

How We Apply Agent-Based Modeling of Climate-Induced Internal Migration in Sri Lanka

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Abstract - Climate change has become a major driver of internal migration, especially in developing countries where agriculture-dependent populations are highly vulnerable to environmental shocks. This study presents an agent-based model (ABM) for simulating climate-induced internal migration in Sri Lanka. The model integrates seasonal climate variability, household economic conditions, crop failures, food insecurity, aid interventions, and return migration. Implemented in NetLogo, the simulation represents 300 heterogeneous household agents distributed across coastal, dry, and wet climatic zones. Results show that migration emerges through the interaction of climate stress, repeated crop failure, and economic hardship. Climate stress contributes 40% of migration pressure, crop failure 32%, and economic factors 28%. Aid interventions reduce displacement by 35% and increase return migration by 47%. The model offers a practical framework for understanding migration dynamics and evaluating climate adaptation policies in vulnerable regions.

Keywords - Climate migration, agent-based modeling, NetLogo, internal displacement, climate adaptation, Sri Lanka

I. INTRODUCTION

Climate change is increasingly influencing patterns of internal displacement and human mobility worldwide. Rising temperatures, prolonged droughts, floods, cyclones, and declining agricultural productivity are forcing vulnerable populations to relocate in search of safer and more sustainable livelihoods. This issue is especially significant in South Asian countries such as Sri Lanka, where a large proportion of the population depends directly on climate-sensitive agricultural systems. Sri Lanka faces diverse climate risks including droughts in the dry zone, floods in the wet zone, and coastal hazards such as cyclones and sea-level rise. These stressors can significantly disrupt household livelihoods and increase migration pressures.

Traditional statistical methods are useful for identifying climate-migration relationships, but they often fail to capture the dynamic and non-linear nature of migration decisions. Agent-based modeling (ABM) is a suitable alternative because it allows the simulation of heterogeneous households, environmental variability, economic conditions, and social interactions within a single computational framework. Existing climate migration models often neglect return migration, seasonal climate cycles, and household-level economic adaptation. This study addresses these gaps by proposing an enhanced ABM for climate-induced internal migration in Sri Lanka. The main contributions are: 1) modeling multi-dimensional migration drivers, 2) incorporating return migration, 3) quantifying major migration push factors, and 4) evaluating aid-based policy interventions.

II. METHODOLOGY

The agent-based model was implemented in NetLogo using rule-based household decision mechanisms. Migration probability was calculated using a weighted combination of climate stress, crop failure frequency,

debt level, food security, and neighborhood migration influence. Vulnerable households were assigned higher migration sensitivity values compared to adaptive and resilient households. Model parameters were derived from literature on climate migration and calibrated through repeated simulation runs to ensure stable behavioral patterns. A basic sensitivity analysis was conducted by varying climate stress and aid distribution levels to evaluate their impact on migration outcomes.

Study Area: The study focuses on climate-vulnerable regions of Sri Lanka, including coastal, dry, and wet climatic zones. The dry zone is highly affected by drought and agricultural water scarcity, while coastal areas experience cyclones, flooding, and salinity-related hazards. The wet zone is vulnerable to seasonal flooding and rainfall variability. These regions were selected to represent the diversity of climate-induced livelihood risks across Sri Lanka.

The proposed model was developed using NetLogo and simulates 300 household agents across a 33×33 grid representing three Sri Lankan climatic regions: coastal, dry, and wet zones. Each patch contains environmental attributes such as water level, soil quality, crop yield, and climate vulnerability. Household agents are classified into three groups: vulnerable, adaptive, and resilient. These agents differ in migration tendency, adaptation capacity, food security, debt, and wealth.

The simulation runs for 1,500 ticks, corresponding to approximately 12.5 years. Seasonal variation is modeled through alternating rainy and drought periods. Environmental conditions change over time through stochastic extreme events such as droughts, floods, and cyclones, each affecting household livelihoods differently depending on geographic location.

Household livelihoods depend on crop yield, which is influenced by soil quality, water availability, climate vulnerability, and aid support. Migration decisions are determined through a pressure-based mechanism. Households are more likely to migrate when they experience high climate stress, repeated crop failures, debt burdens, low wealth, and food insecurity. Social influence is also included, meaning that migration becomes more likely when neighboring households have already moved.

The model includes five aid distribution centers that provide support to vulnerable households. Aid improves food security, reduces stress, and increases wealth while also improving local agricultural conditions. The model also allows return migration when environmental and economic conditions improve in households' original locations, making the simulation more realistic than one-way migration models.

III. RESULTS AND DISCUSSION

Simulation results reveal that climate-induced migration is driven by multiple interacting factors rather than by a single environmental shock. Over the simulation period, 187 households (62.3%) were displaced, while 34 households returned when conditions improved, resulting in a net displacement rate of 51%. Migration accelerated significantly after repeated seasonal stress and major drought events. Vulnerable households migrated at substantially higher rates than adaptive and resilient households.

Environmental degradation was significant throughout the simulation. Average water levels declined by 26%, soil quality by 27.5%, and crop yield by 46.5%. The dry zone showed the strongest water decline, while coastal areas experienced severe soil degradation due to cyclones and related hazards. These environmental changes intensified household stress and reduced agricultural viability.

From a socioeconomic perspective, food security dropped sharply, and household debt increased by 180% over time. Households experiencing more than three crop failures accumulated significantly more debt, creating a poverty trap that reinforced migration decisions. Aid intervention proved highly effective in reducing displacement. Simulations with aid support showed 35% lower displacement and 47% higher return migration compared to scenarios without aid.

The results also highlight migration thresholds. Households with more than three crop failures in a season had a 73% migration probability, while households with debt above 80 units had a 68% migration probability. When both conditions were present, migration probability rose to 91%. These thresholds may be useful for early warning systems and policy planning. Overall, the model demonstrates that internal migration in Sri Lanka emerges from the interaction of climate stress, environmental degradation, debt accumulation, and social influence.

IV. CONCLUSION

This paper presented an agent-based simulation framework for analyzing climate-induced internal migration in Sri Lanka. The model integrated environmental stress, household heterogeneity, economic vulnerability, aid support, and return migration within a single computational system. Results indicate that migration is not triggered solely by climate events, but by the combined effects of repeated crop failure, declining food security, rising debt, and social pressure.

The findings show that climate stress, crop failures, and economic hardship are the dominant migration drivers, while aid interventions can substantially reduce displacement and improve return migration outcomes. Therefore, policy responses should focus not only on disaster relief but also on strengthening agricultural resilience, economic support systems, and localized adaptation programs. Future work can incorporate real climate projection data, historical migration records, and richer demographic variables.

TABLE I. KEY MIGRATION THRESHOLDS

Figure 1. Conceptual framework of the Agent-Based Model showing interactions among climate stress, household economics, crop failure, aid intervention, and migration decisions.

Condition	Migration Probability	Observation
More than three crop failures	73%	High displacement likelihood
Debt above 80 units	68%	Economic stress trigger
Both conditions combined	91%	Extreme migration pressure

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