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The future of sinking coastal cities in Java

British Geological Survey

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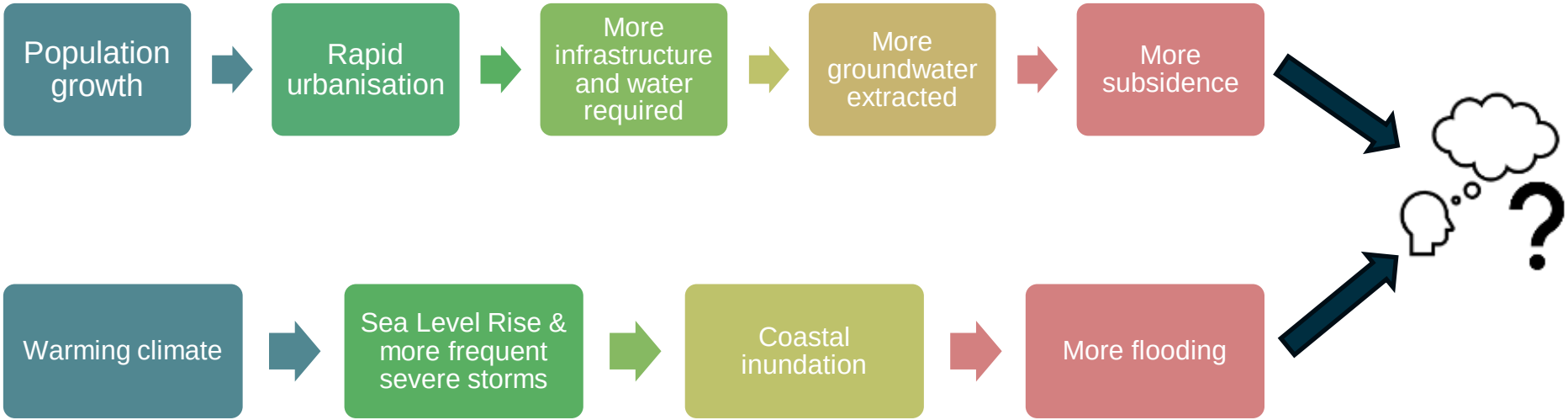
Sea Level Rise - *are we really seeing the full picture?*

Moving from single to multi- hazards…



Why Java?

- Rapid population growth

(270M to 330M by 2050)

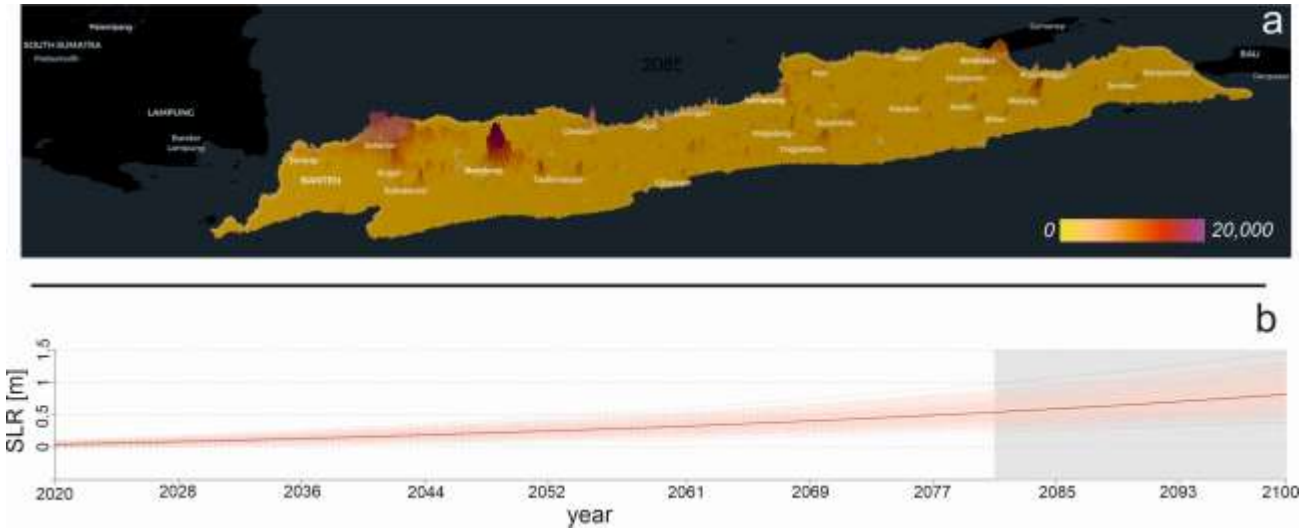
- Rapid urbanisation

(from 56M urban residents in 1990 to 168M in 2025)

- Economic centre of the country

(56% of national GDP)

- One of the country most exposed to SLR



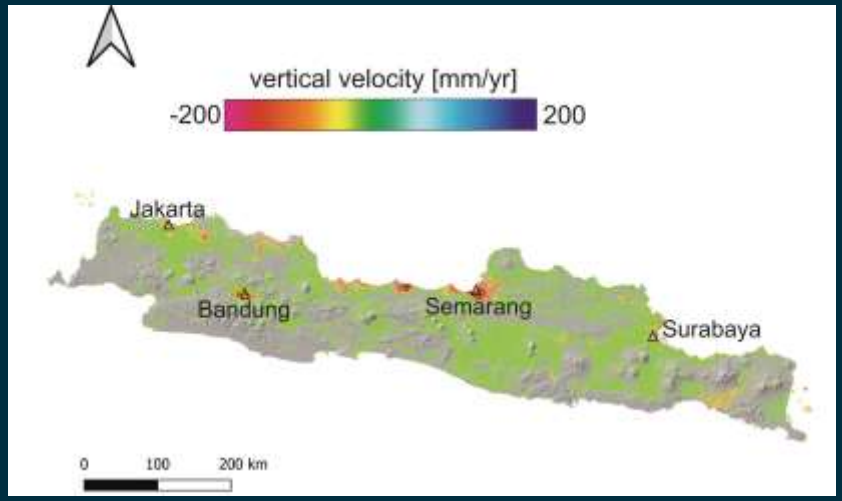
AS REMOTE SENSING GEOLOGISTS…

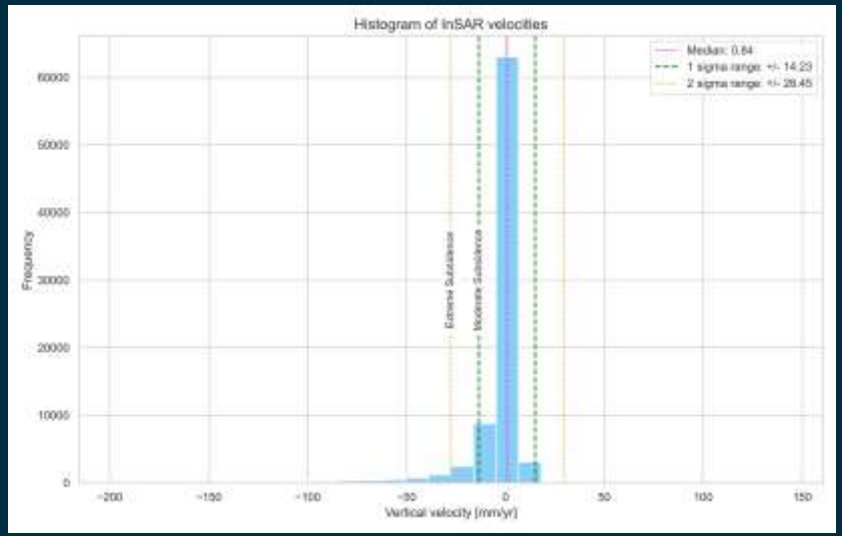
What can we do?

- MAKE NEW MAPS
- USE THESE MAPS TO PROVIDE AN ASSESSMENT OF CURRENT SUBSIDENCE
- LOOK AT FUTURE SCENARIOS TO IDENTIFY VULNERABLE AREAS

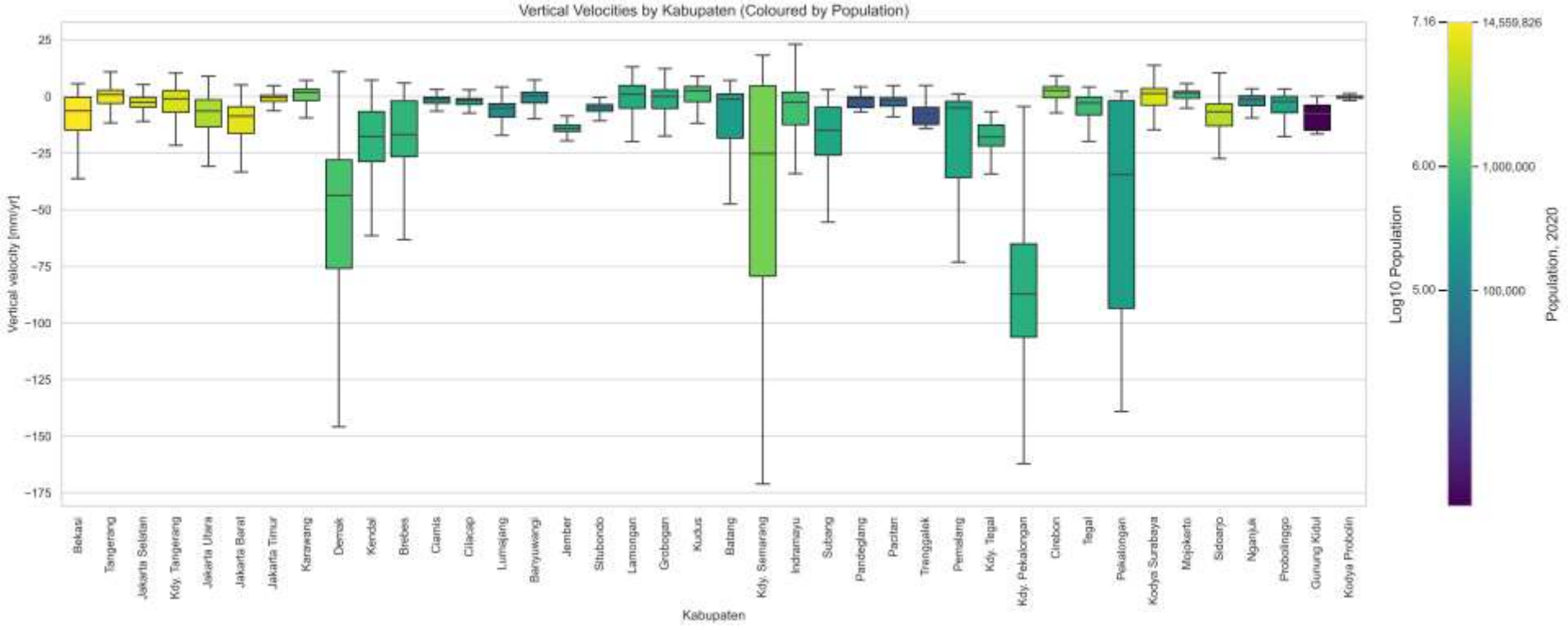
A new C-band InSAR deformation map…

- Deformation map using Sentinel-1 imagery from 2016-2022
- Interferograms generated using LiCSAR system (Lazecký et al., 2020) with timeseries developed from LiCSBAS tool (Morishita et al., 2020)
- Atmospheric noise minimisation using GACOS weather model per interferogram
- MPs were referenced to 63 GNSS stations across Java (maintained by *Indonesia Mapping Agency - BIG*)
- Velocities thresholded to -200 : 200 mm/yr due to outliers





Subsidence per regency with population shows where is currently the most exposed areas to subsidence- which areas have the highest populations, and which areas are therefore most vulnerable **right now**



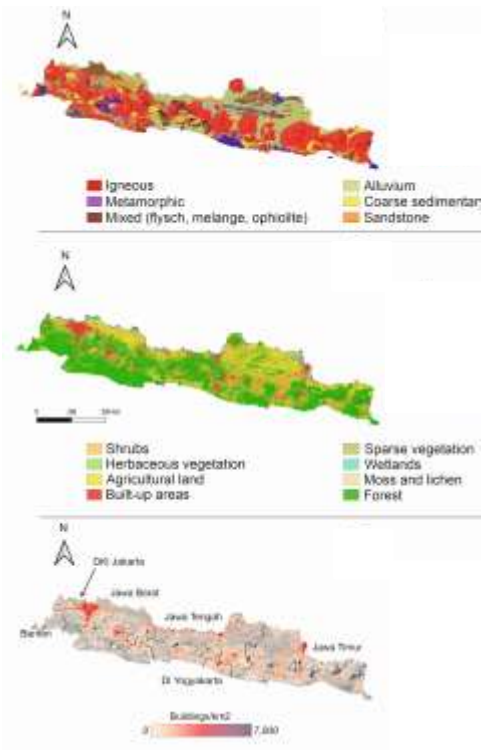
IF SEA LEVEL RISE AND SUBSIDENCE HAVE BEEN THOUGHT ABOUT SEPARATELY, THEN…

What does the future have in store?

Datasets used

InSAR deformation map combined with open-source datasets:

- DEM from DEMNAS (https://tanahair.indonesia.go.id/portal-web/unduh)
- Land cover map from Copernicus Global Land Cover map (https://land.copernicus.eu/en)
- Building locations from Google Open Buildings (https://sites.research.google/gr/open-buildings/)



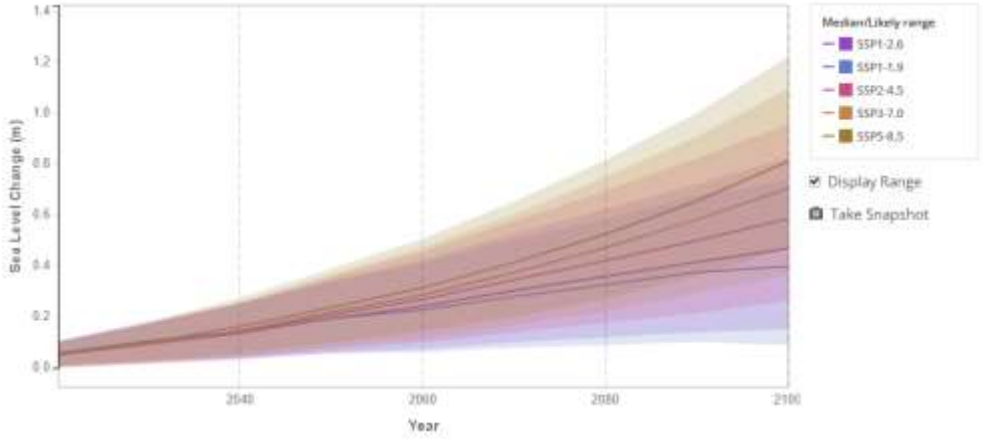
future

- NASA' Sea Level Projection Tool (https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool)
- Shared Socioeconomic Pathways for population up to 2100 (https://www.nature.com/articles/s41597-022-01675-x)

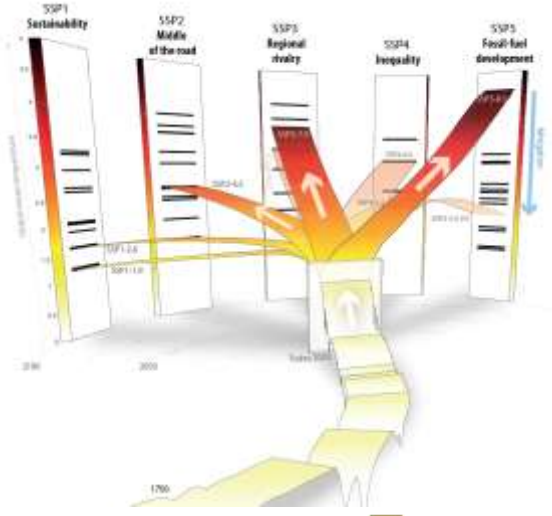
METHOD

Projecting the future

- We consider Sea Level Rise between 2020-2100, under the worst climate scenario (8.5 W/m^2)



- To predict the population, the Shared Socioeconomic Pathways dataset [Wang et al., 2022] provides population predictions for various development pathways

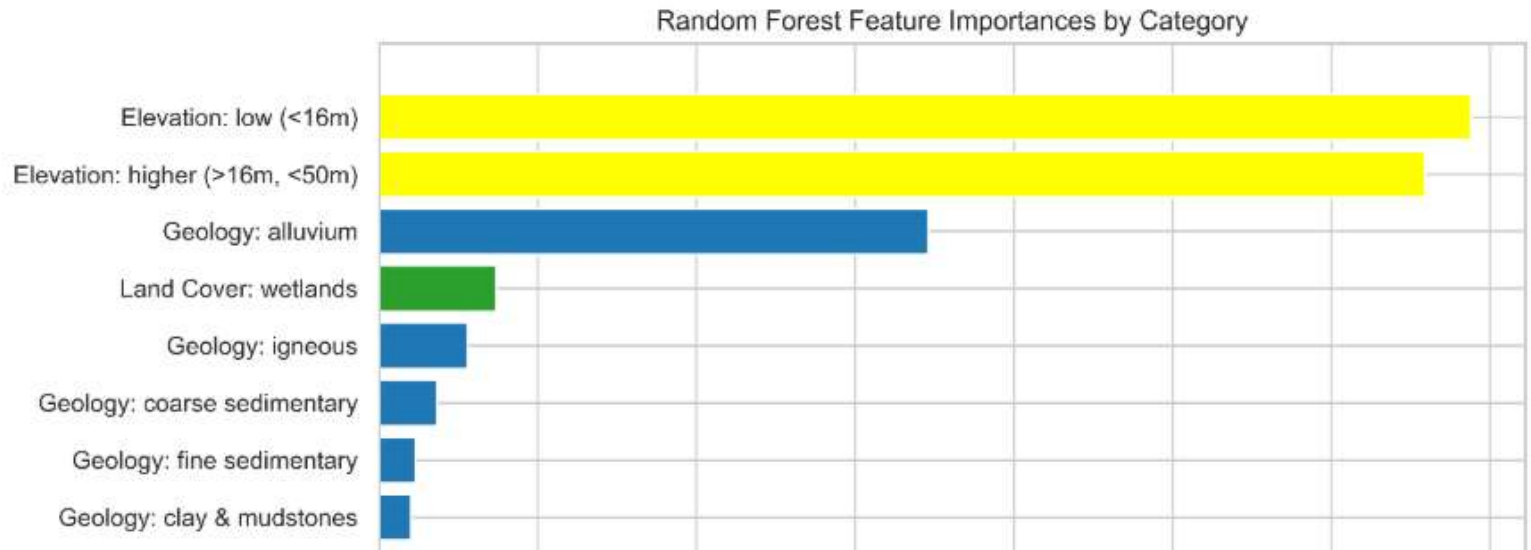


Results & Analysis

accessible at this preprint: https://essopenarchive.org/users/1026245/articles/1385932-the-future-of-sinking-coastal-cities-in-java

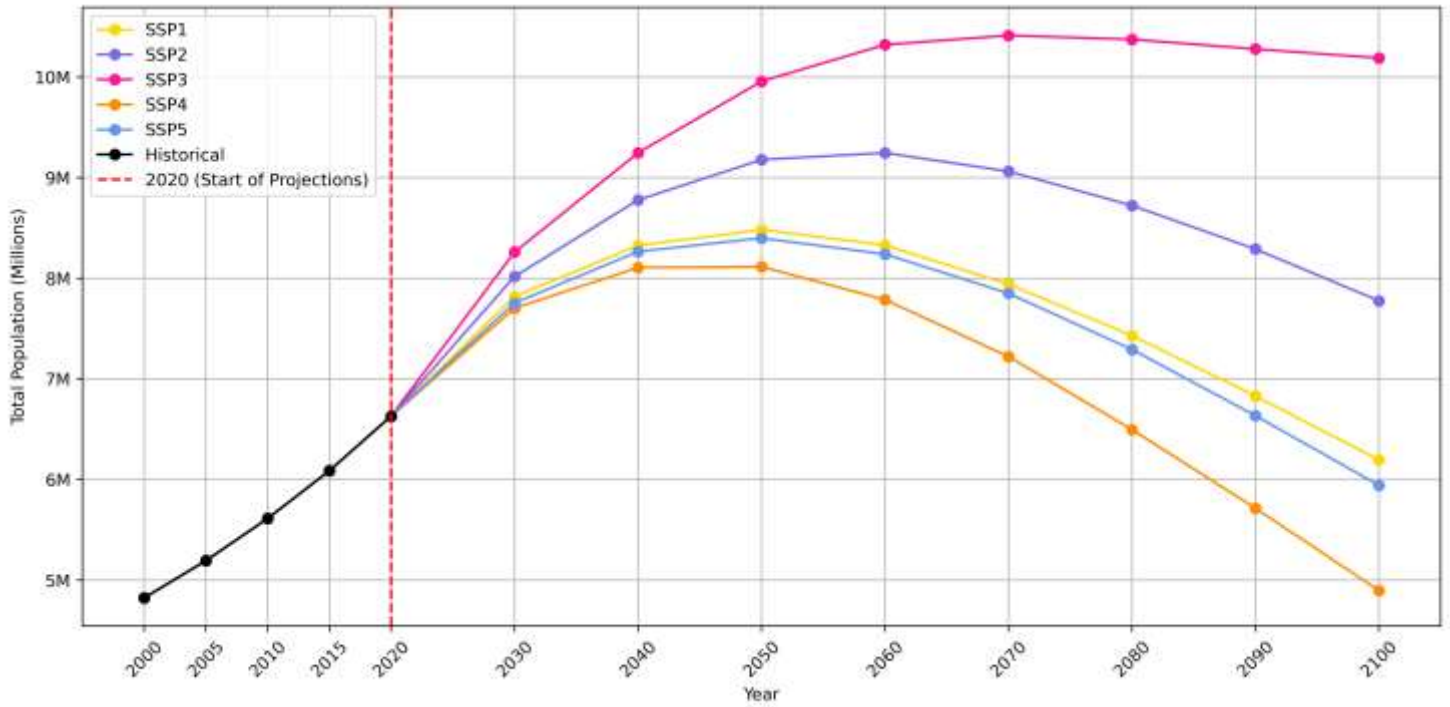
Subsidence results

- The lowest 25% of coastal lowlands in Java (<3.8m) directly correspond to the quickest subsidence rates
- Quickest subsidence occurs over coastal alluvium deposits, which is expected as low-lying alluvium in deltaic environments subsides quickest under urban development and growth [Bateson et al., 2023]
- From our analysis, land cover (as a whole) has little to no correlation with observed subsidence



Population estimates

Whole island – constrained to areas where we have C-band InSAR coverage → underestimation!

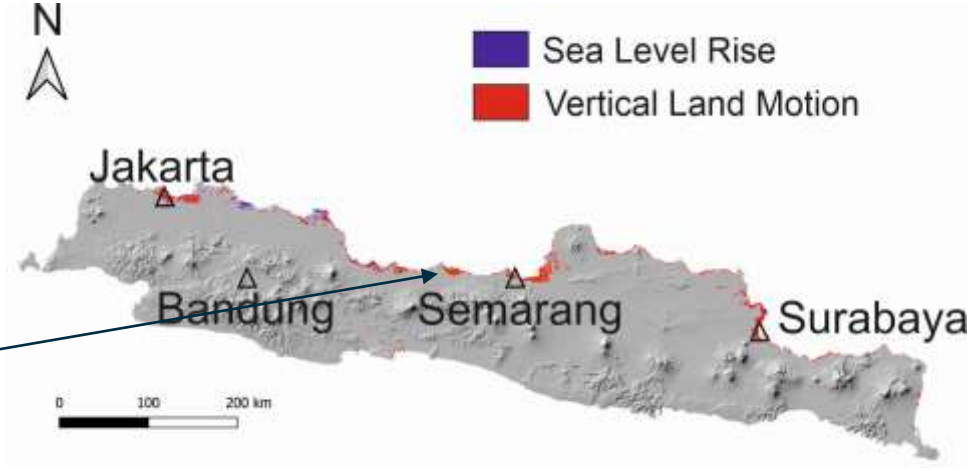


Future predictions

- With SRL, almost 300km^2 of land will be lost in Java alone, up to 850km^2 if we considered also subsidence.

- Pekalongan is projected to sink 7.53m from today's sea level in 2100

- By 2100, climate-driven SLR alone could place ~0.32–0.56 million people at or below sea level. Including subsidence increases this to ~1.1–2.2 million additional exposed residents, depending on the SSP



SSP scenario	Total java coastal population by 2100	Population below sea level by 2100 due to SLR alone	Additional population below sea level by 2100 due to VLM
SSP1	40,520,000	346,710	1,356,000
SSP2	50,700,000	440,000	1,700,000
SSP3	67,030,000	560,000	2,220,000
SSP4	32,380,000	270,000	1,070,000
SSP5	38,860,000	330,000	1,290,000

Concluding remarks

- The northern coastal plain emerges as the most vulnerable region, where subsidence rates are highest and geological conditions (alluvium, clay, mudstone) amplify vertical land motion.
- Six times more people will be living below sea level due to land subsidence compared to climate-driven sea level rise alone.
- Our analysis is limited to Sentinel-1 coverage and average velocities we plan to build on this methodology with NISAR timeseries