Calibrating Displacement Curves to Forecast Forced Migration due to Sea-Level Rise and Tropical Storms

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INTRODUCTION

The link between climate change and human mobility is an emerging field of study and requires empirical investigation to establish the mechanisms through which the impacts of climate change shape mobility responses and decisions. Studies examining the impact of climate change-induced hazards on displacement of migration have used housing damage as a proxy for displacement risk. However, these studies use a fixed threshold of damage, above which displacement is theorised to occur, and these thresholds are not empirically calibrated.

In order to address this gap, this study utilises historical housing damage and displacement data from typhoons that have occurred in the Philippines to calibrate displacement curves that link flood- and wind-damage to the risk of being displaced. These curves are intended to be used as part of a model of displacement risk, as shown in Figure 1.

This project is part of a PhD thesis investigating the impact of sea-level rise on human migration and displacement in Southeast Asia.

Displacement Risk Model

In order to address the 'who' dimension of climate change-induced displacement, a displacement risk model is developed to assess the risk of displacement of populations in the face of sea-level rise and tropical storms.

Variable

POP	DIS	HD	FD
No. of people displaced	Proportion of people displaced	Proportion of housing damage	Flood depth

Rate of exceedance function

-	$G_{DIS\mid HD}$	$G_{HD\mid FD}$	$\lambda(FD)$

Equation to calculate Average Annual Displacement (AAD)

$$AAD = \sum_i POP_i \times \int_{FD} \int_{HD} G_{DIS\mid HD}(DIS|HD) \mid dG_{HD\mid FD}(HD|FD)\, d\lambda(FD)$$

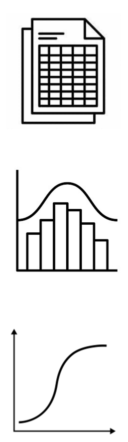
Figure 1. Schematic diagram of the displacement risk model, which computes the probability of displacement due to housing damage suffered from flooding due to sea-level rise and tropical storms. This study is calibrating an empirical curve relating housing damage to displacement, as highlighted in red in the diagram.

METHODOLOGY

Data for the following typhoons was obtained from the situation reports published by the Philippines' Disaster Response Operations Monitoring and Information Centre (DROMIC):

- Typhoon Ompong (Mangkhut), 2018
- Typhoon Rolly (Goni), 2020
- Typhoon Vamco (Ulyssess), 2020
- Typhoon Rai (Odette), 2021
- Tropical Storm Nalgae (Paeng), 2022

The data for calibration was taken from reports 2 weeks after each typhoon made landfall in the Philippines. The data includes counts of partially and totally damaged houses per municipality (ADM 3), as well as displaced individuals and families inside evacuation centres and outside evacuation centres. The data for all storms listed above was used to calibrate a final displacement curve for the Philippines. The process of this calibration is shown in Figure 2.



Housing damage and displacement data from DROMIC

Generate Beta distribution for categorical housing damage data (i.e. partial and total damage)

Calibrate logistic curve using data for all storms from all municipalities

Figure 2. Diagram illustrating the process of developing the displacement curves in this study.

The probability of displacement is computed by:

$$P = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x)}}$$

The probabilities are optimised by computing the absolute error between predicted and observed displaced individuals for each municipality.

RESULTS

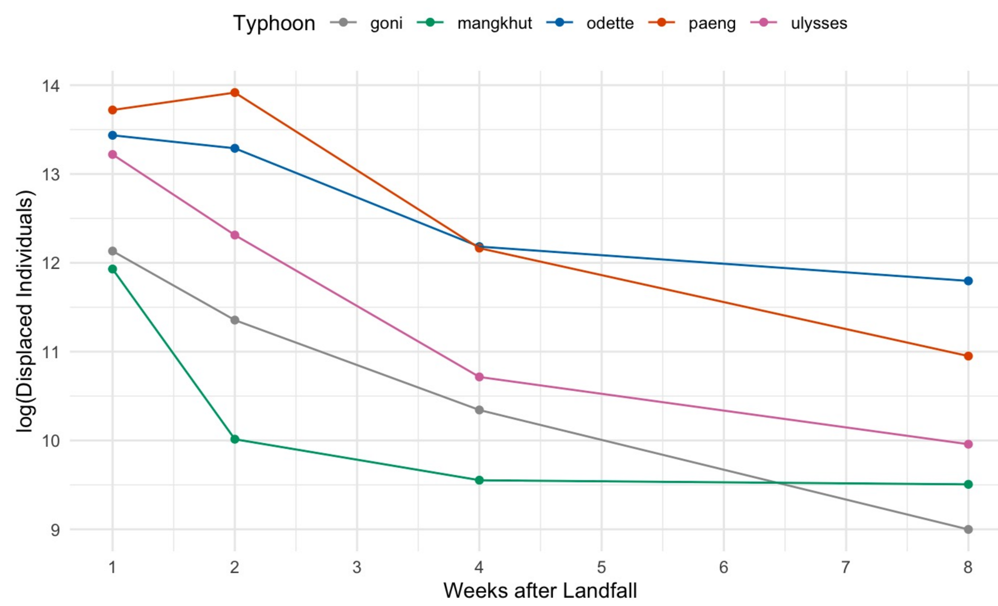


Figure 3. Time-series graph of displaced individuals at 1, 2, 4 and 8 weeks of landfall of each typhoon. This includes individuals both within and outside evacuation centres. The y-axis is on a log scale.

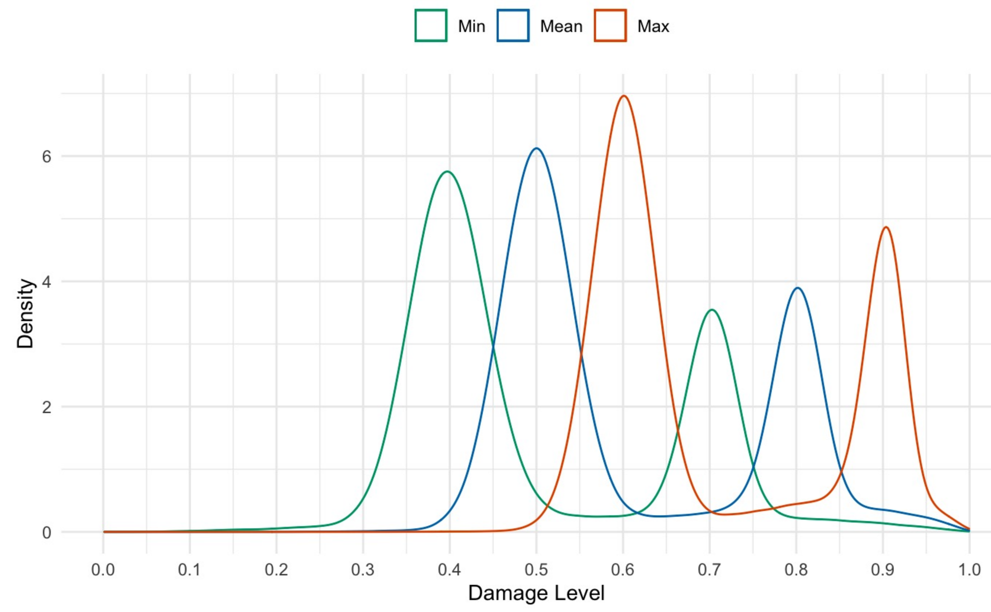


Figure 4. Density plot of the Beta distributions generated for the categorical housing damage data. Min refers to partial damage is centred at 40% and total damage is centred at 70%, mean refers to partial damage of 50% and total damage of 80%, and max refers to partial damage of 60% and total damage of 90%.

- Displacement is highest in the first few days after a typhoon makes landfall, as this data includes pre-emptive evacuations. In order to capture prolonged displacement, it is necessary to look at data in the weeks after landfall
- The displacement curves in this study are developed for time-steps 2 weeks and beyond landfall, as there is completeness of data for the necessary variables and most pre-emptive evacuees (particularly those who have not suffered housing damage) have returned home
- The curves encompass displacement both within and outside evacuation centres
- As seen from Figures 4 & 5, the curves are sensitive to the distribution of housing damage. Given that the housing damage was reported as categorical data (i.e. partial or total damage), Beta distribution curves were developed for the min., mean, and max. theorised distributions of the data, so as to capture the uncertainty in this variable
- The curves are also sensitive to the time at which displacement is considered. As seen from Figure 5, the curve developed for displacement 2 weeks after typhoon landfall show a higher probability of displacement at lower levels of housing damage as compared to the curve for 1 month after landfall
- The curves demonstrate that applying a threshold of housing damage, above which displacement would occur, would be insufficient in capturing displacement that occurs even at lower levels of housing damage
- As these curves are developed for housing damage rather than hazard intensity, they are hazard-agnostic
- The curve was tested against each storm used in the calibration and the percentage absolute error ranged from 14 - 44%

Displacement Curves

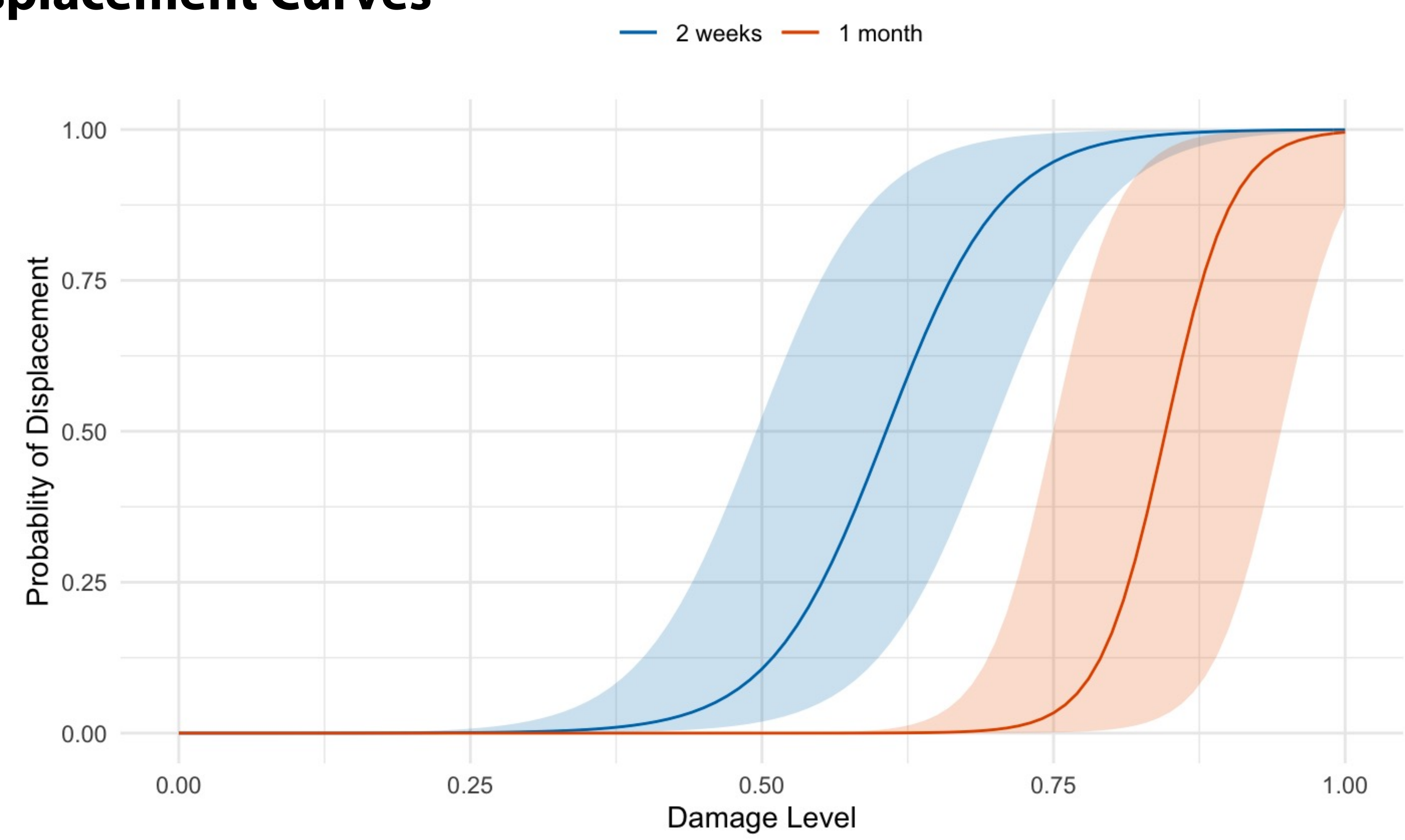


Figure 5. Displacement curves calibrated on data from 5 typhoons in the Philippines, with the curve in blue representing the probability of being in displacement 2 weeks after typhoon landfall, and the orange curve representing that 1 month after landfall. The shaded area around each curve represents the range of uncertainty around the housing damage levels that were reported.

NEXT STEPS

- Improve model performance
  - Change the underlying distribution for housing damage and/or the objective function
  - Train on additional storms
- Test transferability of displacement curves by validating against data from storms in other countries
- Integrate displacement curves into displacement risk model (Figure 1) and compare displacement estimates against the threshold method
- Develop predictions of duration of displacement based on housing damage

MAIN MESSAGES

- Empirically-grounded displacement curves are required to reliably predict the risk of displacement due to housing damage
- This study uses municipality-level housing damage and displacement data from 5 typhoons in the Philippines to calibrate displacement curves for the country
- The curves demonstrate that displacement is likely at lower levels of housing damage than previously assumed
- These curves will be integrated into a displacement risk model (Figure 1) to forecast forced migration due to sea-level rise and tropical storms

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