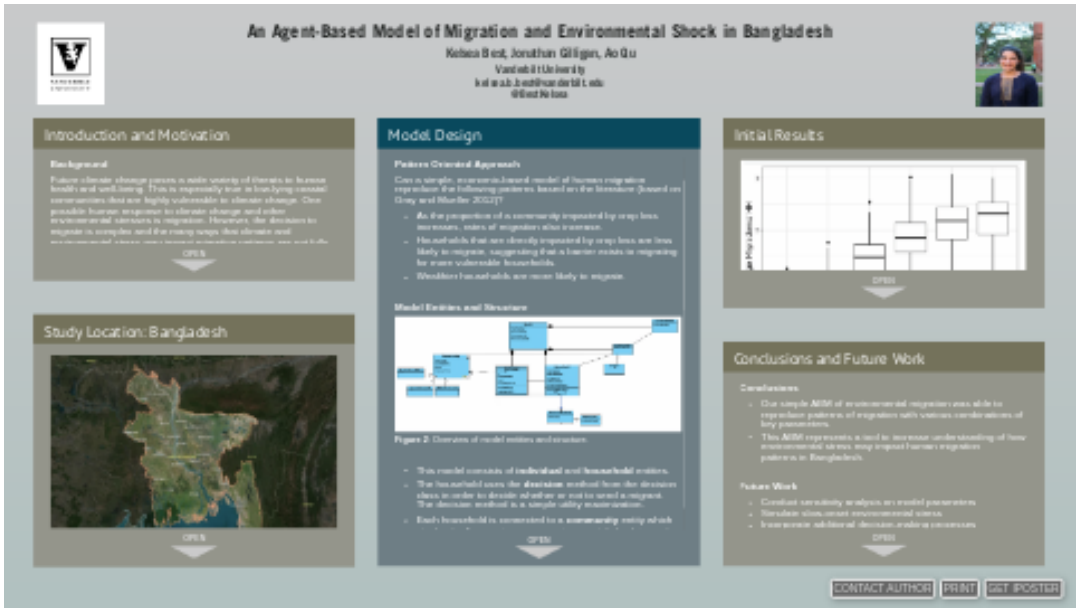
An Agent-Based Model of Migration and Environmental Shock in Bangladesh



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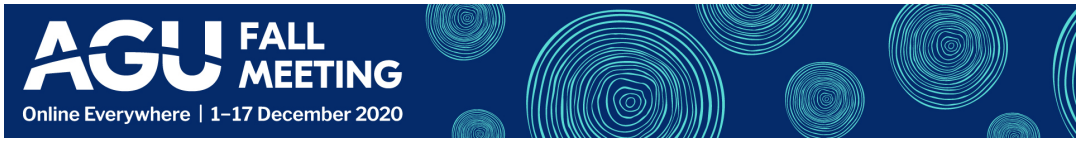

INTRODUCTION AND MOTIVATION

Background

Future climate change poses a wide variety of threats to human health and well-being. This is especially true in low-lying coastal communities that are highly vulnerable to climate change. One possible human response to climate change and other environmental stresses is migration. However, the decision to migrate is complex and the many ways that climate and environmental stress may impact migration patterns are not fully understood.

Motivating Question

How changing environmental conditions and livelihood opportunities impact migration decisions in coastal Bangladesh?

Project Summary

- This work utilizes original agent-based model (ABM) that combines stylized environmental shocks with livelihood decisions to understand how these dynamics impact migration.
- ABM aims to reproduce known patterns of migration in Bangladesh and explore feedbacks that may exist.
- The purpose of the model is to simulate household migration decisions in Bangladesh under environmental pressure.

STUDY LOCATION: BANGLADESH

Figure 1: Satellite image of Bangladesh (highlighted).

Bangladeshi context

- Bangladesh is located on the low-lying deltaic floodplain of the Ganges-Brahmaputra-Jamuna Delta, which includes the Ganges, Brahmaputra, Jamuna, Padma, and Meghna Rivers (**Fig. 1**).
- It is estimated that more than 50 million people live in the coastal areas of Bangladesh where they are highly vulnerable to natural disasters and environmental shocks.
- Both natural and human changes to the environment are causing shifts in livelihood choices.

Migration in Bangladesh

- In Bangladesh, migration has long been a way of life as a common method of livelihood diversification and adaptation to stressful natural conditions, especially seasonal rural to urban migration.
- There is little agreement as to how environmental changes will alter migration patterns.

MODEL DESIGN

Pattern Oriented Approach

Can a simple, economic-based model of human migration reproduce the following patterns based on the literature (based on Gray and Mueller 2012)?

- As the proportion of a community impacted by the environmental shock increases, rates of migration also increase.
- Households that are directly impacted by the environmental shock are less likely to migrate, suggesting that a barrier exists to migrating for more vulnerable households.
- Wealthier households are more likely to migrate.

Model Entities and Structure

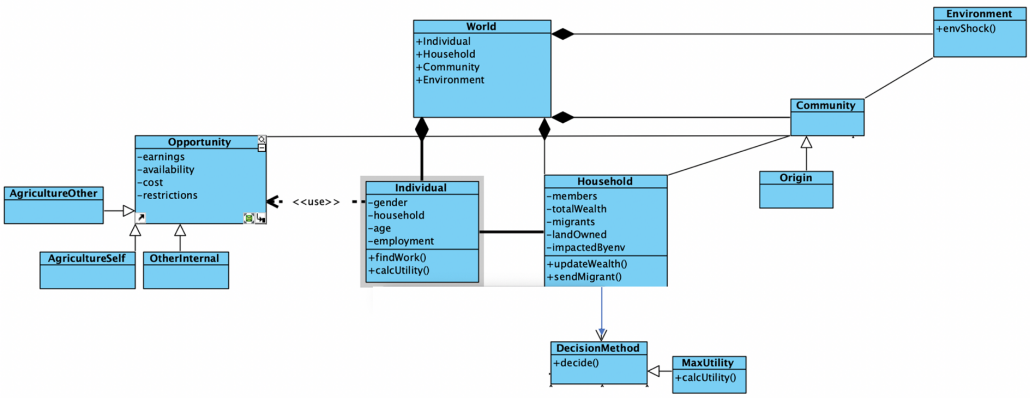

Figure 2: Overview of model entities and structure.

- This model consists of **individual** and **household** entities.
- The household uses the **decision** method from the decision class in order to decide whether or not to send a migrant. The decision method is a simple utility maximization.
- Each household is connected to a **community** entity which stochastically experiences an environmental shock impacting land productivity and, in turn, livelihood.

Parameterization and Calibration

- Parameterized based on available datasets (Table 1).
- Calibration of uncertain paramters (migration threshold and migration utility) based on Grimm, V., & Railsback, S. F. (2012)

Table 1: Model parameters and sources used for parameterization.

Model Parameter	Source
Wealth distribution	Adams H., Adger W.N. 2016. UK Data Service ReShare.
Household size distribution	Carrico A., Donato K., BEMS Survey Data
Land owned distribution	Carrico A., Donato K., BEMS Survey Data
Age distribution	Carrico A., Donato K., BEMS Survey Data
Salaries and expenditures	Adams H., Adger W.N. 2016. UK Data Service ReShare.

- We use a Latin Hypercube to sample the possible parameter space of migration threshold and migration utility. We then select which parameter combinations are able to reproduce patterns of interest are identified (Fig. 3).

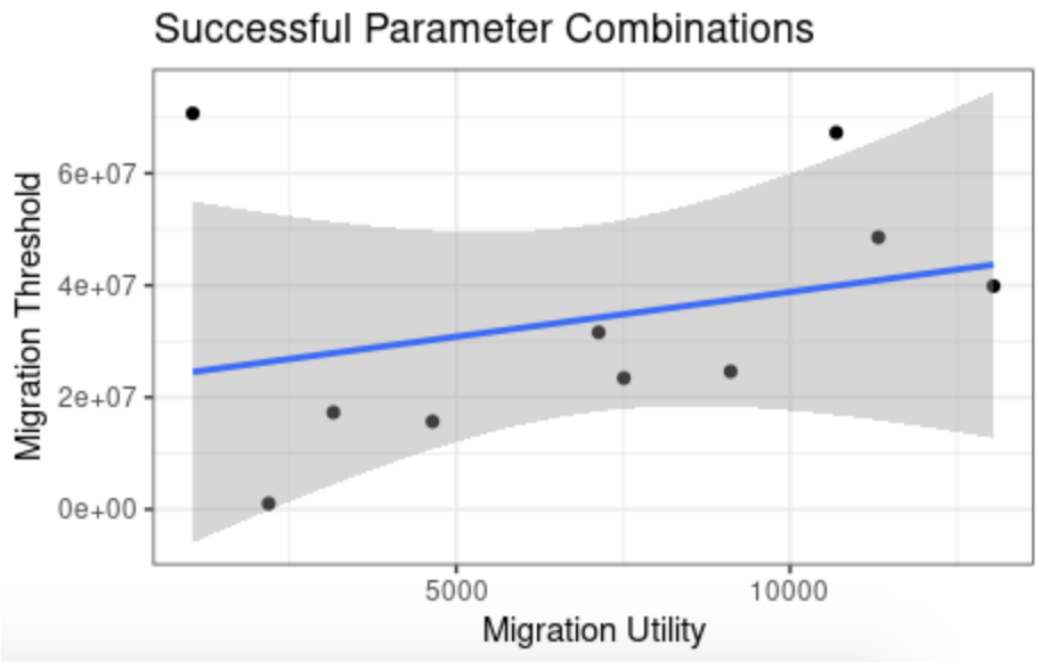

Figure 3: Combinations of migration utility and migration threshold values (both in units of Bangladeshi taka) from the Latin Hypercube sample that were able to reproduce key patterns in the migration outcomes (black points), and linear regression fit to those values (blue line).

INITIAL RESULTS

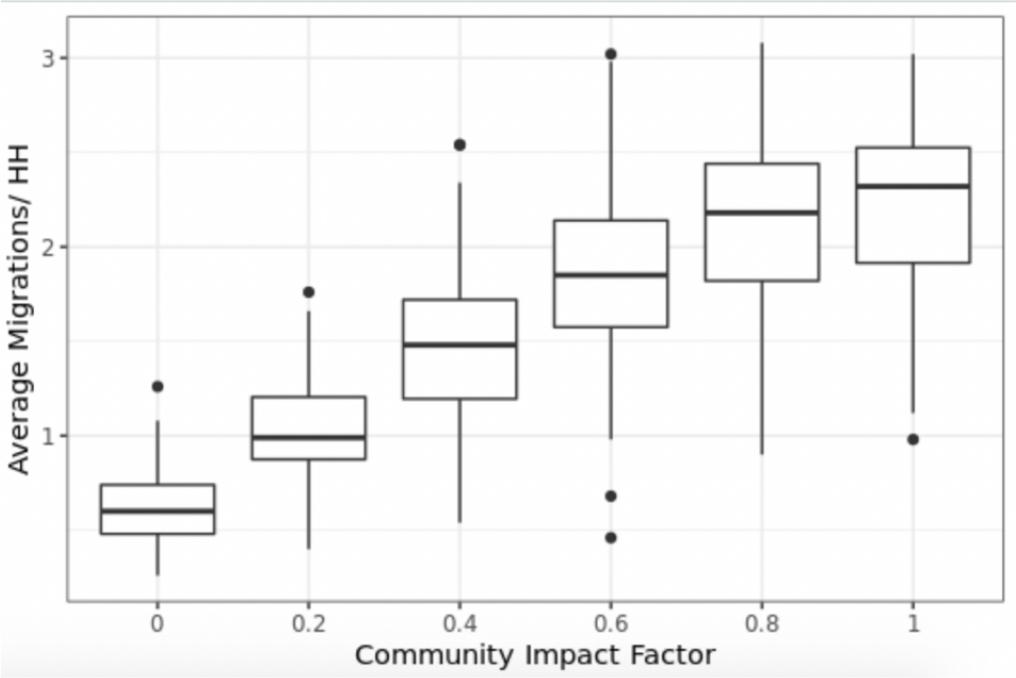

Figure 4: Results of ABM run with varying community impact factor from 0 to 1 show that migrations increase (shown as average number of migrations per household in a 20 year simulation period) with impact factor.

Key Results

- After parameterization and calibration, ABM was run 50 times at varying scale of community impact (i.e. what proportion of the community is impacted by an environmental schok) with various combinations of migration threshold and migration utility. Each run consisted of 100 households and 700 individuals.
- The average number of migrations per household increase with scale of environmental impact (Fig. 4).
- As scale of environmental shock increases, migrating households have greater wealth.
- At sufficienty high migration thresholds, households that are not directly impacted by an environmental shock are more likely to migrate (Fig. 5).

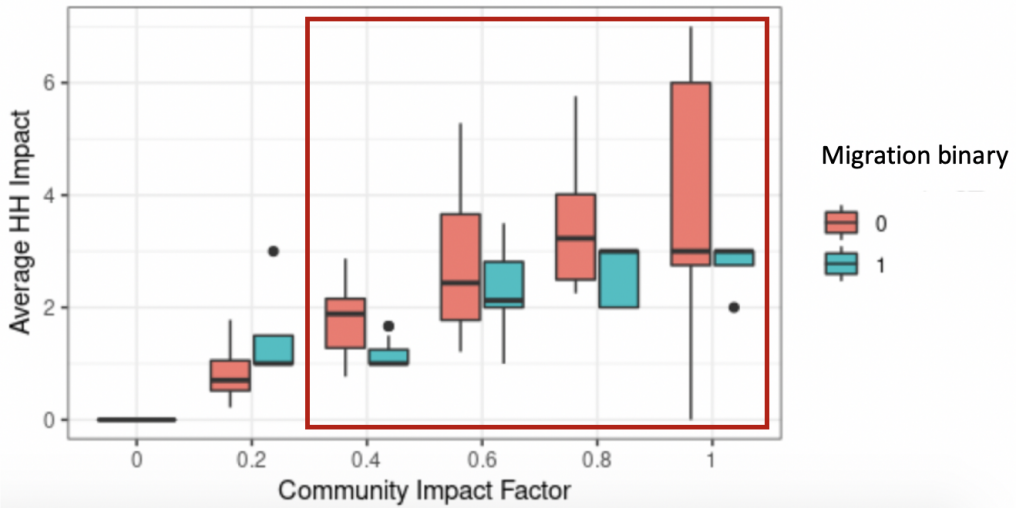

Figure 5: Results of ABM run with combination of migration utility and migration threshold identified by calibration exercise (Fig. 3). At various community impact factors from 0 to 1, the number of times a household was impacted by the envrionmental shock (Average HH Impact) is shown for migrating (blue) and non-migrating (pink) households. These results show that model

is able to reproduce the pattern that households that are not directly impacted are more likely to migrate (combinations within red box).

CONCLUSIONS AND FUTURE WORK

Conclusions

- Our simple ABM of environmental migration was able to reproduce patterns of migration with various combinations of key parameters.
- This ABM represents a tool to increase understanding of how environmental stress may impact human migration patterns in Bangladesh.

Future Work

- Conduct more detailed sensitivity analysis on model parameters
- Simulate slow-onset environmental stress
- Incorporate additional decision-making processes

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ABSTRACT

One possible human response to climate change and other environmental stresses is migration. However, migration is complex, multi-causal phenomenon, and the complexity of human migration poses a challenge for researchers who aim to study the effects of environmental changes on population mobility. This project aims to understand how changing environmental conditions and livelihood opportunities impact migration decisions in coastal Bangladesh. We are developing an original agent-based model (ABM) that combines stylized environmental change dynamics with livelihood to understand how these dynamics impact migration decisions as well as what feedbacks may exist between them. The ABM uses agents to represent households, which consist of individuals, within a single origin community. At each step of the model, the household assesses the expected utility of different livelihood options within the community for each of its members, including agricultural work on the household's land (if any), seeking paid employment within the community, and pursuing non-agricultural livelihood activities. After assessing opportunities within the community, households will decide whether or not a household member should seek opportunities outside the community. The model imposes stochastic droughts that impact crop yields. We report preliminary results from this model, comparing simulated migration patterns to empirical observations. Future work will incorporate more complex and psychologically realistic decision-making heuristics, as well as diverse destination locations and the possibility of return migration.

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1. Adams H., Adger W.N. 2016. UK Data Service ReShare. http://dx.doi.org/10.5255/UKDA-SN-852356, **2.** Carrico, A. R., & Donato, K. (2019). Extreme weather and migration: evidence from Bangladesh. Population and Environment. https://doi.org/10.1007/s11111-019-00322-9 3. Gray, C. L., & Mueller, V. (2012). Natural disasters and population mobility in Bangladesh. Proceedings of the National Academy of Sciences, 109(16), 6000–6005. https://doi.org/10.1073/pnas.1115944109 4. Grimm, V., & Railsback, S. F. (2012). Pattern-oriented modelling: a 'multi-scope' for predictive systems ecology. Philosophical Transactions of the Royal Society B: Biological Sciences, 367(1586), 298–310. https://doi.org/10.1098/rstb.2011.0180