MIGRATION-LAND SYSTEMS MODEL

NON-TECHNICAL DESCRIPTION

What is the model?

The Migration-Land Systems Model (MLSM) is a theoretical model that integrates concepts from migration and land system sciences. Its purpose is to support the development and testing of theories that articulate the role of rural migration and land system interactions in driving coupled socio-environmental dynamics in linked landscapes, and in forecasting future behaviors. MSLM represents a stylized agropastoral system with two sites, each with distinct structural characteristics. Agents, also with unique characteristics, are distributed in sites. Rainfall and environmental conditions fluctuate as the model runs, and agents use their environment, assess multiple candidate locations for migration, and move locally or to the other site.

Conceptual summary or how the model works

Agents are agropastoral households with livestock herds, a local social network, land, and a fixed number of local (within sending landscape) and non-local (within receiving landscape) sites of which they are aware.

At setup, agents are distributed on patches with randomly assigned levels of conflict and land owned and occupied. During the simulation, spatio-temporally varying precipitation drives biomass production on each patch. Agents interact with the patches they are located on through their livestock herds. Within sending and receiving sites, changes in land function result from precipitation, biomass production, and biomass removal by livestock.

At each timestep, agent and patch-specific characteristics determine the level of comfort each agent experiences while being located on a patch. Owning land and having social networks positively influence agent comfort, whereas conflicts, low availability of unowned land, and adverse environmental conditions have a negative impact. A combination of these factors at each step determines the comfort an agent experiences. The function determining agent comfort is calculated at each step; if comfort is below a minimum threshold, an agent experiences a commensurate decline in their contentedness level. Contentedness carries over from each step, meaning the represents the cumulative satisfaction an agent experiences when located on a particular patch. Over time, if an agent's contentedness score reaches 0, they begin to assess the suitability (relative to the current patch) of other local and non-local patches of which they are aware. If within their assessment agents encounter a more suitable patch than their current one, they migrate, and their contentedness score is reset. If a more suitable alternative patch is not available, agents do not migrate. Multiple local and non-local moves occur.

For a technical description of model procedures, see below.

How to use the model

Setup: Sets up the model

Go: Runs the model

User controls

- Average-precipitaton-site: Set mean annual precipitation in the sending site (receiving site)
- Precipitation-CV-site: Set the coefficient of variation around mean annual precipitation in the sending (receiving) site.
- Land-owned-site: The fraction of land in the sending (receiving) site that is owned
- Percent-owling-land-site: The fraction of agents in the sending (receiving) site that own land
- Core-area-in-conflict-site: The fraction of patches in sending (receiving) site that experiences conflict.
- Site-awareness-mean: The mean number of local and non-local sites that agents are aware of
- Site-awareness-sd: The standard deviation associated with the site-awareness-mean
- Percent-of-people-in-Site: The fraction of agents that are initiated in the sending site
- Herd-size: The number of livestock owned by each agent.

Things to try

- First, run the model by setting up the receiving site as a frontier landscape with low population density, low conflicts and land ownership.
- Holding all other variables constant, vary precipitation levels in the sending site and observe changes in migration rates
- Repeat above exercise, by similarly varying other variables associated with the sending site and agents.

How to cite

Warrier R, Boone R, Salerno J. 2023. Migration land systems model: a theoretical agent-based model. Mountain Scholar. DOI: 10.25675/10217/236080

TECHINCIAL DESCRIPTION

Process overview

The model includes seven procedures. They are listed in the order in which they are executed. The first two procedures are executed during the ‘Setup’ phase while the remaining procedures are repeated at every time-step after the model is initiated.

Initiate patches

The spatial domain is composed of patches divided equally to represent a migrant sending and a migrant receiving landscape. For each landscape, intensity and variation of annual precipitation, prevailing levels of conflicts and land-ownership patterns are defined by users. These settings are used to determine monthly rainfall, the intensity of conflicts, and land-ownership patterns at the patch level. All patch-level variables except monthly rainfall are static i.e., once set, they do not change during a simulation run. At the start of each iteration, landscape-scale annual precipitation characteristics are used to randomly assign a monthly precipitation level to each patch.

Initiate agents

Agents are agropastoral households who are initiated with a fixed number of livestock, a social network, site awareness and land holdings. The sizes of an agent’s social network and site awareness are randomly assigned by drawing from distributions with user-defined means and standard deviations. An agent’s social network size negatively affects their proclivity to migrate. The site awareness variable determines the number of local and distant sites that an agent is aware of during the simulation.

Feed livestock

At the start of each time-step (month), patches generate forage biomass proportional to the rainfall they received. Households use the forage available on the patch they are located on and on a fixed number of neighboring patches to feed their livestock herds thereby depleting the available biomass. This change in biomass availability on a patch is interpreted as a change in land function.

Assess comfort

Once livestock are fed, households assess their current comfort levels based on information on structural (prevailing conflicts, land availability, forage condition), and agent-specific (social networks and land ownership) variables. Pre-defined functions translate each variable into a score. Together, these scores determine the overall comfort agents experience being located on a patch each month (Fig.1). These scores can be further modified by using variable-specific weights that may be interpreted as the importance that agents may attribute to these variables. For the purposes of our simulation, we assume that agents value all variables equally.

Comfort Score = Environment Score + Conflict Score + Social Score + OwnLand Score + LandOwned Score

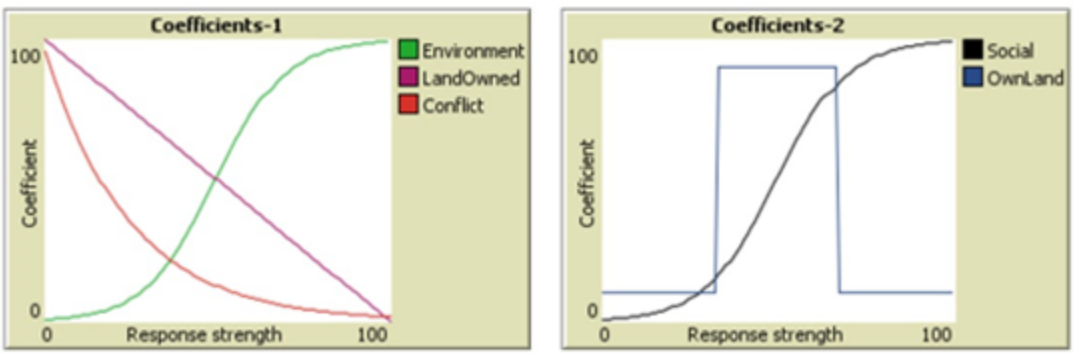

Figure 1: Functions relating structural and agent-specific variables to agent comfort

Each month, agents aspire to achieve a fixed maximum possible comfort score. When they fail to do so, agents experience a decline in their contentedness index. This index is a scalar quantity that is the same for all agents and is at its maximum at the start of the simulation, or when an agent arrives at a new patch. At each step, an agent's contentedness index is updated as follows

Contentedness Index = Contentedness Index – (Max Comfort Score – Current Comfort Score)

Migration decision

If at any time-step an agent's contentedness index reaches 0, they assess the comfort score they can achieve if they were to migrate to one of the patches that they are aware of either within (local patches) or outside (distant patches) the landscape they are located in. If the potential for comfort on one of these patches exceeds that for the current patch by a pre-defined value (short-migration or long-migration threshold), agents migrate to the most suitable patch. The migration is recorded either as long-distance or short-distance depending on whether or not the agent moved outside of their current landscape. The movement results in the resetting of an agent's contentedness index to its maximum passible value.

Design Concepts

There are three design concepts that underpin MLSM.

- Integrating migration and land system concepts: Agent migration drives land function changes which in turn drives further migration. In this conceptualization, land function changes are both the cause and consequence of migration decisions.

- Thresholds: In the model, threshold-type responses emerge because migration decisions are contingent on an agent's cumulative experience on a patch. Separating an agent's immediate experiences on a patch (comfort) from their long-term experience (contentedness) of it, decouples migration decision-making from proximate environmental drivers allowing agents to accrue experiences of environmental change. Moreover, the environment is one among several factors contributing towards agent comfort. Consequently, this model feature allows for more complex behaviors such as threshold responses and even immobility to emerge when agents experience environmental changes such as droughts.
- Telecoupling: The sending and receiving landscapes are telecoupled via migration flows. Environmental change in one landscape can drive land function changes in the other through the behavior of agents. The strength of this telecoupling is also governed by information flows. Agent awareness of patches, beyond the landscape they are in, is central to landscape telecoupling in the model.