Maricar Rabonza (Dr)[1,2], David Lallemant (Asst Prof)[1,2]
[1] Earth Observatory of Singapore, [2] Asian School of the Environment Nanyang Technological University Singapore

Abstract ID: 1386090
Paper Number: GH23D-0935
AGU 2023, San Francisco - 11-15 Dec 2023

Modeling Time-Dependent Urban Risk for Policy Analysis in Disaster Risk Management

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE · EARTH OBSERVATORY OF SINGAPORE · DISASTER ANALYTICS FOR SOCIETY LAB @NTU

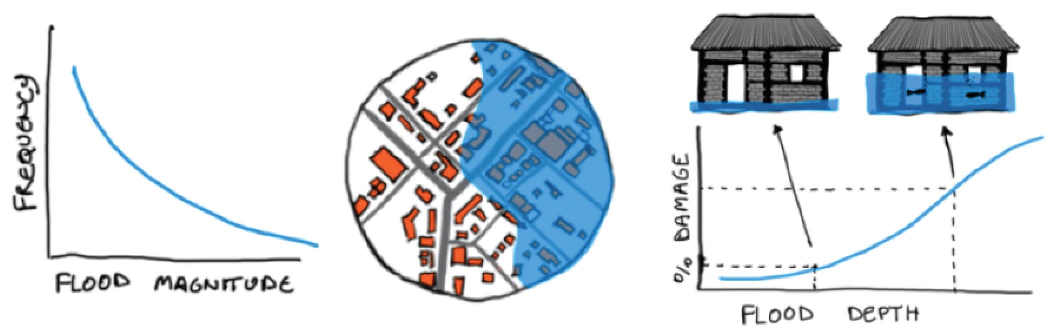
We estimated the **future risk from climate hazards** of physical infrastructures in a large-scale region in the Philippines

Modelling time-dependent risk is key to understanding the hazard-related risk in urban environment over the lifespan of its infrastructures.

Issue:

There is a lack of focus in accounting for time-dependent variations in exposure and vulnerability for large-scale risk analysis

HAZARD ⊗ EXPOSURE ⊗ VULNERABILITY

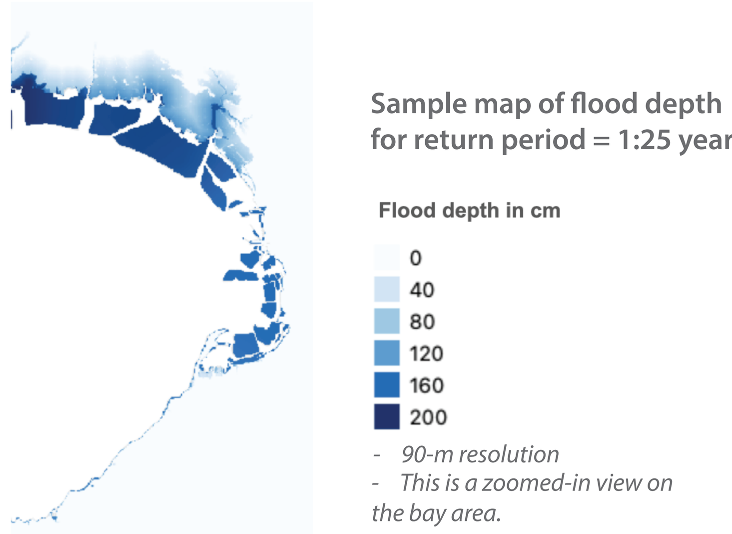


Adapted from drawings by: D. Lallemant

Study area:

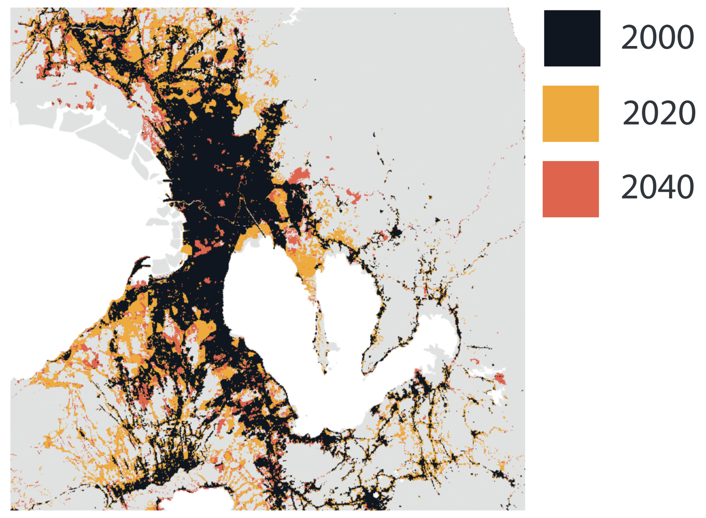
1 How can we calculate large-scale urban risk from climate hazards while considering time-dependent variations in urban extent (exposure)?

Hazard data:

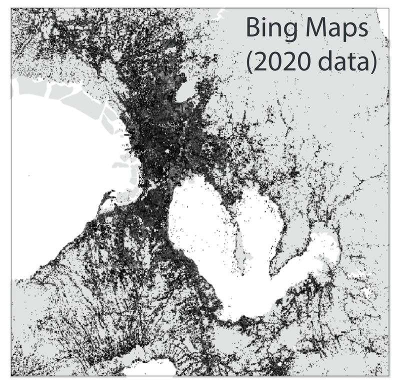


- We used coastal surge-induced flood depth maps for 2020 and 2040 and for the following return periods: 1 in 1 yr, 2yrs, 5 yrs, 10 yrs, 25 yrs, 50 yrs, 100 yrs, 250 yrs, 500 yrs, and 1000 yrs.
- The maps are developed by the Disaster Analytics for Society lab. The model accounts for climate change, hydraulic connectivity and path-based attenuation (Kasmalkar 2023, Under review). Here, we use 90-m for the analysis, but the flood models are also available in 30-m resolution globally, which is useful for future work.

Exposure data:

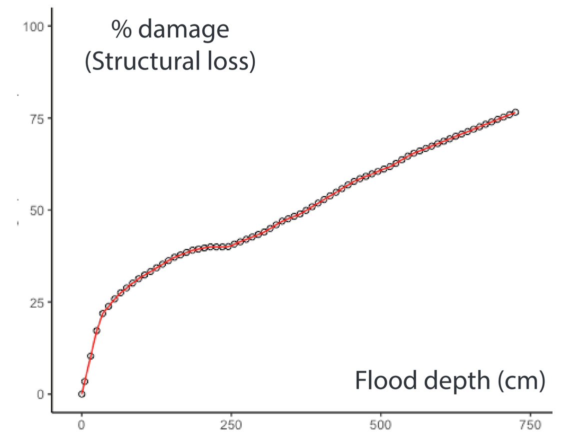


We simulated urban growth for 2040 using an urban growth model that accounts for socio-economic factors.



We consider historical building count data to translate the exposed urban extent to number of buildings.

Vulnerability data:

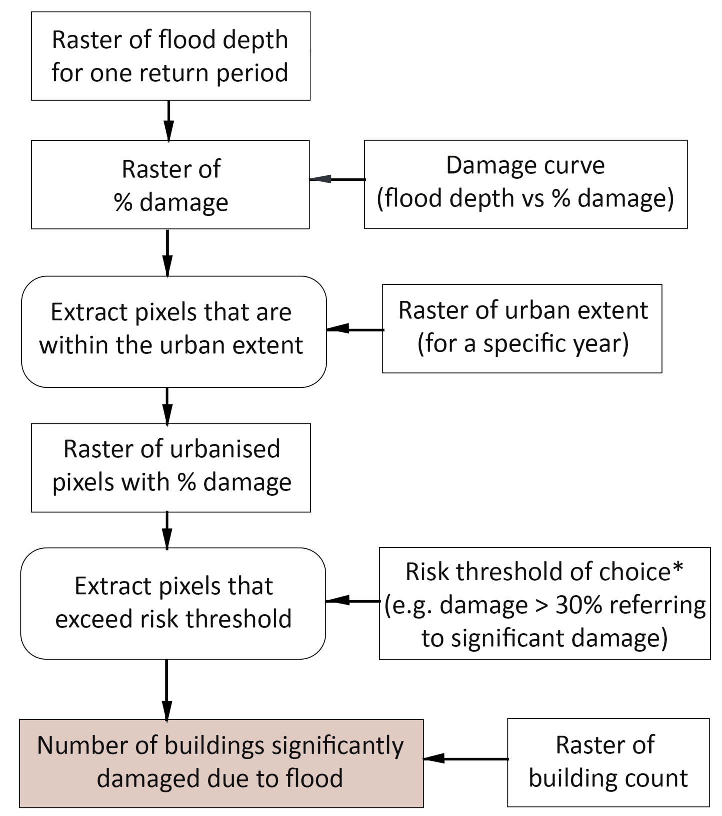


We assumed a single building type and adopted a damage-flood depth function from FEMA HAZUS.

This damage curve represents the expected structural damage for a 2-storey single family dwelling with no basement.

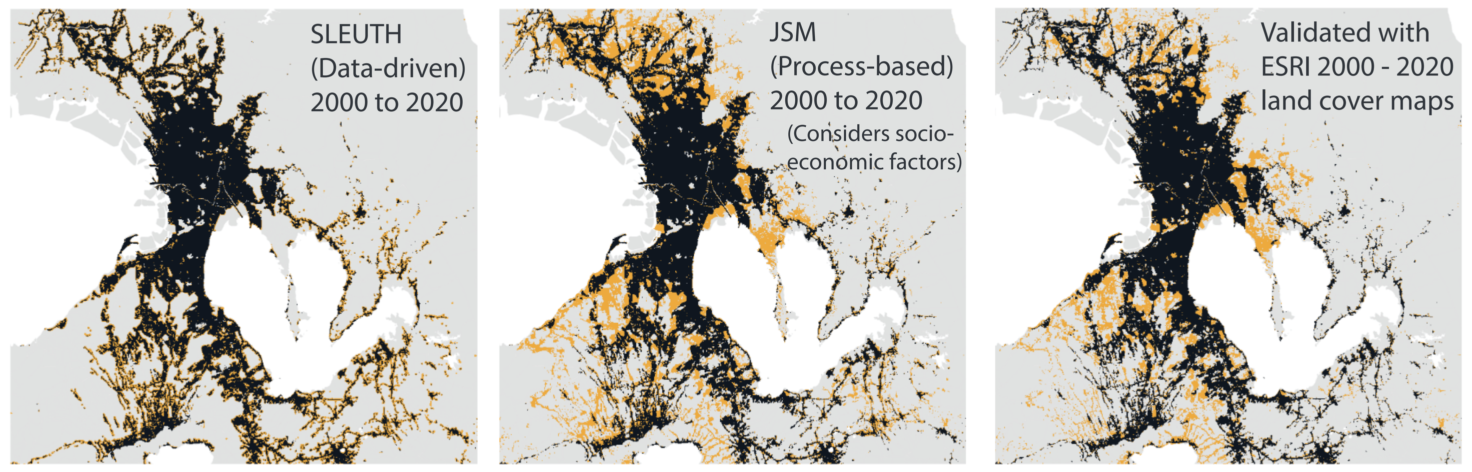
Methodology in a GIS/R environment

This procedure is repeated for multiple return periods.



*The analysis can be adopted to account for the cost of building repair instead.

How do we select a suitable urban growth model?



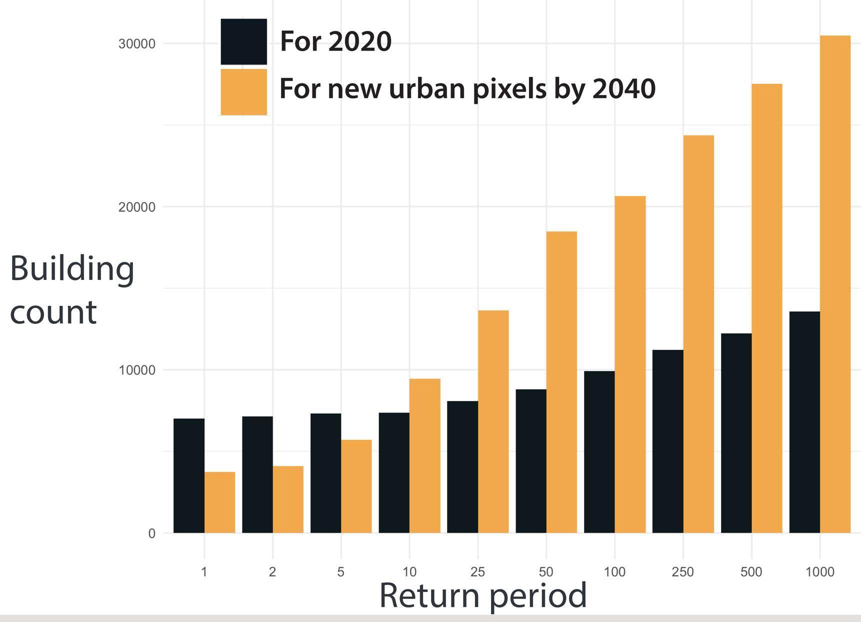
- We tested the performance of 2 models (SLEUTH and Java Spatial model) to predict the urban growth in 2020 (Liu et al, 2023, In-prep).
- We used the 2020 ESRI global land use map as reference for the validation
- We selected the Java Spatial model for our analysis to model the 2040 urban growth.

2 How can we simulate the future benefits of policy interventions / mitigation?

Scenario 1: Baseline

We calculated the number of buildings of significant exposure (damage > 30%) for the year 2020 and 2040 considering the hazard, exposure and vulnerability inputs above. The buildings at the new urban pixels (shown in yellow) does not include 2020 buildings.

Number of buildings of significant exposure
(Buildings with expected damage of >30%)

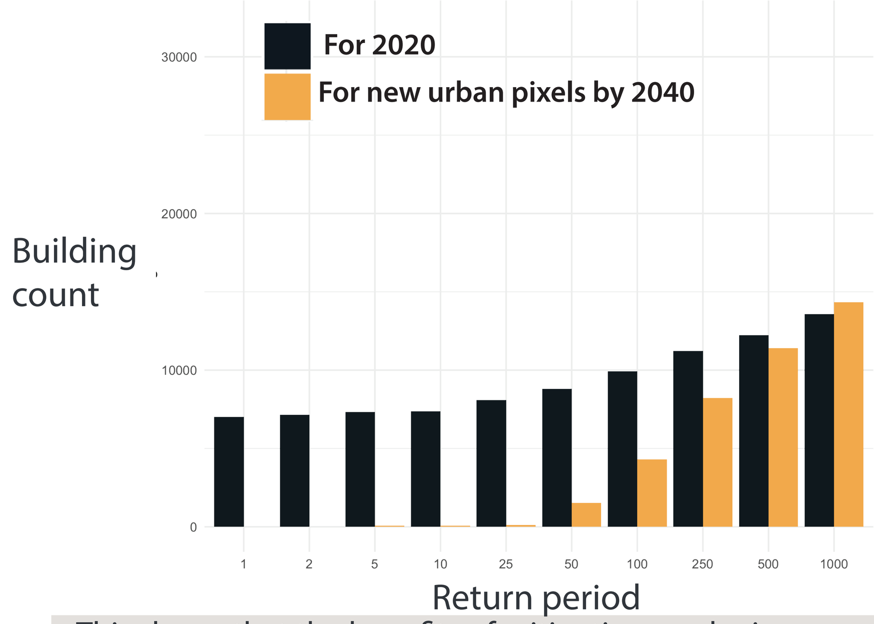


New buildings built after 2020 will experience significant exposure to more extreme events. This could indicate that many of these new buildings will likely be located at more hazardous zones.

Scenario 2: With flood buffer policy.

This implements a policy that restricts placing new buildings at zones that will experience >1-meter flood depth from a 100-year flood in 2040. This increases the building density at other areas to accommodate the expected growth in 2040.

Number of buildings of significant exposure
(Buildings with expected damage of >30%)



This shows that the benefits of mitigation can be incorporated in a dynamic risk analysis framework. Here, the flood buffer policy mitigated the potential increase in significantly damaged buildings for new buildings in 2040.

Takeaways:

Not only the impact of climate change on natural hazards, but also population growth, economic development, and changing vulnerabilities are significant long term drivers for risk that should be accounted for within risk reduction planning and risk modeling.

The process can be adopted for other policy applications that may involve:
- A different urban extent (corresponding to another year or buffer policies)
- Another damage curve (for another building type, or to implement a policy
- that makes buildings more resilent to floods).
- Another hazard type (e.g. large-scale seismic retrofitting programs that
- enhance seismic vulnerability)

Year	Average annual buildings of significant exposure
2020 (Start year)	3631
2040 (Scenario 1: Baseline)	6360
2040 (Scenario 2: With flood buffer policy)	3702

Calculating the risk for different return periods allows us to get the average annual buildings of significant exposure.

In future risk analysis, we need to consider the potential **changes in each component of the risk triangle.**

Presenter: Dr. Maricar L. Rabonza (maricar.rabonza@ntu.edu.sg). Funded by NRF Singapore and EOS.