UNDRR
UN Office for Disaster Risk Reduction

Earthquake Hazard & Risk Assessment of Bangladesh

Technical Panel Session #4

Earthquake-induced liquefaction hazard assessment: scenario and probabilistic analysis

GLOBAL EARTHQUAKE MODEL FOUNDATION

31 January 2024

working together
to assess risk

GEM
GLOBAL EARTHQUAKE MODEL

OQ
OPENQUAKE

Why bother?

- Contemporary regulations require risk due to ground failure to be minimized
- Avoidance of large co-seismic settlements (coarse-grained) and post-seismic consolidation (fine-grained) in non-saturated soils
- Shear strength and stiffness of saturated, cohesionless soil decrease during shaking
- Substantial permanent deformations of soils
- Losses due to liquefaction contribute to 2.2% of direct economic loss (Daniell et al., 2017)
- Damage and economic loss associated to the soil deformation (e.g., 1964 M9.2 Good Friday, Alaska; 1964 M7.6 Niigata, Japan)
- Indirect losses due to liquefaction occurrence
- Moderate magnitude events may lead to considerable losses

Why bother?

https://constrofacilitator.com/liquefaction-phenomenon-and-mitigation-strategies-for-soil-engineering/

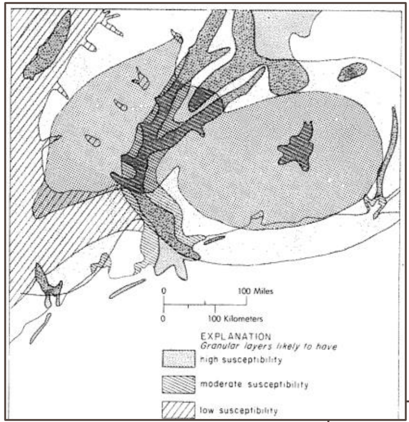
The New York Times: A tsunami didn't destroy these 1,747 Homes. It was the ground itself, flowing.

https://www.geoengineer.org/events/geotechnical-earthquake-engineering-a-berkeley-virtual-short-course-series

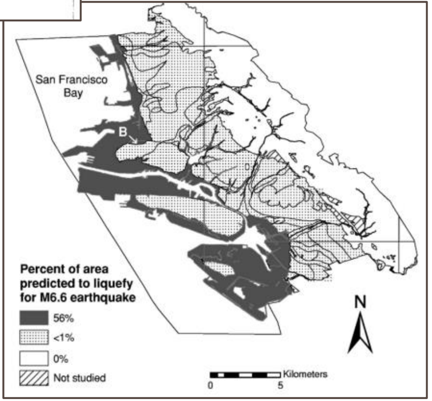
Critical aspects of liquefaction hazard assessment

- Susceptibility, initiation and effects are considered in comprehensive evaluation
- Soil liquefaction is a spatially localised phenomenon limited to certain geological and hydrological settings
- Assessing geological units and depositional processes can assist in identifying areas prone to liquefaction
- High susceptibility to soil liquefaction is observed in:
  - Young, saturated sediments in coastal regions susceptible to liquefaction
  - Soils with uniform grain-size distribution
  - Artificial fills when placed without compaction
- Given the topography, various ground failure types are possible (e.g., crack openings in flat terrain, lateral spreading on gentle slopes)

Multi-tier modelling of liquefaction



Youd et al. (1978) – Generalised susceptibility map delineating sedimentary deposits with different likelihood of containing sediments susceptible to liquefaction



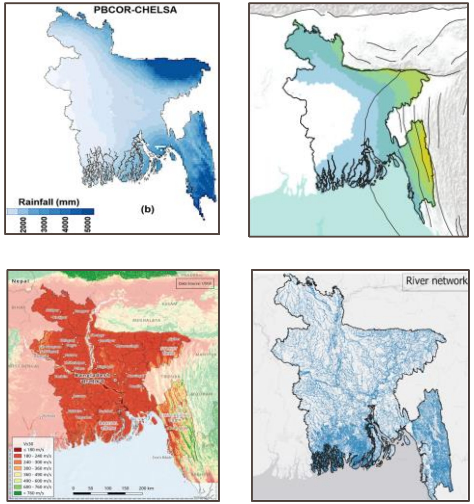
Holzer et al. (2006) – % of land area that would exhibit surface manifestation of liquefaction given a M6.6 earthquake

- Instability occurring at a local scale
- Initial attempts to link the liquefaction susceptibility to surficial geology
- Contributing factors include sedimentation process, age of deposition, geologic history, water-table depth, grain-size distribution

- Improved and more informative hazard mapping with parameters that predict liquefaction potential of the geological unit

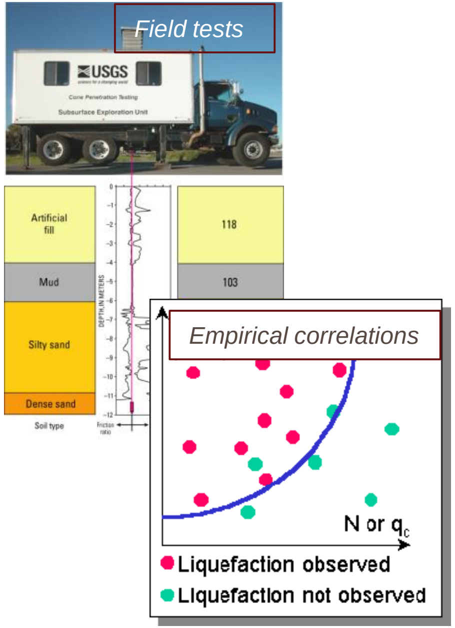
Multi-tier modeling of liquefaction

Tier 1 based on:

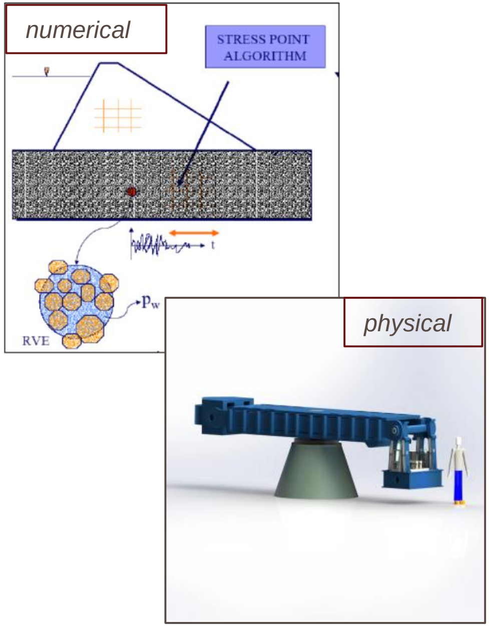


Empirical models relying on explanatory variables that have global coverage (e.g., precipitation, gwd, vs30, pgv, pga)

Tier 2 based on:



Tier 3 based on:



Complexity & cost

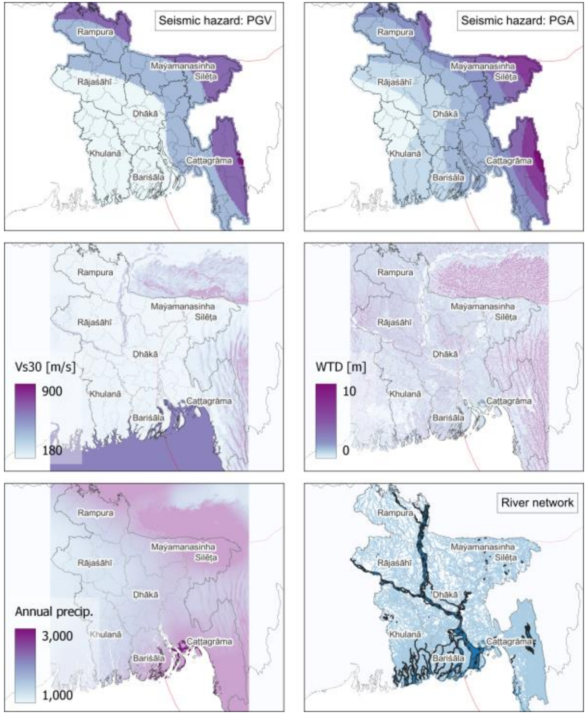
Tier 1 – geospatial modelling of liquefaction

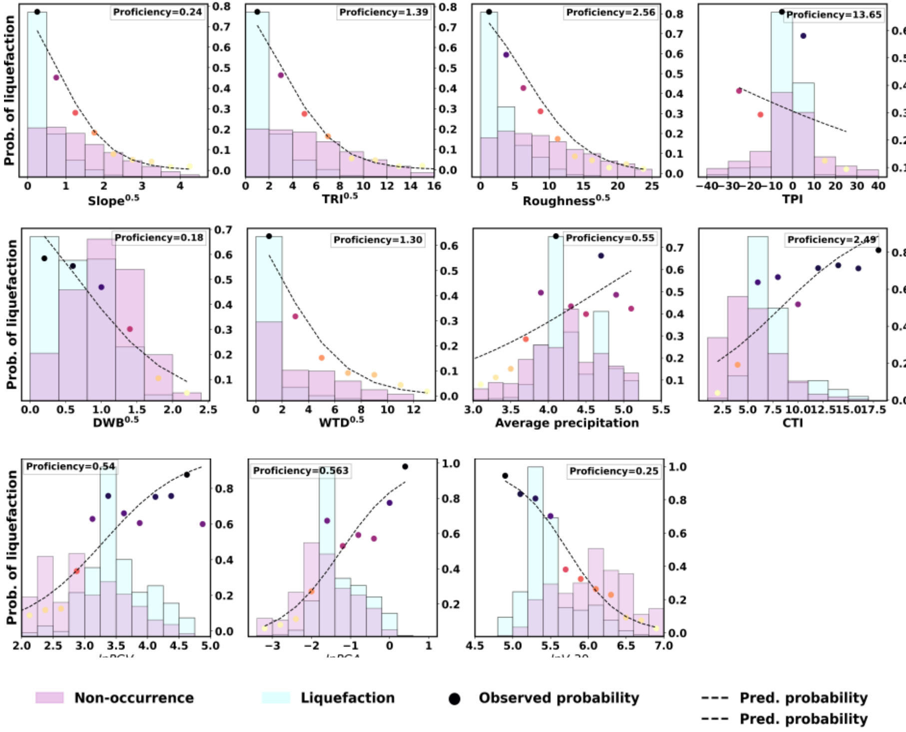
- Models combine seismic, geological, hydrological information
- Use of parameters with global coverage (water-table depth, distance to the water bodies, vs30, slope) in lieu of field tests results (from SPT, CPT)
- Seismic demand is characterised via ground motion intensity measure such as pga and/or pgv
- Use magnitude-corrected shaking parameter to indirectly account for duration

Load	Density	Saturation
pga(m)	Vs30	gwd
pgv	slope	dr
	TRI	dc
	dc	CTI

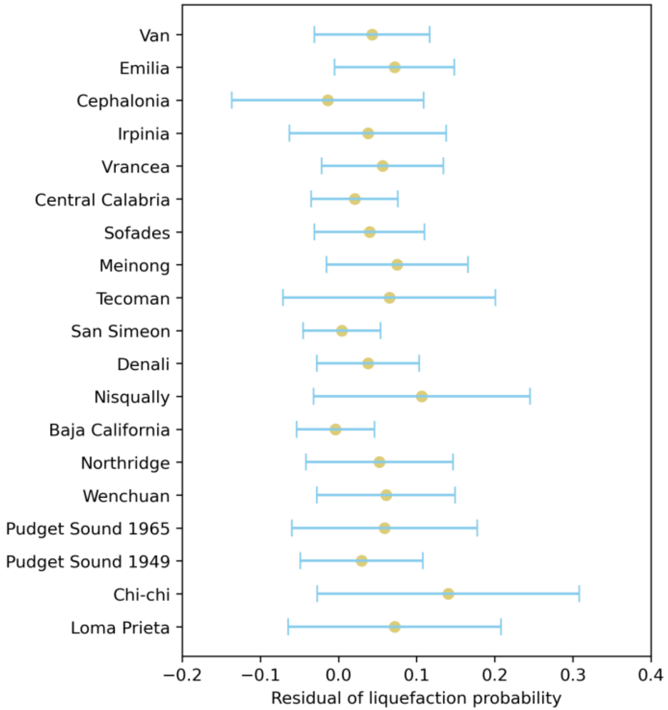
- Existing models: Zhu et al. (2015, 2017), Allstadt et al. (2022), Todorovic and Silva (2022)

Tier 1 – geospatial modelling of liquefaction



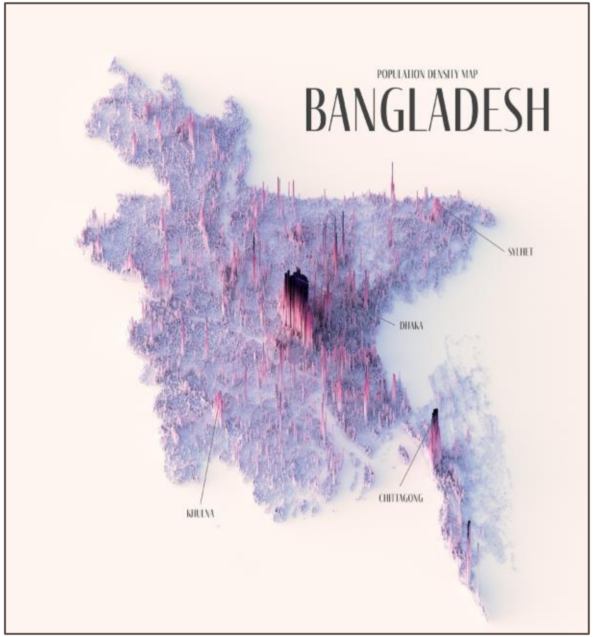


Tier 1 – geospatial modelling of liquefaction



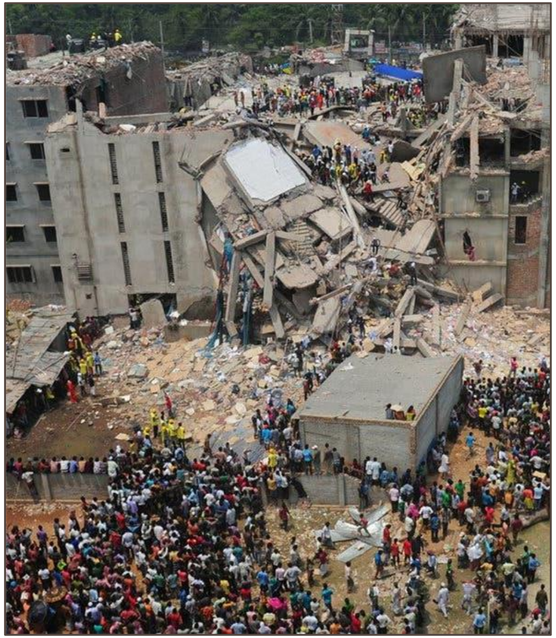
- Database of liquefaction surface manifestations mapped during geotechnical reconnaissance and/or using remote sensing techniques
- Associate observations with the corresponding input variables
- Select the optimal set of variables using the Luco and Cornell (2007) approach
- Selection of parametric or non-parametric model to fit the data and its evaluation on the unseen dataset
- Expected output: probability of liquefaction, binary output, liquefaction spatial extent

Need for nationwide earthquake (and liquefaction) assessment



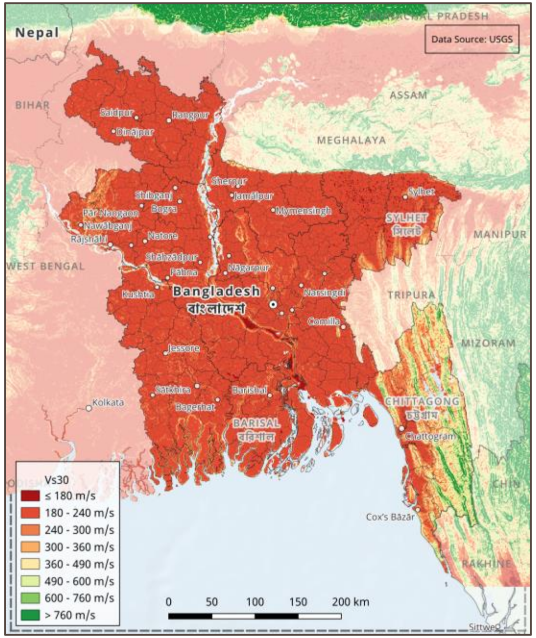
High population across the country, with a particular concentration in Dhaka

Bangladesh population: 165 million (2022 census)
Dhaka metropolitan area: 22.5 million (2022 census)



Rapid urbanization coupled with poor quality RC construction & slums

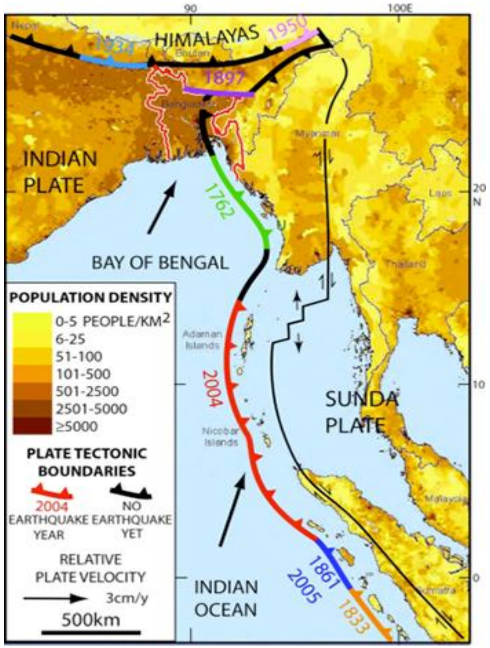
Collapse of Rana Plaza in Savar, Dhaka led to 1,134 fatalities and around 2,500 injuries



80% of the country is a river delta – deep deposits of soft clay & silt

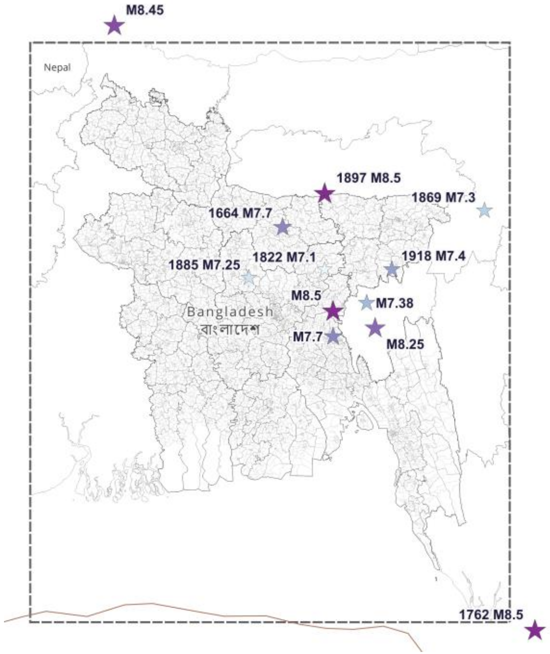
Potential for significant amplification of ground motions and liquefaction

Scenario liquefaction hazard assessment



Subduction plate boundaries

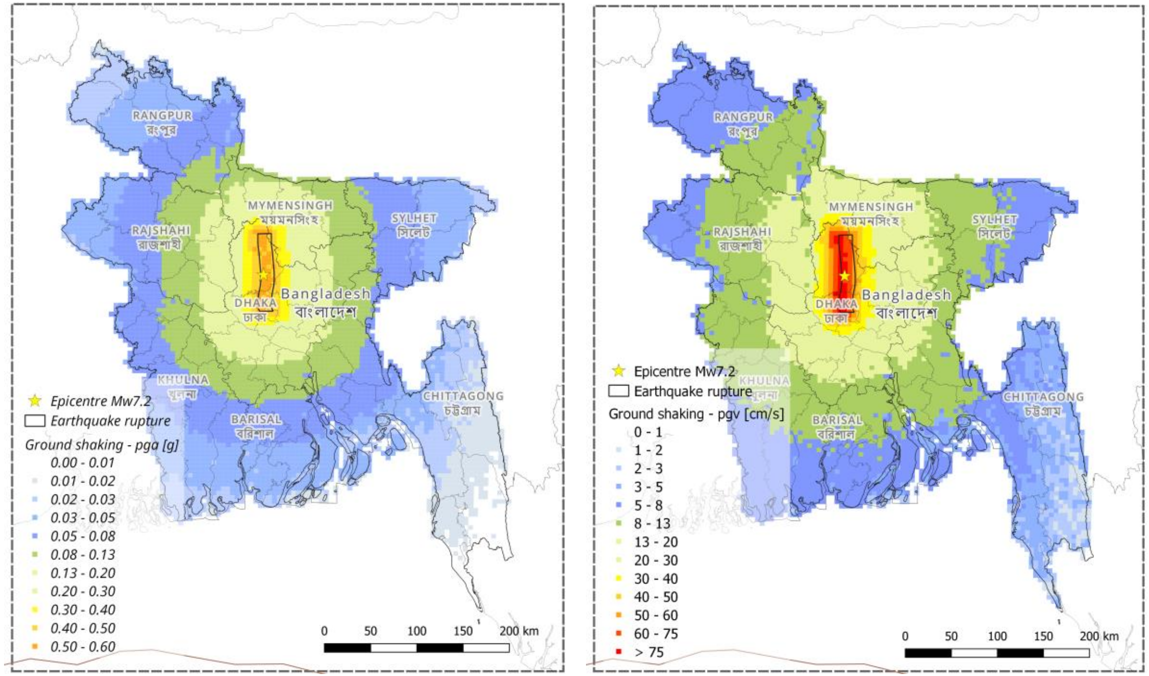
Source: Michael Steckler / Lamont-Doherty Earth Observatory



Scenario selection based on historical and likely potential events

- Ruptures solution from existing GEM research in region
- Mapped based on publications and topography (e.g., Madhupur)
- OpenQuake Engine scenario calculator

Scenario: 1885 M7.25 Bengal



- Proximity to densely populated city - Dhaka
- Active shallow crust
- Ground motion models:
  - AbrahamsonEtAl2014
  - ChiouYoungs2014
- Bradley (2012) cross correlation model

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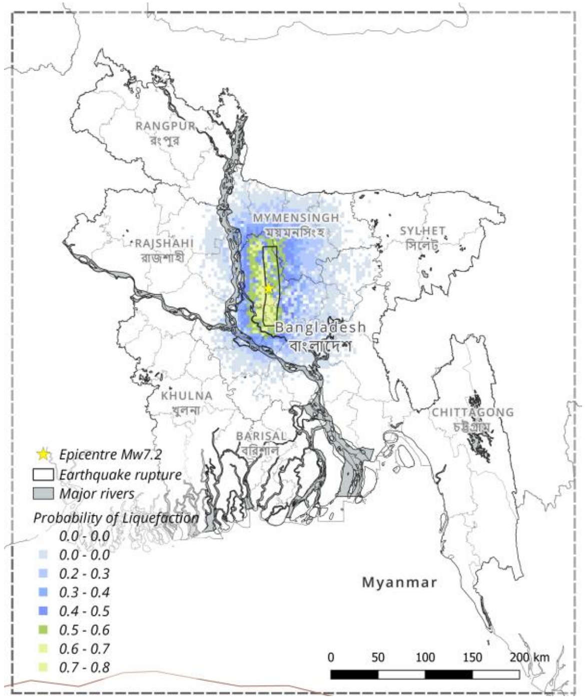
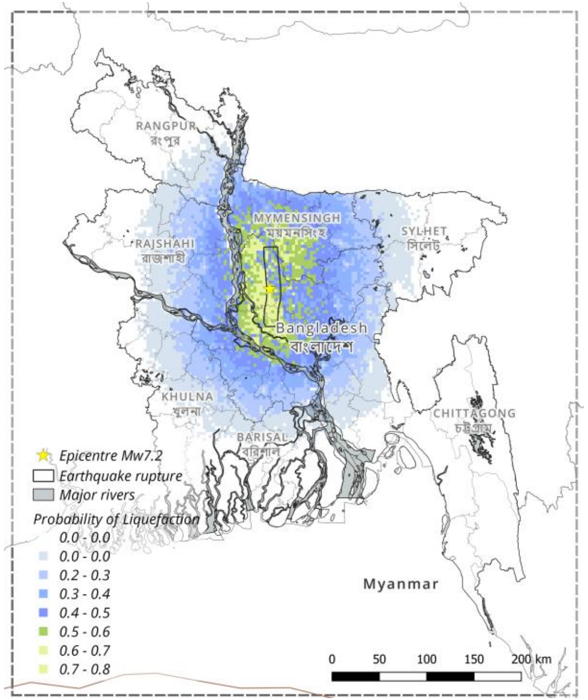
Scenario: 1885 M7.25 Bengal



Liquefaction model: Todorovic and Silva, 2022



Liquefaction model: Allstadt et al., 2022

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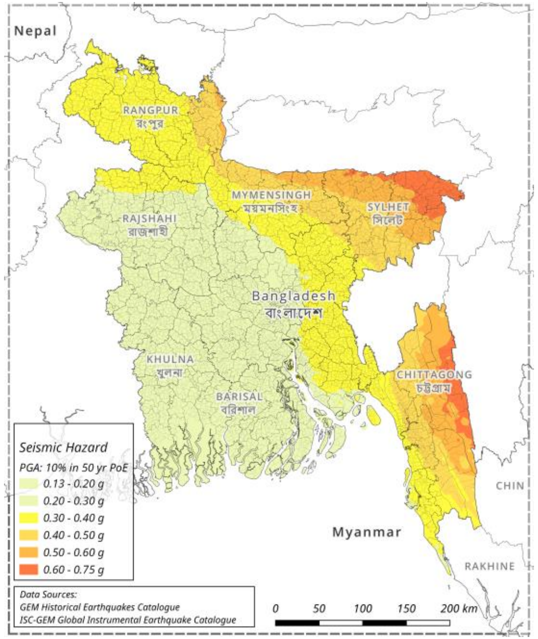
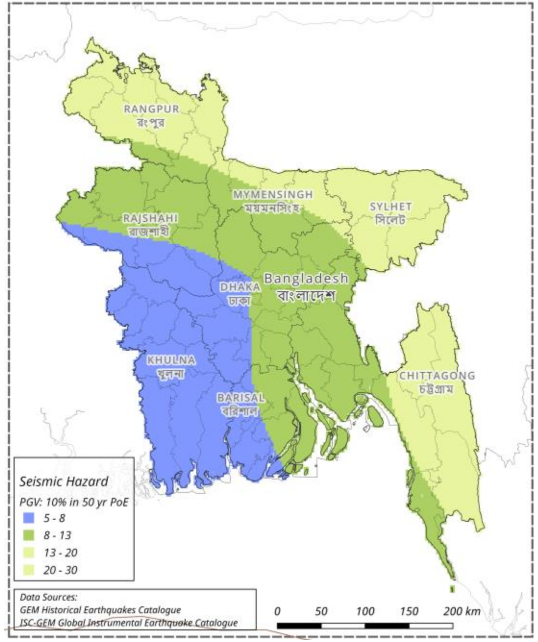
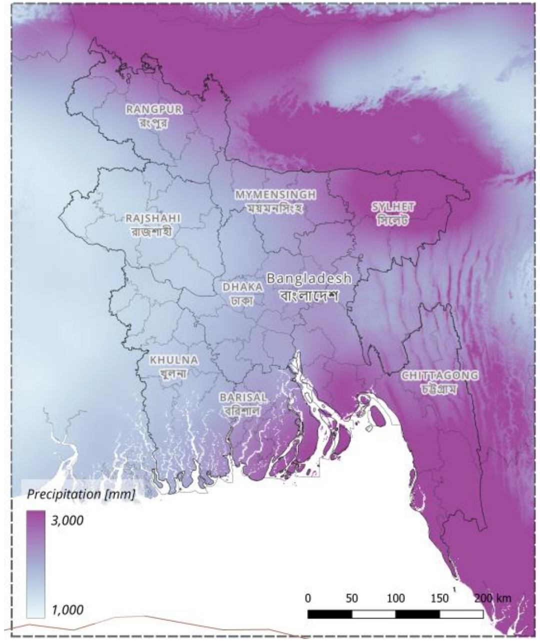
Event-based PLHA







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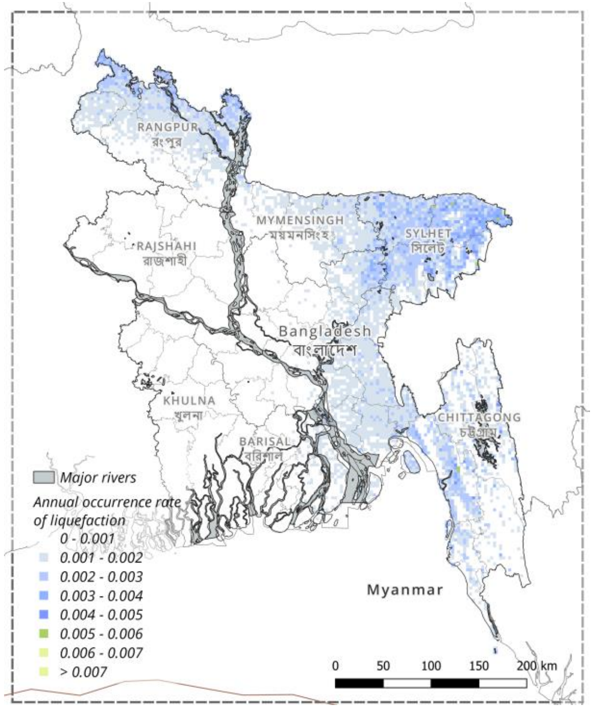
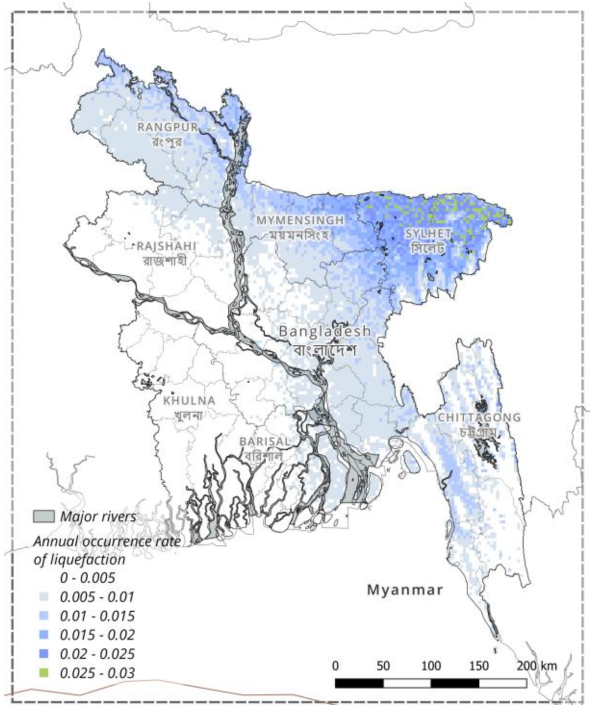


Liquefaction model: Todorovic and Silva, 2022



Liquefaction model: Allstadt et al., 2022

- Contribution of various events to liquefaction occurrence
- Holistic representation of liquefaction hazard
- Annual rates are computed for 100,000-year long stochastic catalogue

Concluding remarks

- Liquefaction hazard assessment has been mostly explored at the local (or urban) level, but new geospatial methodologies (Tier 1) have been proposed in the last decade
- Assistance in identifying areas with higher likelihood of occurrence where more detailed studies could be conducted
- Demonstrate potential despite their approximate nature
- Comparison of Geospatial and Geotechnical models
- Increase of data availability (e.g., NGL) could contribute to the increase of number of data-driven approaches

Thank you!

Please attribute to the GEM Foundation with a link to:
https://www.globalquakemodel.org