ABM narrative summary (Grazing)

Thank you so much for taking the time to help us! Please before proceeding any further, kindly read the following instructions to maximize your answer quality.

Given an Agent Based Model (ABM), we want you to produce a human-readable summary that captures the essential dynamics of the ABM which will then be used as a reference for evaluating LLM-generated summaries.

This ground truth is a narrative summary describing:

1. What the ABM is and does

2. What trends appear in the simulation outputs

3. Key numeric values and time points

We expect your summary to be 3 to 4 paragraphs long. We suggest keeping it concise and structured as followed:

Paragraph 1 focuses on the ABM purpose and parameters. It is describing what the model investigates, its goal, and key parameters with exact numeric values. We suggest to include which agents are involved as well as their role, the key initial parameters of the simulation setup and their exact value with units when applicable. We request you to please not paraphrase parameter names incorrectly and to not add parameters not present in the source.

Paragraph 2 focuses on key trends (initial/early phase). It is describing what happens early in the simulation including initial values, early dynamics, key time points.

Paragraph 3 focuses on key trends (middle phase), if applicable. It is describing intermediate trends, secondary metrics, or continuing dynamics.

Finally paragraph 4 focuses also on key trends (later/final phase). It is describing what happens over time, final outcomes, stabilization, long-term patterns.

While describing trends, we recommend the following guidelines:

What to include:

- Initial values: What the metrics start at (e.g., "starts at 100,000 units")

- Direction of change: Increase, decrease, stable, fluctuating

- Key time points: Specific time steps where changes occur (e.g., "by time step 10", "at step 40")

- Numeric values: Exact or approximate values at key points (e.g., "drops to 6", "stabilizes at 500")

- Patterns: Cyclical, linear, sigmoidal, plateau, etc.

What NOT to include:

- Don't interpret causation (e.g., "because of X, Y happens"), just describe what happens

- Don't add explanations not in the data

- Don't use vague terms like "significant" without numbers

- Don't mention the plot itself (no "as shown in the figure")

In addition, here is a small collection of bad and good examples:

❌ Bad

"The number of agents goes down a lot"

✅ Good

"The number of agents declines from 80 to 10 by time step 5"

❌ Bad

"The biomass fluctuates"

✅ Good

"Reserve biomass starts at 300,000 units, drops by step 10, then stabilizes around 400,000 by step 500"

You will be provided simulation outputs using a plot format (one plot for each variable). Each plot represents the evolution of this variable over time. You will also be provided with the ABM documentation as well as the the simulation parameters.

Here is a quality checklist for you to quickly verify the summary you write. This quality checklist only includes some important aspects but is non exhaustive:

- Goal sentence: Clear one-liner explaining model purpose

- All key parameters: Numeric values from source included

- Initial values: Starting point for each metric mentioned

- Time points: Specific steps where changes occur

- Numeric accuracy: Values match source data

- Trend direction: Clear increase/decrease/stabilize

- Final outcomes: How the simulation ends

- No interpretation: Only describe, don't explain why

- No visual references: Don't mention "figure", "plot", "graph"

Below is the documentation of the ABM:
This is an extension of the original RAGE model where we add learning capabilities to agents, specifically learning-by-doing and social learning (two processes central to adaptive (co-)management).

The original model can be found here:

The RAGE model is a *multi-agent simulation model* that captures *feedbacks between pastures, livestock and household livelihood in a common property grazing system*. It implements three stylized *household behavioral types* (traditional *TRAD*, maximizer *MAX* and satisficer *SAT*) which are grounded in social theory and reflect empirical observations. These types can be compared regarding their long-term social-ecological consequences. The types differ in their preferences for livestock, how they value social norms concerning pasture resting and how they are influenced by the behavior of others.

Besides the evaluation of the behavioral types, the model allows to adjust a range of ecological and climatic parameters, such as rainfall average and variability, vegetation growth rates or livestock reproduction rate. The model can be evaluated across a range of social, ecological and economic outcome variables, such as average herd size, pasture biomass condition or surviving number of households.

The extension module is applied to smallholder farmers' decision-making - here, a pasture (patch) is the private property of the household (agent) placed on it and there is no movement of the households. Households observe the state of the pasture and their neighbours to make decisions on how many livestock to place on their pasture every year. Three new behavioural types are created (which cannot be combined with the original ones): E-RO (baseline behaviour), E-LBD (learning-by-doing) and E-RO-SL1 (social learning). Similarly to the original model, these three types can be compared regarding long-term social-ecological performance. In addition, a global strategy switching option (corresponding to double-loop learning) allows users to study how behavioural strategies diffuse in a heterogeneous population of learning and non-learning agents.

An important modification of the original model is that extension agents are heterogeneous in how they deal with uncertainty. This is represented by an agent property, called the r-parameter (household-risk-att in the code). The r-parameter is catch-all for various factors that form an agent's disposition to act in a certain way, such as: uncertainty in the sensing (partial observability of the resource system), noise in the information received, or an inherent characteristic of the agent, for instance, their risk attitude.

A detailed description of the model and its processes can be found in the accompanying ODD+D protocol
#The model consists of two main sub-models: _**Vegetation**_, and _**Household decision-making**_. Those components are linked by the following **yearly sequence**, which processes each **tick**:

1. Green biomass is updated (with fixed rain, for comparability purposes)
2. Households with E-RO-SL1 update their r-parameter
3. Households update their behavioural strategy (if strategy switching enabled)
4. Households make decisions on how many livestock to place on their pasture in the next round
5. Livestock feeds on biomass
6. Households observe the performance of their neighbours
7. Reserve biomass is updated
8. Households observe and remember reserve biomass

#Extension model parameters: Standard value / range

- extension-model?: true
- risk-mode?: true
- number-households: 60
- timesteps: 100
- b: 0 (reproduction not used in extension model)
- knowledge-radius: 1
- homog-behav-types?: true
- number-E-RO, number-E-LBD, number-E-RO-SL1: 20, 20, 20
- rain: 282.71
- SL2-strategy-switch?: false
- behavioral-type: E-RO

Original model parameters used by the extension model:

- w: 0.8
- gr1: 0.5
- gr2: 0.1
- rue: 0.002
- mg: 0.1
- mr: 0.05
- R0part: 0.6
- lambda: 0.5
- Rmax: 0.5
- intake: 640

#Varying the initial *number-households* and the initial *livestock-init* in the system.

#Comparing the performance of homogeneous groups of agents (*homog-behav-types?* true) of each type: non-learning agents (*behavioral-type* E-RO), learning-by-doing (*behavioral-type* E-LBD), and social learning single-loop (*behavioral-type* E-RO-SL1).

#Comparing the results of heterogeneous groups of households (*homog-behav-types?* false) with strategy switching enabled vs. disabled (*SL2-strategy-switch?* true or false).

#Observe visually the evolution of numbers of agents of each type (corresponding to different colors) in a heterogeneous population (*homog-behav-types?* false) of agents.

#Dressler, G., Groeneveld, J., Buchmann, C.M., Guo, C., Hase, N., Thober, J., Frank, K. and Müller, B. (2018): _**Implications of behavioral change for the resilience of pastoral systems – lessons from an agent-based model**_, Ecological Complexity.

Dressler, G., Müller, B. and Frank, K. (2012): _**Mobility – a panacea for pastoralism? An ecological-economic modelling approach.**_, *Proceedings of the iEMSs Fifth Biennial Meeting: International Congress on Environmental Modelling and Software (iEMSs 2012)*. International Environmental Modelling and Software Society, Leipzig, Germany, July 2012.

Martin, R., Müller, B., Linstädter, A. and Frank, K. (2014): _**How much climate change can pastoral livelihoods tolerate? Modelling rangeland use and evaluating risk.**_, *Global Environmental Change*, 24, 183-192.

Müller, B., Frank, K. and Wissel, C. (2007): _**Relevance of rest periods in non-equilibirum rangeland systems - a modelling analysis**_, *Agricultural Systems*, 92, 295–317.

Schulze, J. (2011): _**Risk Measures and Decision Criteria for the Management of Natural Resources Under Uncertainty - Application to an Ecological-Economic Grazing Model**_, *Master Thesis*, Helmholtz Centre for Environmental Research & Ernst- Moritz-Arndt-University of Greifswald.

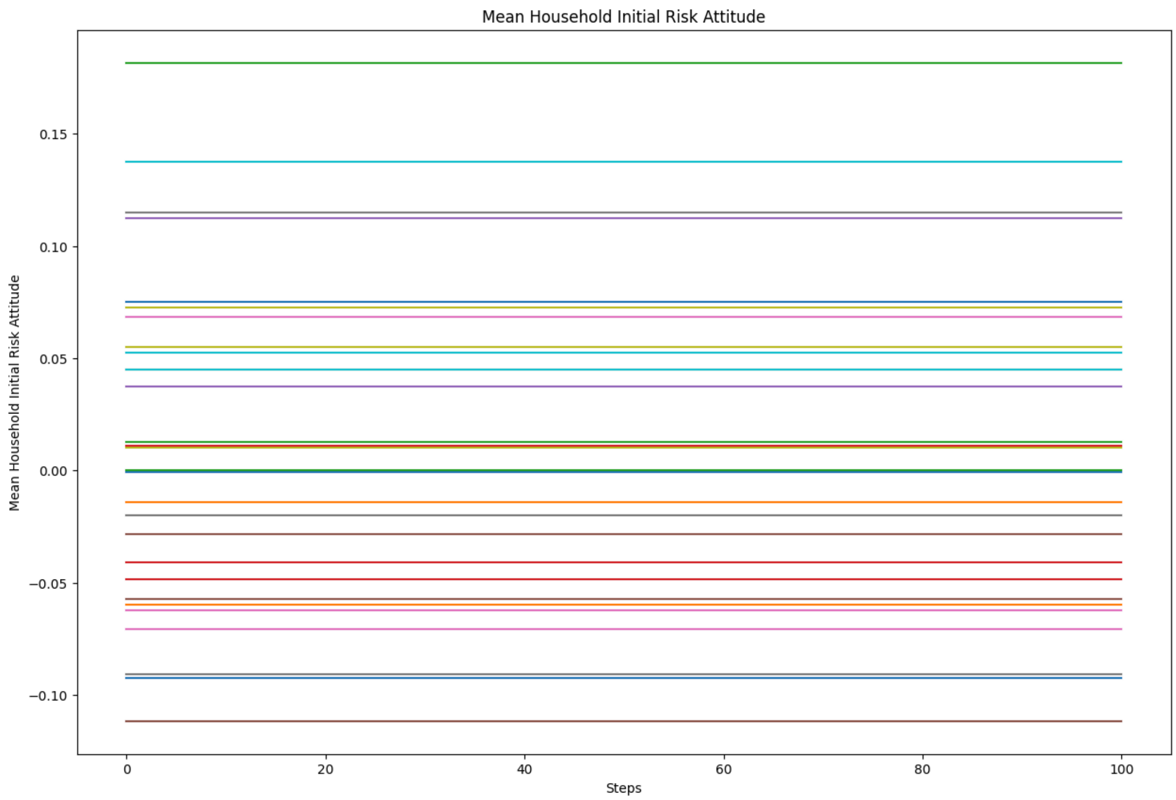
Below are the parameters used for our simulation run:

We have 31 parameters:

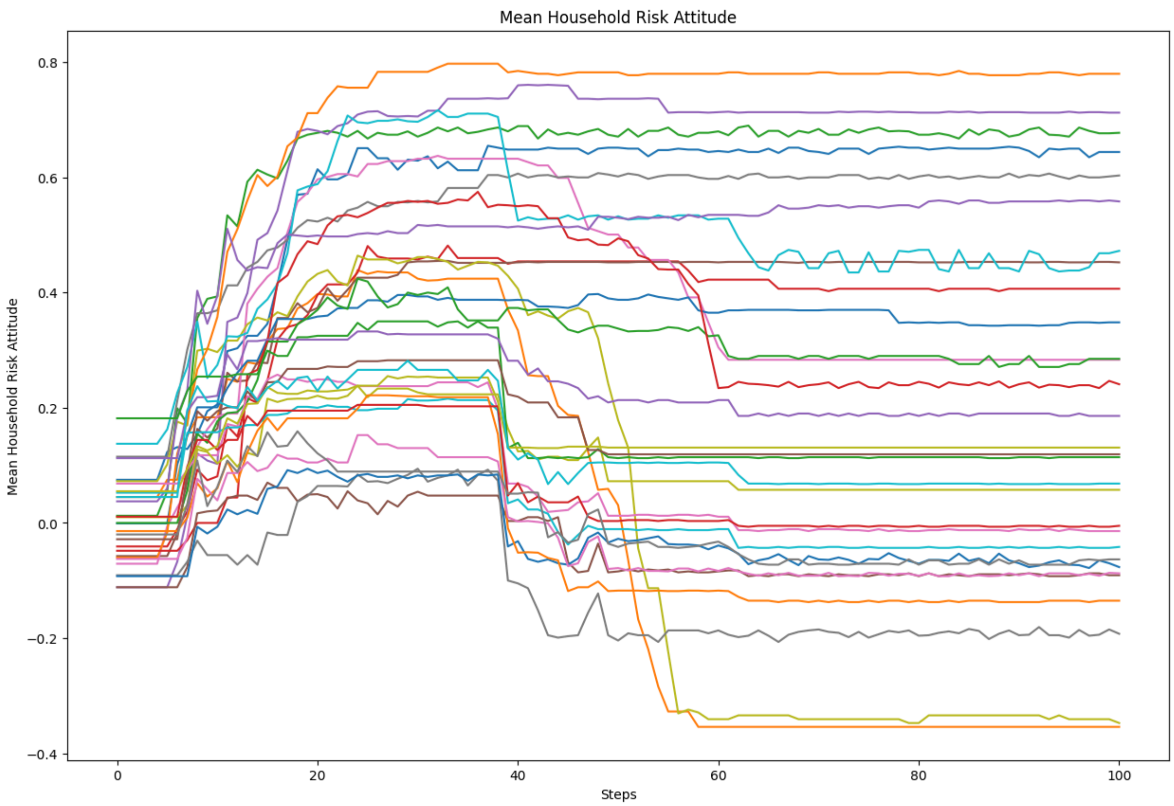
- number-households, from 1.0 to 100.0. We set it to 60.
- satisficing-threshold, from 0.0 to 100.0. We set it to 0.
- satisficing-trials, from 0.0 to 100.0. We set it to 21.
- knowledge-radius, from 0.0 to 5.0. We set it to 1.
- resting-threshold, from 0.0 to 1.0. We set it to 0.1.
- intrinsic-preference, from 0.0 to 1.0. We set it to 0.
- social-susceptibility, from 0.0 to 1.0. We set it to 0.
- global-rain?. We set it to True.
- start-on-homepatch?. We set it to True.
- resting?. We set it to False.
- homog-behav-types?. We set it to True.
- extension-model?. We set it to True.
- SL2-strategy-switch?. We set it to False.
- risk-mode?. We set it to True.
- behavioral-type. We set it to E-RO.
- number-SAT. We set it to 0.
- number-E-RO. We set it to 20.
- number-TRAD. We set it to 0.
- b. We set it to 0.
- number-MAX. We set it to 0.
- rain-mean. We set it to 200.
- risk-att-init. We set it to 0.5.
- gr1. We set it to 0.5.
- number-E-LBD. We set it to 20.
- gr2. We set it to 0.1.
- number-E-RO-SL1. We set it to 20.
- timesteps. We set it to 100.
- w. We set it to 0.8.
- number-random. We set it to 0.
- livestock-init. We set it to 90.
- rain-std. We set it to 100.

Below are the plots representing the simulation outputs

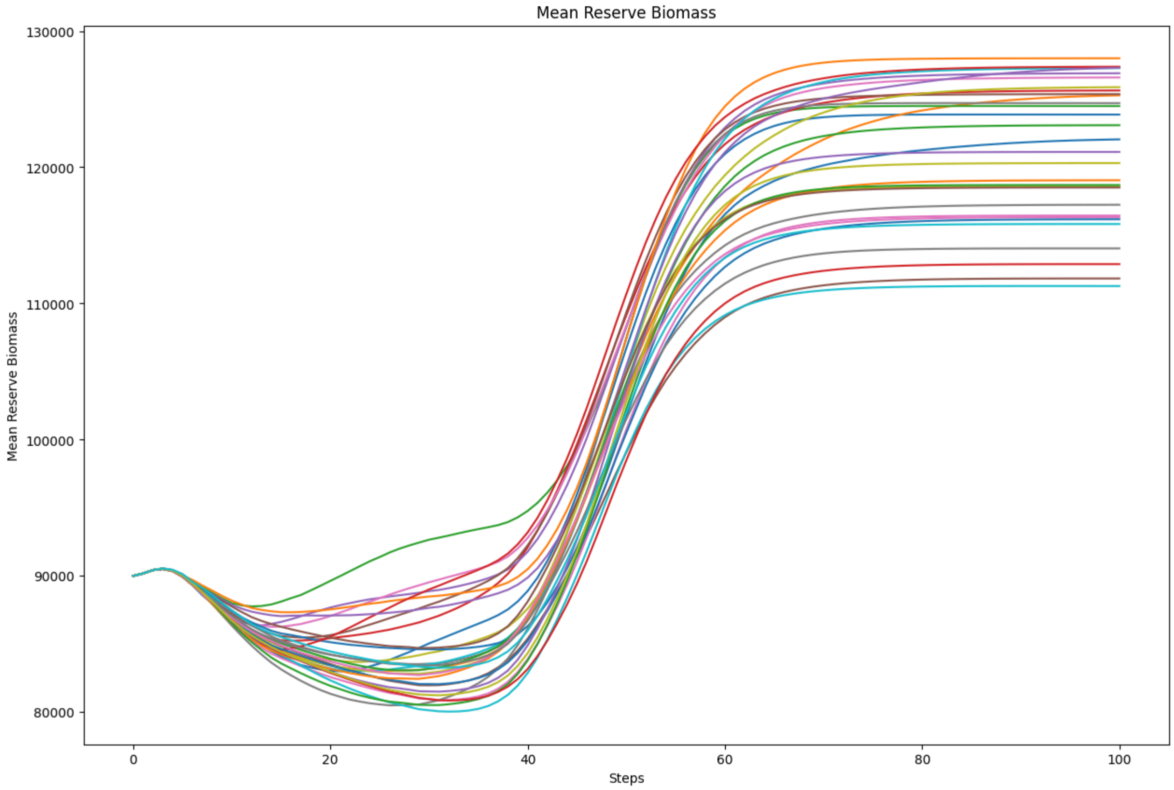
1) Mean household initial risk attitude



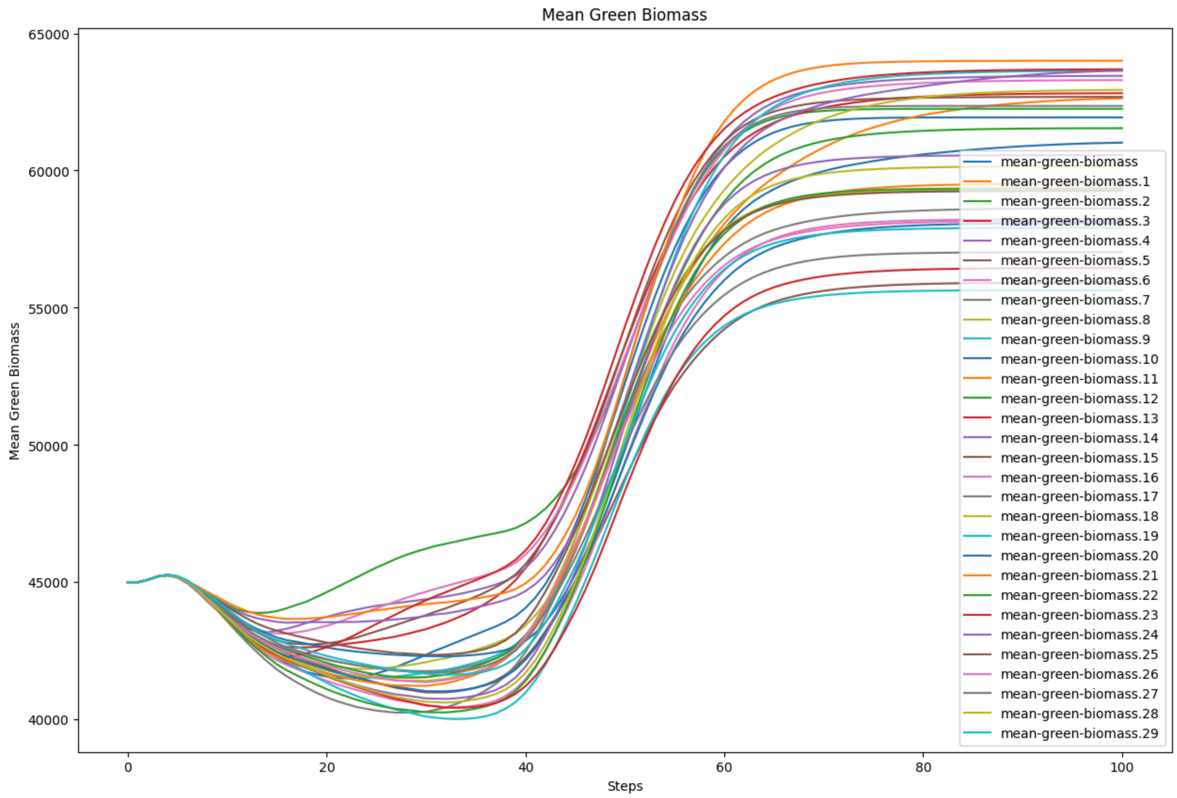
2) Mean household risk attitude



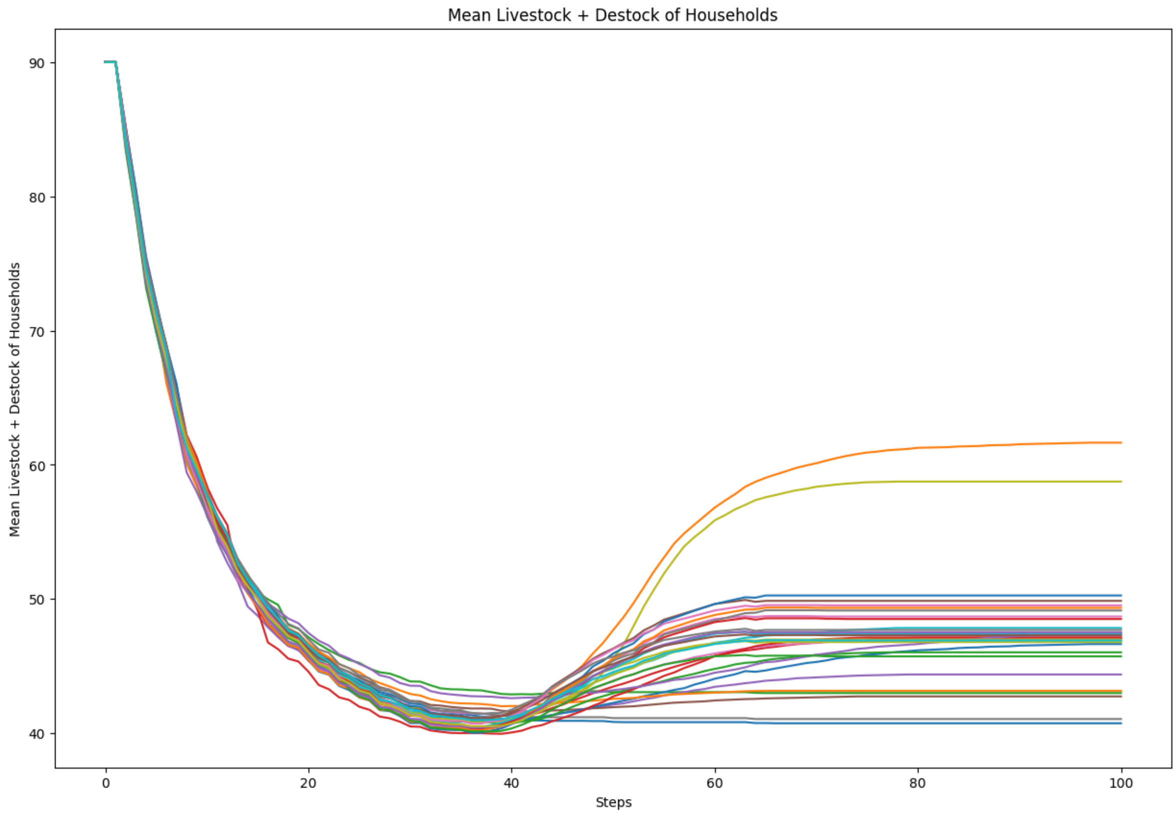
3) Mean reserve biomass



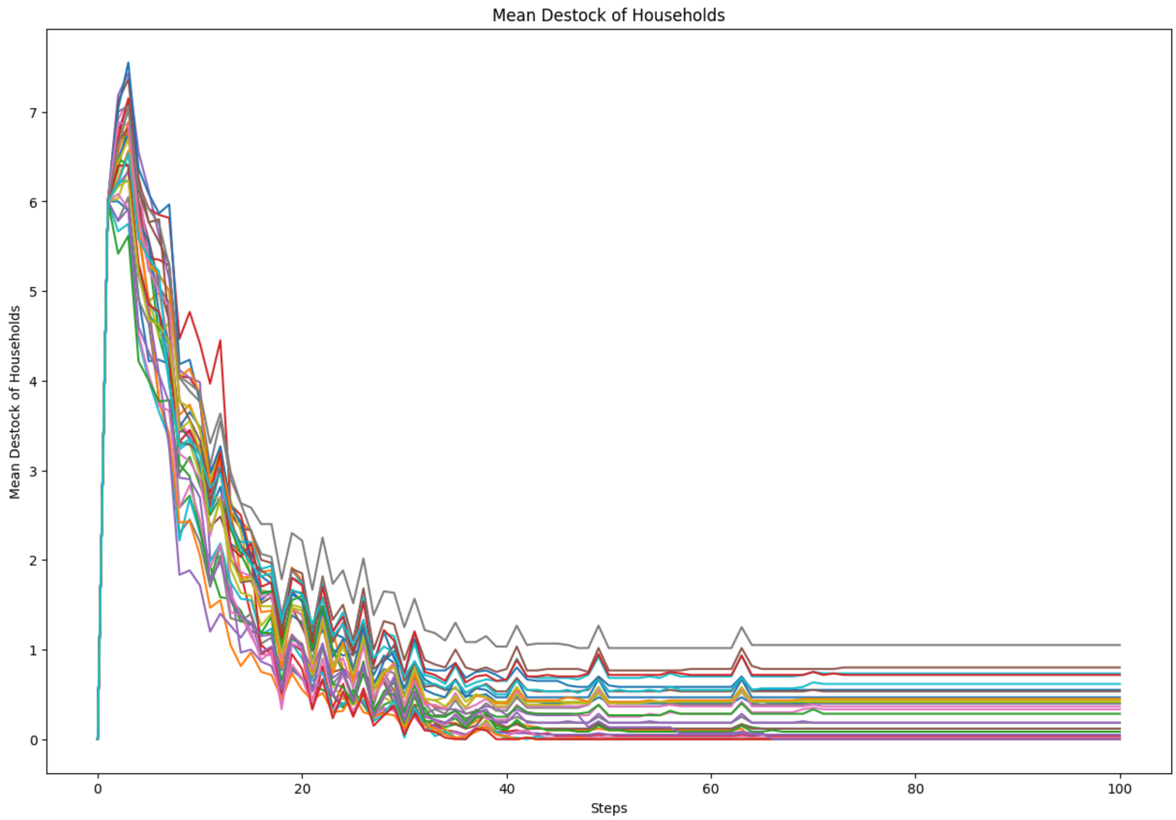
4) Mean green biomass



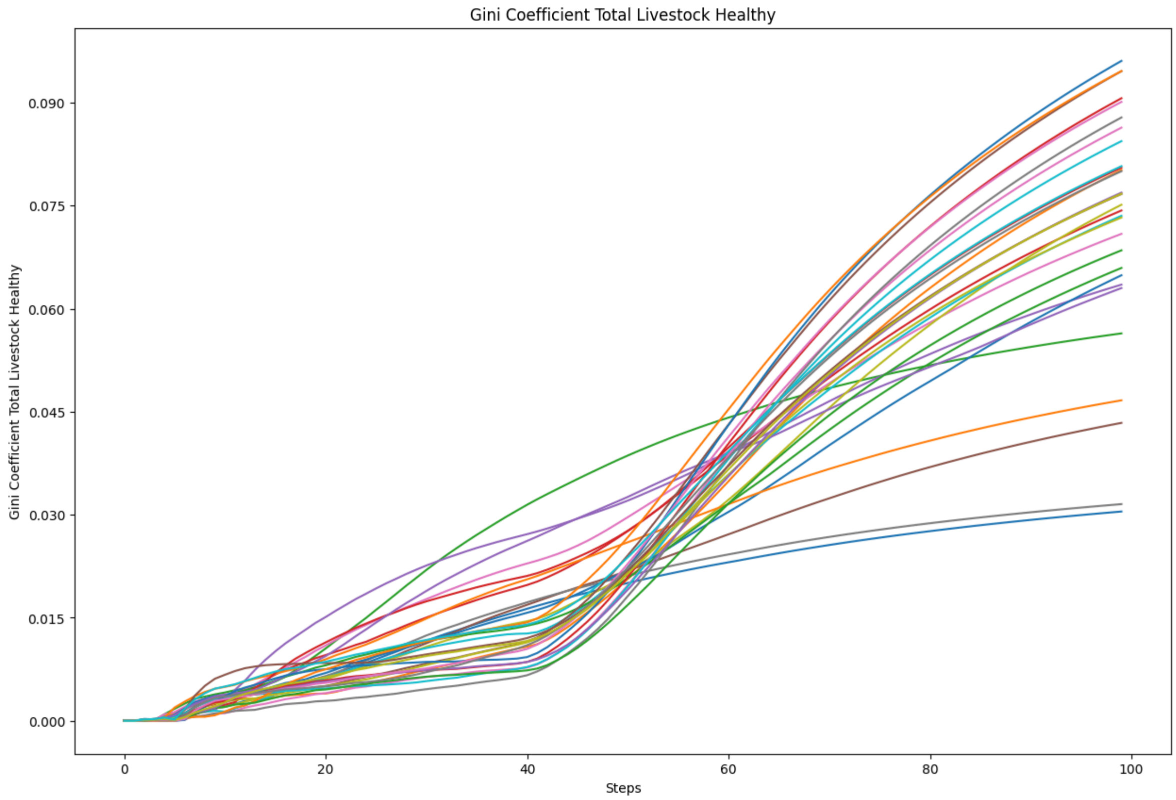
5) Mean livestock + destock of household



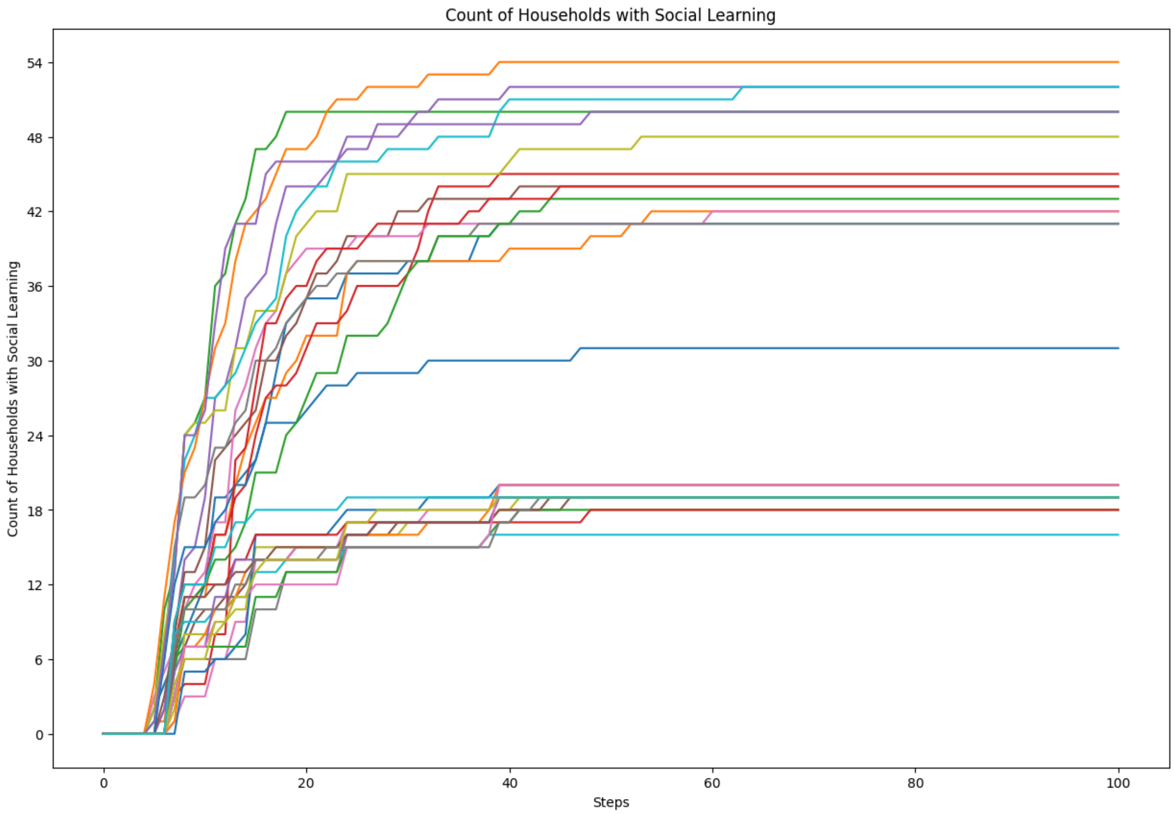
6) Mean destock of households



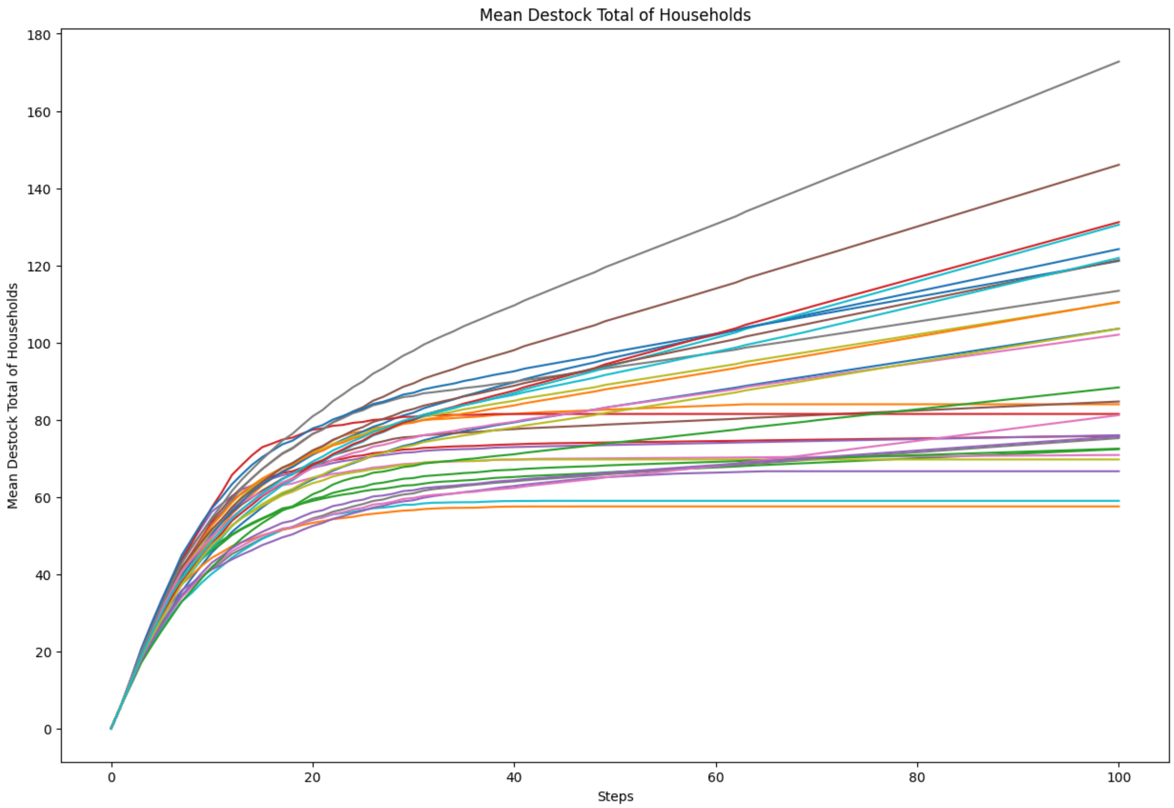
7) Gini coefficient total livestock healthy



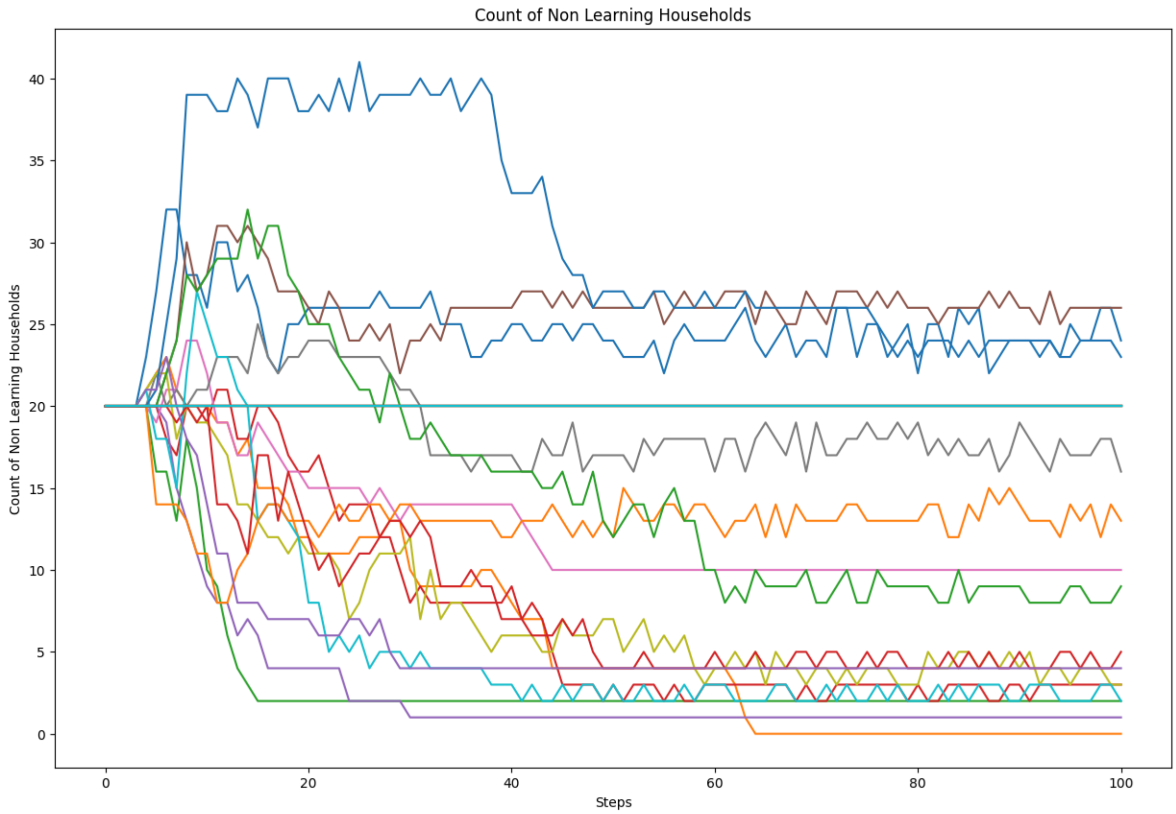
8) Count of households with social learning



9) Mean destock total of households



10) Count of non learning households



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