# A multi-temporal landslide inventory for Wetar Island, Indonesia

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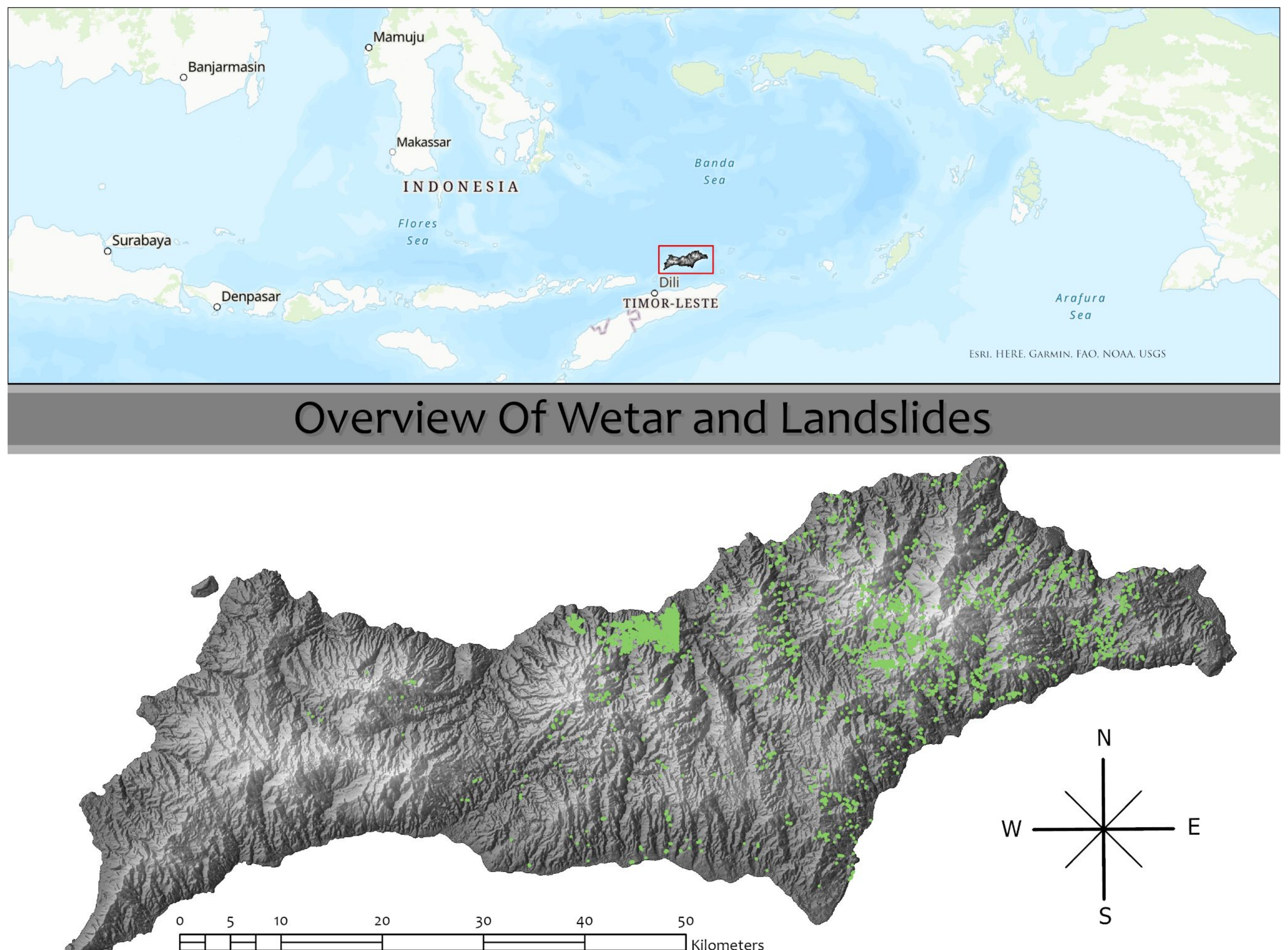
**Introduction:**

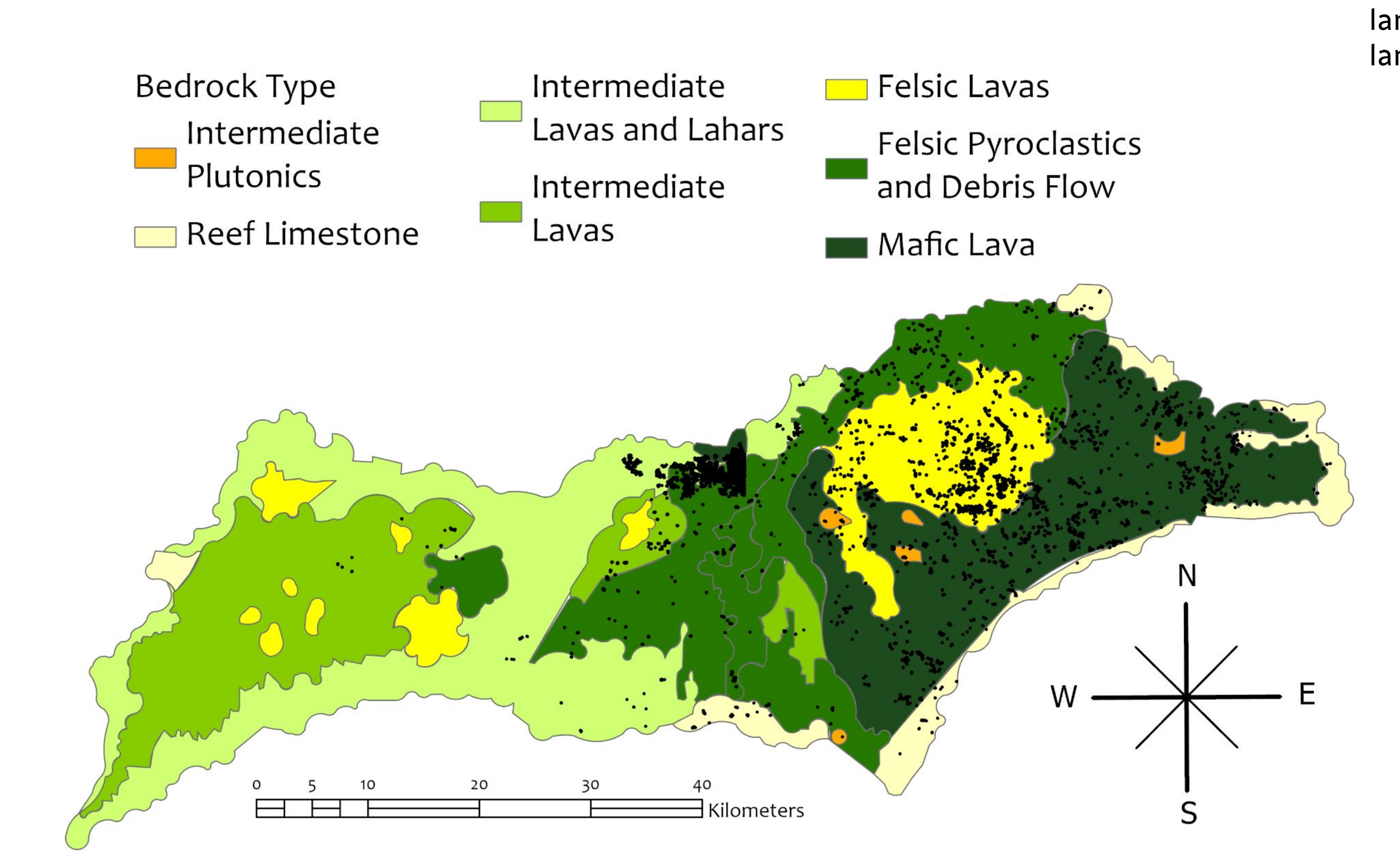
Wetar is a ~2650 km$^2$ rapidly uplifting island in the inner Banda Arc of Eastern Indonesia, located at the center of the transition from subduction to arc-continent collision. While the bedrock is primarily Neogene volcanics, volcanism has shut off due to cessation of subduction and collision with Australian continental margin. High uplift rates (>1 mm/yr - Miller et al., 2021) are balanced by rapid erosion. This is a tectonically complex but understudied area, in part due to its remoteness and small population (~8,000 people live on Wetar), but landslides are frequent and trends may offer insight into tectonic geomorphology and hazard potential in similar landscapes. We have assembled a multitemporal landslide inventory for the past two decades using Google Earth imagery to map nearly 5,000 landslides, focusing on Eastern Wetar. Here, we examine the relationship between landslides and topography, precipitation, and lithology to better understand landscape dynamics in this region.




**Above:** overview map of Wetar showing landslides mapped for this study. Constraints on image coverage force boundaries on mapped areas, such as the east side of the high-density area on the north central coast.

## Geologic Map of Wetar with Landslides

Modified from Scotney et al. 2002




**Above:** Geologic map showing distribution of landslides with respect to bedrock lithology on Wetar. No obvious relationships are present, but more formal analysis is needed.

**References:**

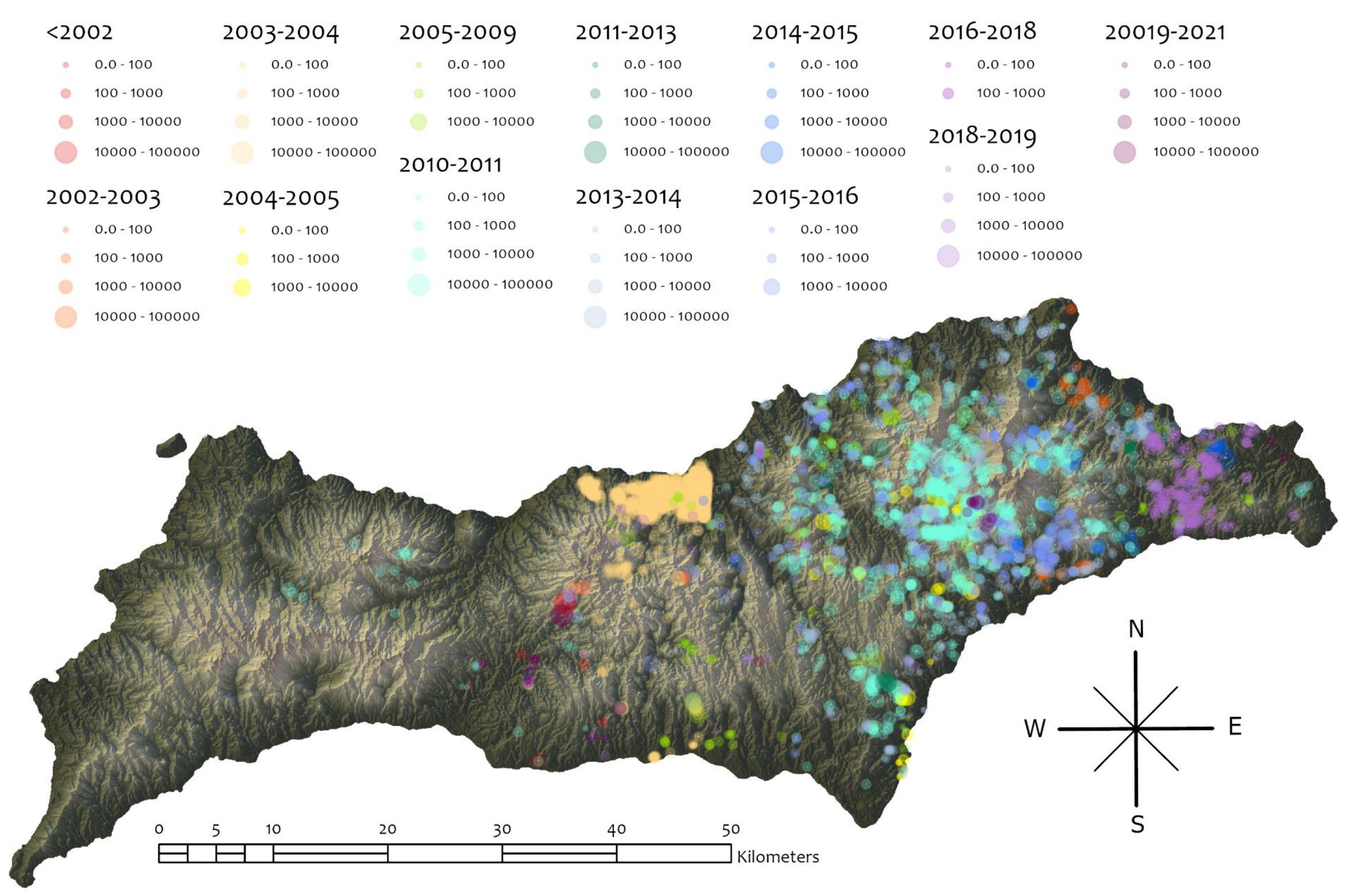
Forte, A. M. and Whipple, K. X.: Short communication: The Topographic Analysis Kit (TAK) for TopoToolbox, Earth Surf. Dynam., 7, 87–95, https://doi.org/10.5194/esurf-7-87-2019, 2019.

Hou, A. Y., Kakar, R. K., Neeck, S., Azarbarzin, A. A., Kummerow, C. D., Kojima, M., et al., The global precipitation measurement mission. Bulletin of the American Meteorological Society, 95(5), 701–722. https://doi.org/10.1175/BAMS-D-13-00164.1. 2014.

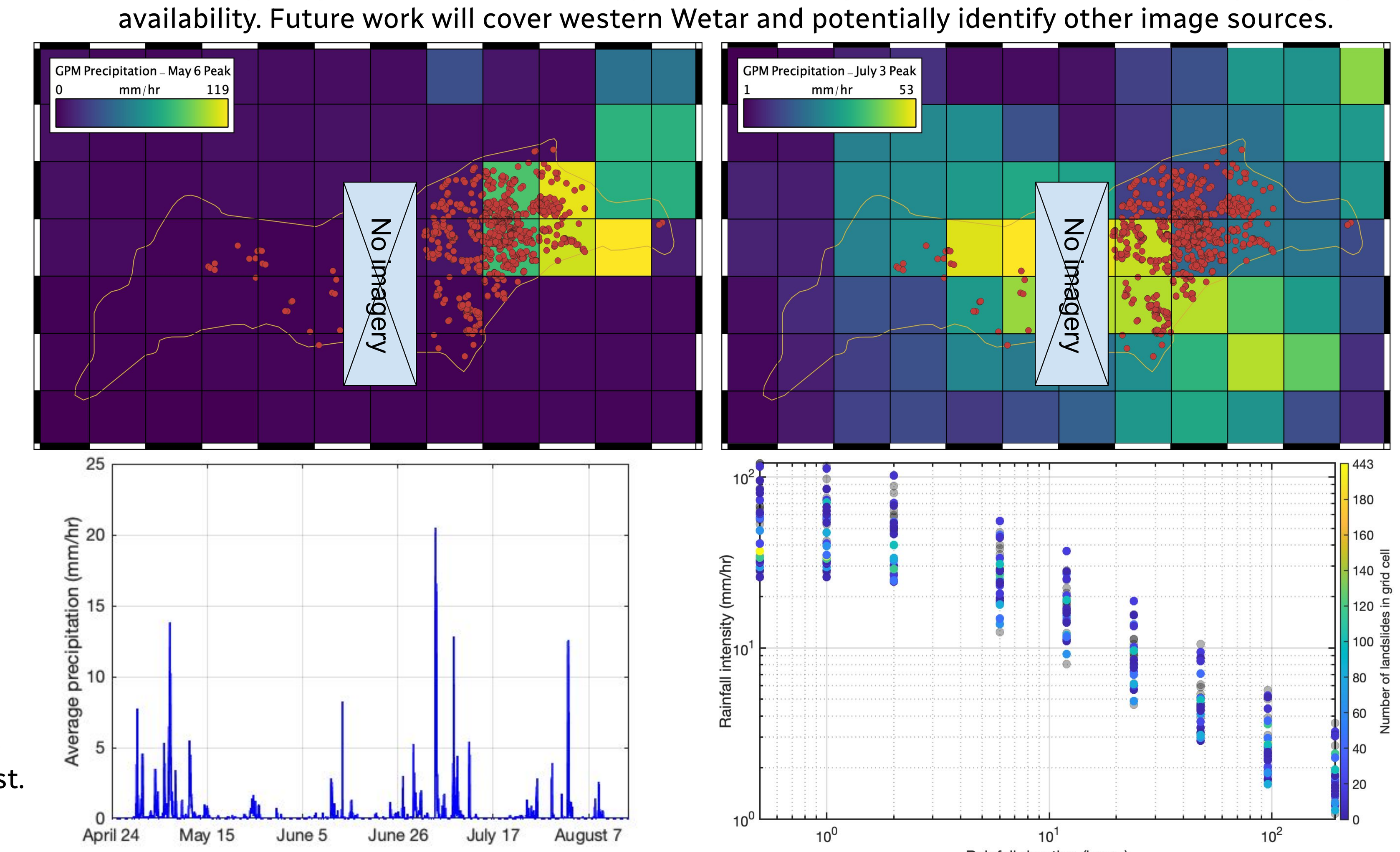
Miller, M.S., Zhang, P., Dahlquist, M., West, A.J., Becker, T.W., & Harris, C.W., Inherited lithospheric structures control arc-continent collisional heterogeneity, Geology, 49,doi:10.1130/G48246.1. 2021.

## Distribution by year of Inventoried Landslides

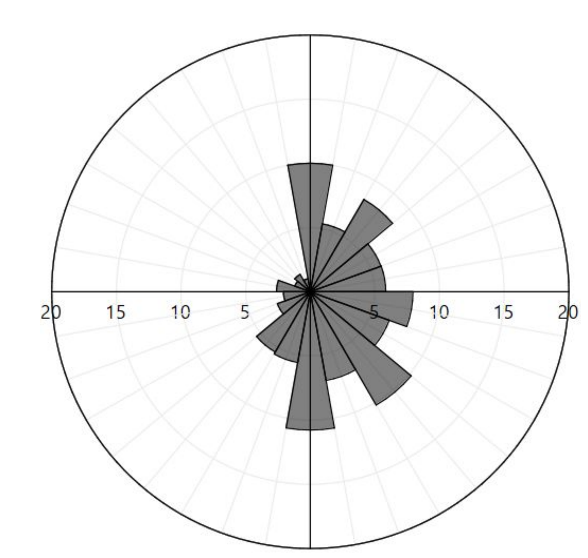
With Graduated Symbols Showing Landslide Area (m^2)



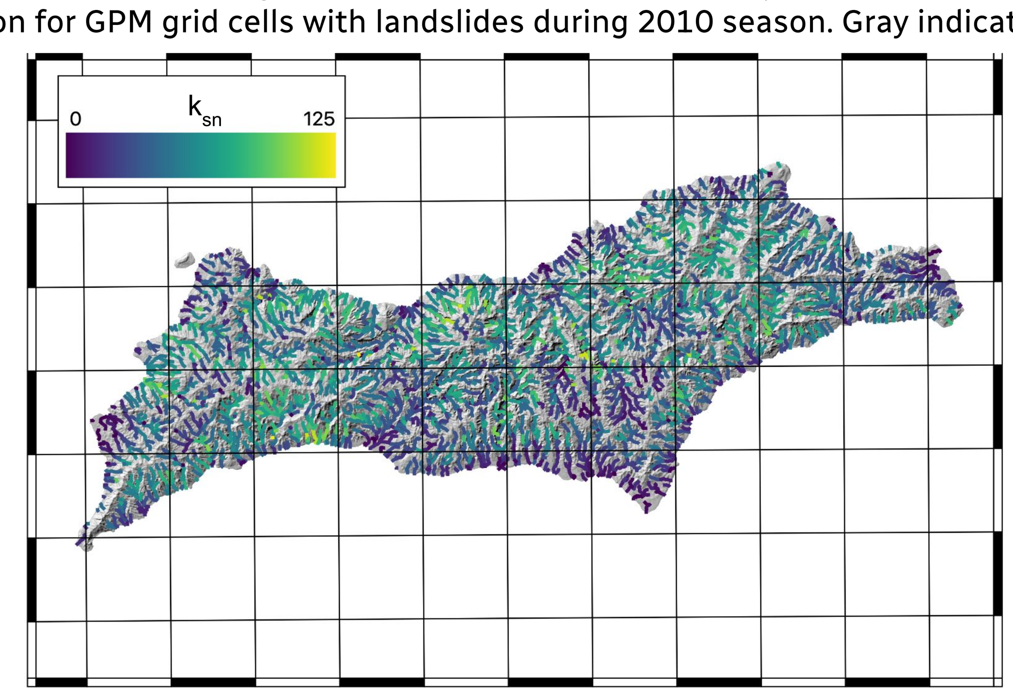

**Above:** Temporally binned landslides mapped for this study. Bin sizes were determined by imagery availability. Future work will cover western Wetar and potentially identify other image sources.



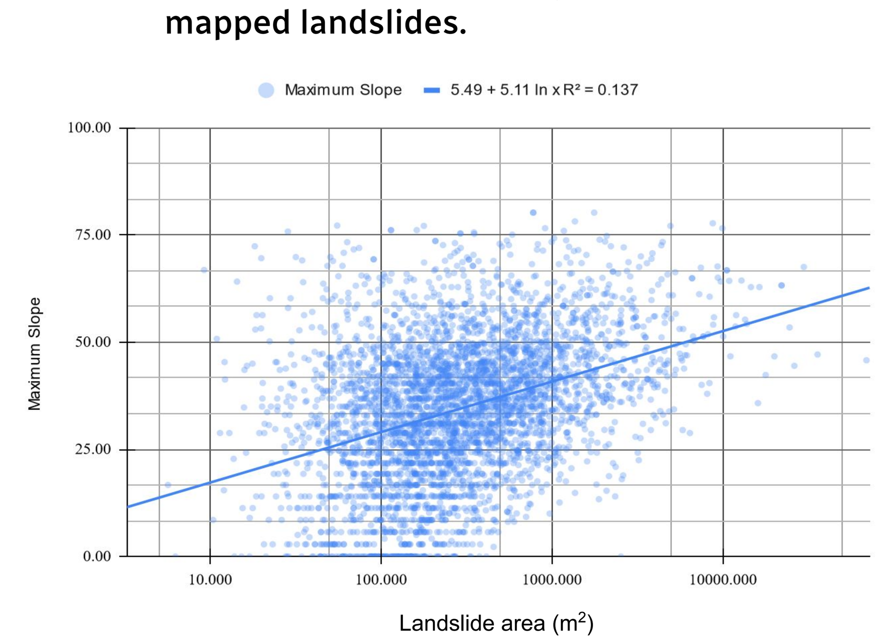

**Above:** Analysis of 2010 landslides with respect to Global Precipitation Measurement satellite rainfall data. **Top:** Rainfall intensity map for two peak rainfall events that year with landslides. **Bottom left:** Average rainfall over Wetar for the time period when most landslides occurred. **Bottom right:** Rainfall intensity-duration for GPM grid cells with landslides during 2010 season. Gray indicates landslides were mapped in cell during another year studied.



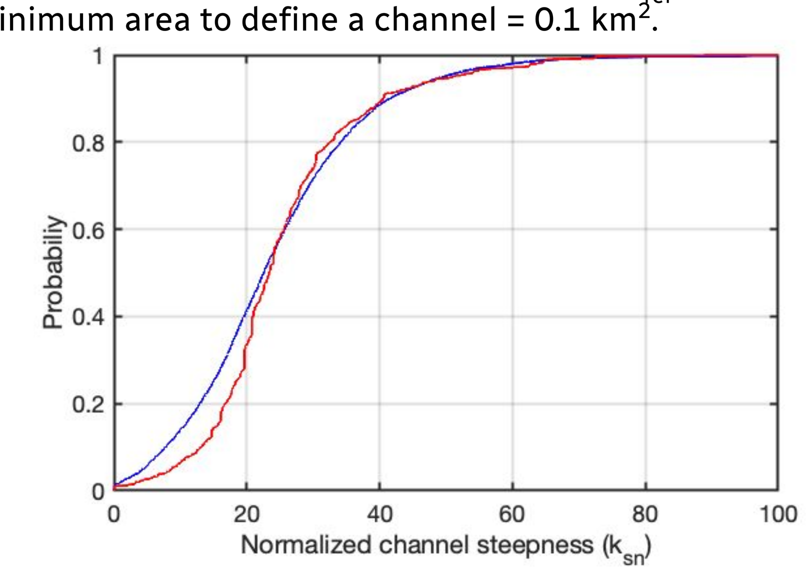
**Above:** Distribution of aspects of mapped landslides.




**Above:** $k_{sn}$ map for Wetar - topographic metrics calculated using Topographic Analysis Kit and QGIS. $\Theta_{ref}$ = 0.38, minimum area to define a channel = 0.1 km$^2$.

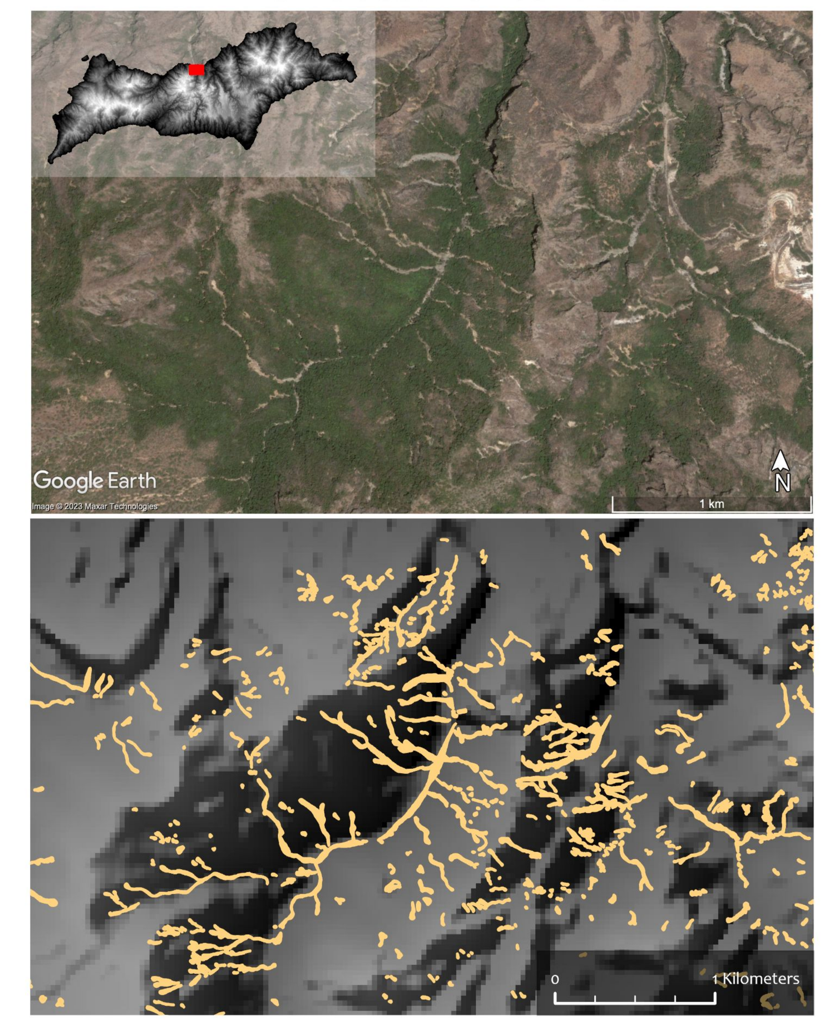



**Above:** Landslide slope vs. area showing tendency toward larger slope failures on steeper hillslopes.




**Above:** Empirical cumulative distribution functions for ksn showing all channels on Wetar (blue) and nearest channel segments to mapped landslides (red). P<<0.05

Mine Related Landslides




**Left:** Landslides from a major event in 2004 clustered near a rapidly expanding copper/gold mining operation.

**Land use and landslides on Wetar - Main Points:**

- The largest event we identified (n=2016) landslides occurred in the middle of Wetar's mining region, with several large open-pit operations nearby and associated development.
- We also identified many recently logged areas, though we have not conducted analysis on them at this time.
- Further analysis of landslides with respect to land use is necessary.

**Precipitation analysis - Main Points:**

- 2010 was a strong La Niña year, which brings unusually wet winters and winds from the east to Wetar. Typically, Wetar has a winter dry season.
- We were able to constrain ~1282 landslides to occurring between April and August, 2010. Two rainfall peaks occurred in May and July. We analyzed Global Precipitation Measurement (GPM) rainfall data for this span of time.
- Highest intensity of rainfall occurred in May, but was spatially more confined to far eastern Wetar. A secondary storm occurred in July which was not as intense but affected a larger area.
- In the region with mapped landslides from 2010, intensity-duration trends do not correlate with number of landslides that occurred in affected areas. We infer this to mean that a substantial portion of slopes on Wetar exist in a critical state, primed to fail with any major rainfall.
- The predominance of landslides on eastern aspects may imply dominance of La Niña years on landsliding, when weather systems come from the east. La Niña years during the studied years were: 2005-2006, 2007-2008, 2008-2009, 2010-2011, 2011-2012, 2016-2017, 2017-2018, 2020-2021, 2021-2022.

**Topographic and lithologic analysis - Main Points:**

- Landslides occur predominantly on east-facing slopes, possibly corresponding with the La Niña-associated landslides we have identified occurring in 2010.
- The low resolution of available topographic data (30-meter SRTM) precluded close analysis of hillslope angle and landslide occurrence, but the strong aspect preference encourages a closer look at hillslope metrics in future work.
- Normalized channel steepness ($k_{sn}$), expressed by $S = k_{sn}A^{-\theta_{ref}}$ where S is channel slope, A is drainage area, and $\Theta_{ref}$ is a best fit reference channel concavity, is a means of comparing the relative erosional capacity of channels. We find landslides cluster near channels with higher $k_{sn}$.
- Landslides occurring on steeper slopes tended to be larger.
- Based off of initial examination of landslide distribution on the geologic map there does not appear to be a correlation with bedrock type. Future work will examine lithology and landslide occurrence more closely.