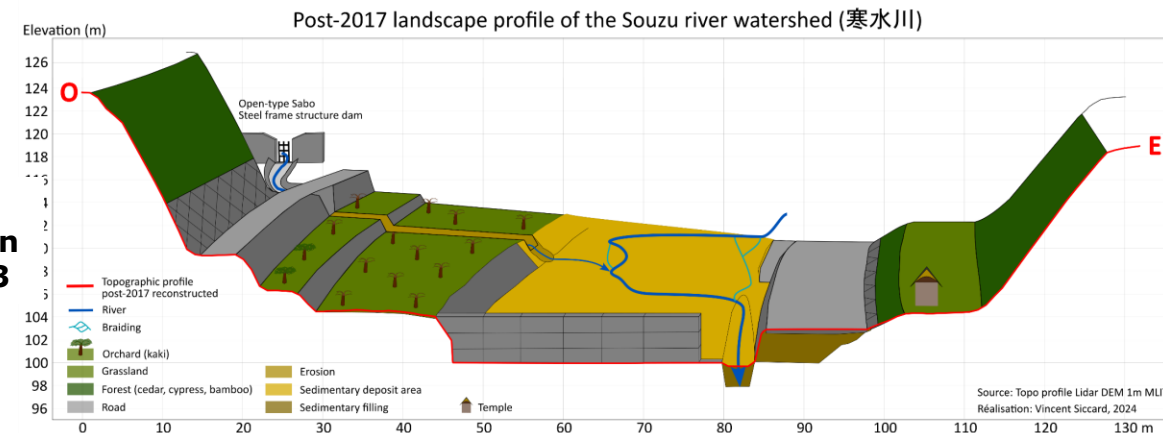
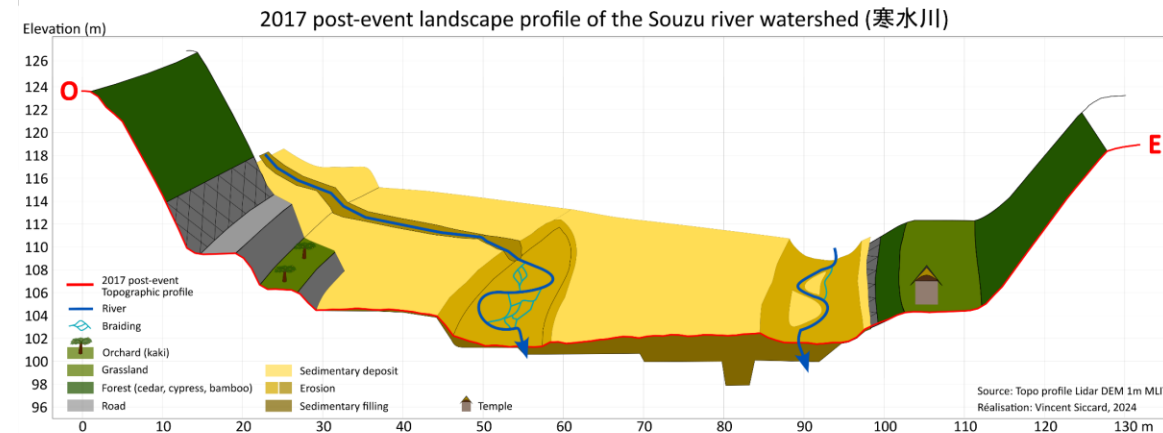
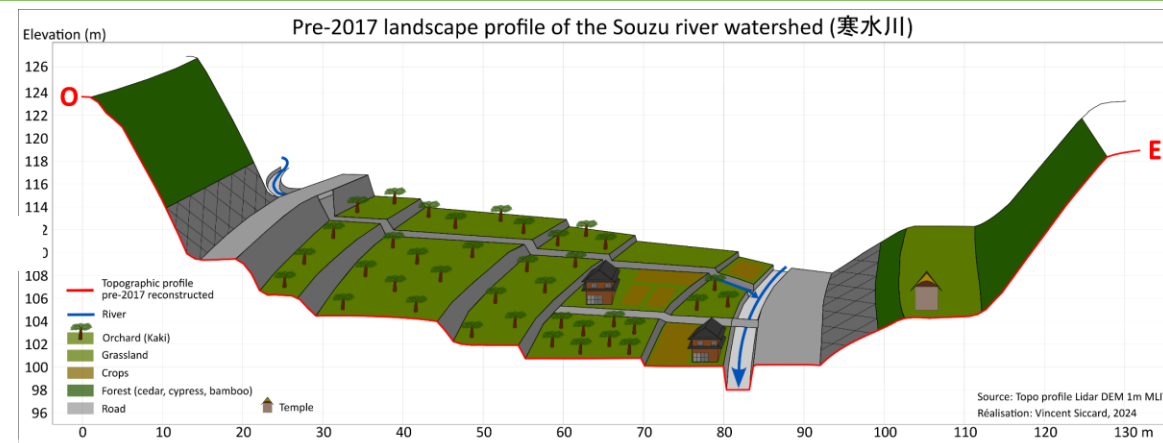
Post 2017 reconstruction: A strong post-event intervention through the development of structural countermeasures system and land use changes

- Aligning the social use with geomorphological dynamics
- Sediment storage area
- Efficiency of the sediment capture countermeasures but higher sediment fluxes in a context of increased landscape sensitivity

Before 2017

2017 post-event

Post 2017 Reconstruction / Before 2023



Thank you !

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