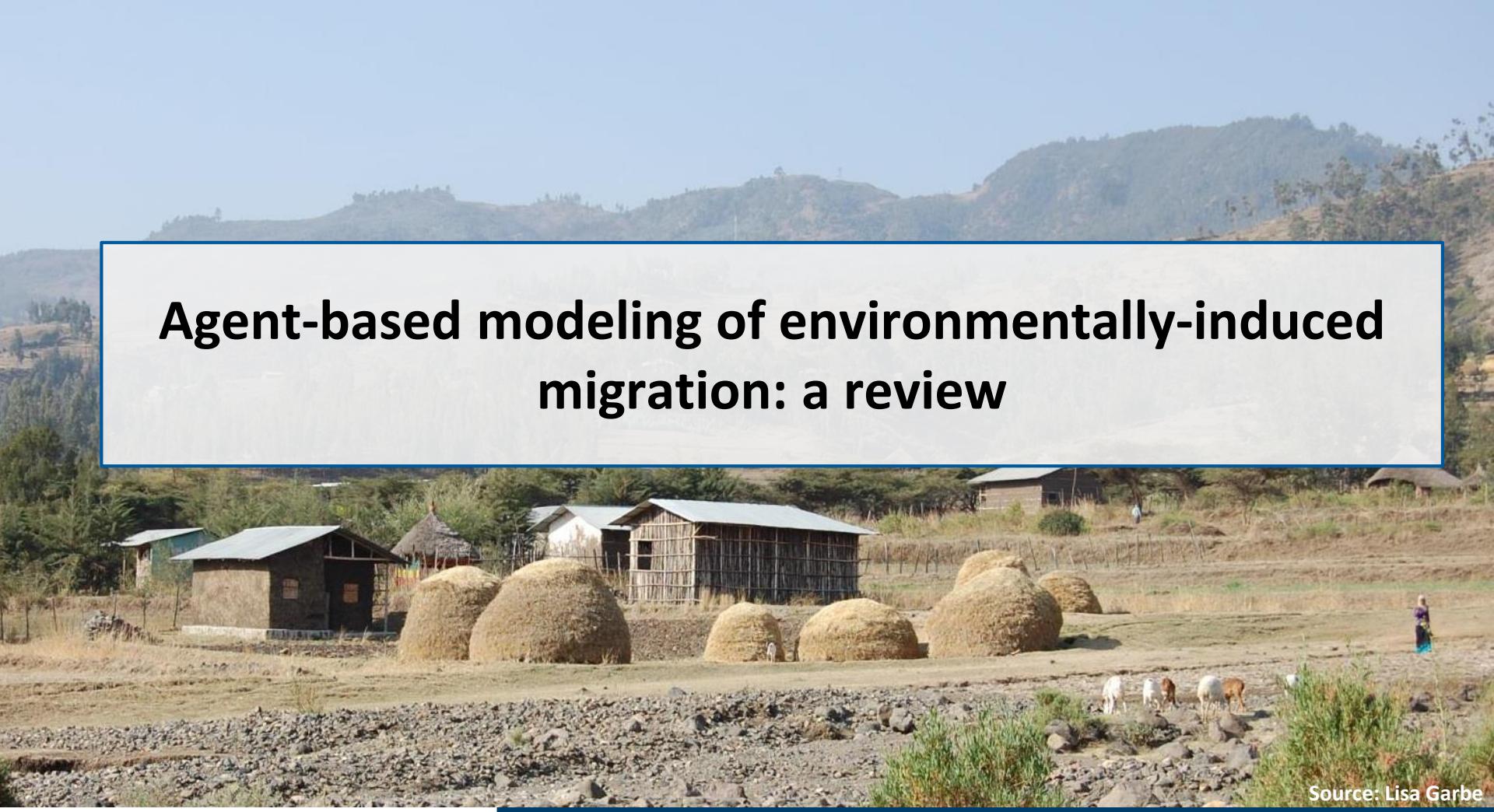
Agent-based modeling of environmentally-induced migration: a review



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Conference 'Environmental Non-Migration: Framework, Methods and Cases', TU Dresden, 19 – 21 June 2019

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STUDY AIM & RESEARCH QUESTIONS

Potential of agent-based models for studying environmental (non-)migration:

- Ability to depict individual behavior, social interactions & social-ecological feedbacks[1]
- Recently increasing number of ABMs that consider the role of the natural environment in rural migration processes[2]

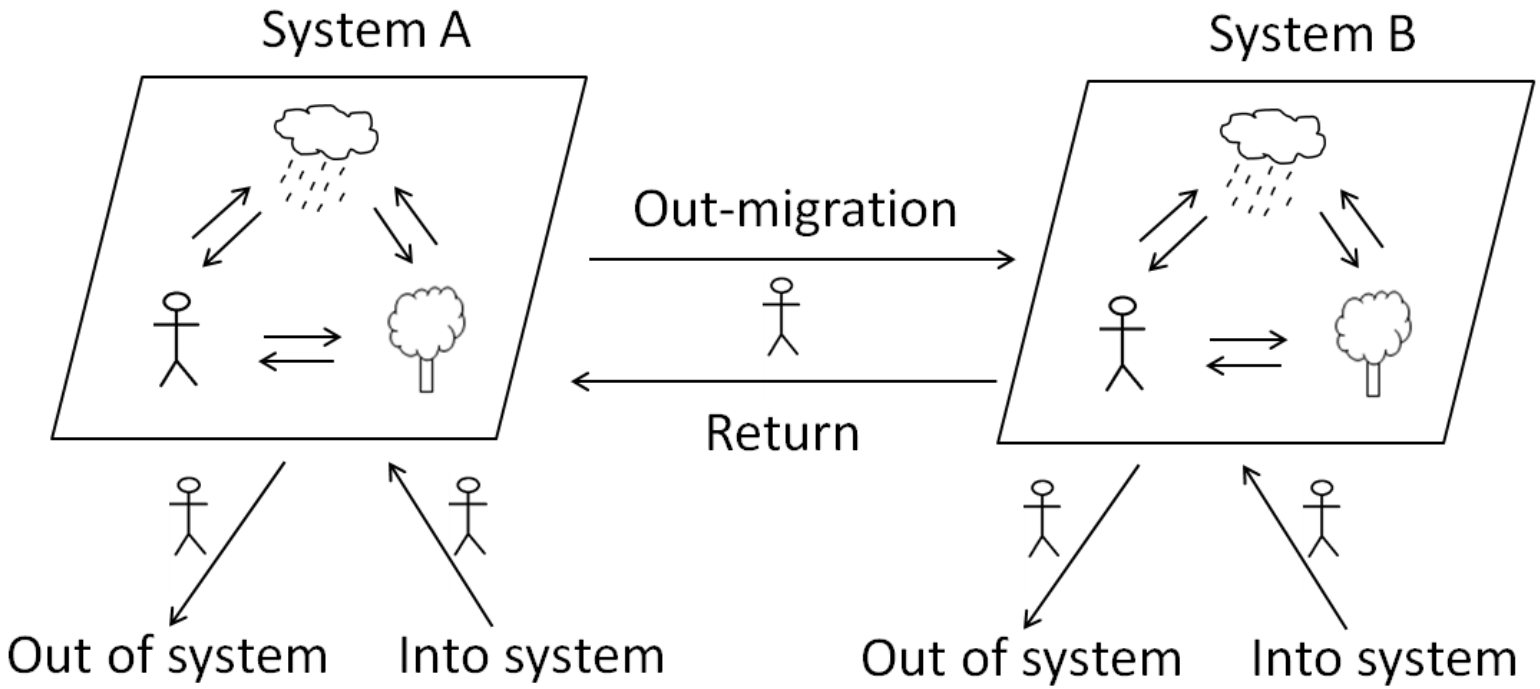
→ **Systematic review** of existing **ABMs of the environment-migration linkages** to synthesize the current state of the art

Research questions:

- Which migration flows have been studied with ABMs (e.g. in- and/or out-migration, return)? How are migration decisions modeled?
- How are social and ecological systems coupled in ABMs of environmentally-induced migration? In particular, have environmental consequences of migration been studied with ABMs?

[1]Schlüter et al. 2012; [2]McLeman 2013; Klabunde & Willekens 2016

CONCEPTUAL FRAMEWORK



PAPER SELECTION & EVALUATION

Selection:

- *Agent based models* and *migration*
- Focus on ABMs of environmentally-induced migration in rural contexts of natural resource use
- Exclusion of urban-urban migration & constantly moving societies (e.g. pastoral systems, hunter-gatherer-systems)

→ **15 agent-based models**

Systematic evaluation:

- Each ABM was classified by two of us
- Cross-check by developers of the ABM (response rate was 87%)
- According to conceptual framework and standardized protocol

RESULTS
GLOBAL DISTRIBUTION OF CASE STUDIES

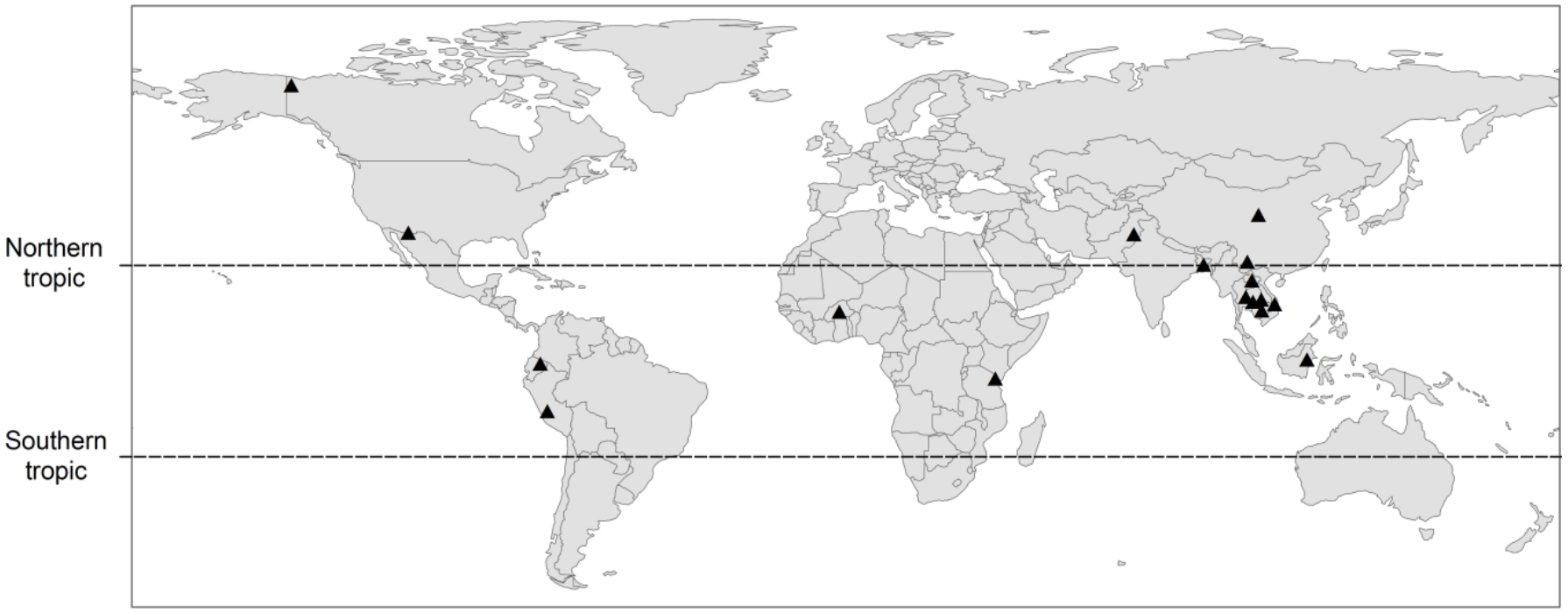
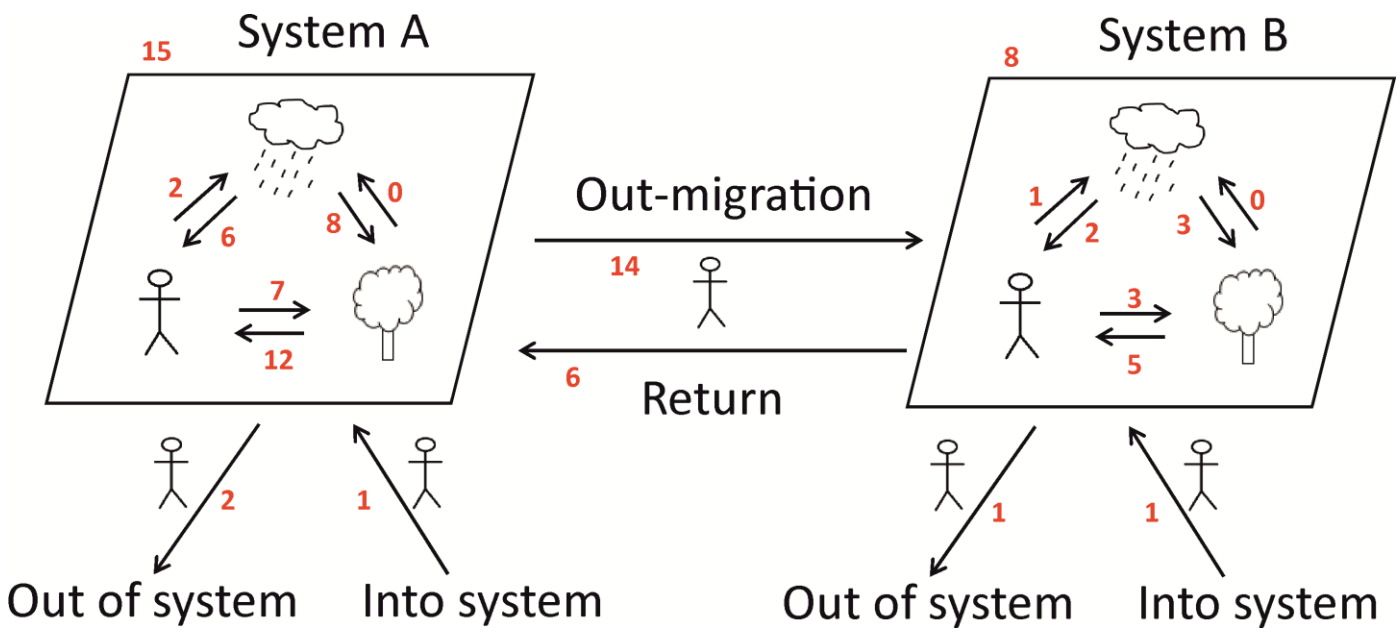


Fig. Global distribution of model applications.

Thober, J., Schwarz, N., Hermans, K., (2018): Agent-based modeling of environment-migration linkages: a review. Ecol. Soc. 23 (2), art. 41.

RESULTS
REPRESENTATION OF THE FRAMEWORK'S ELEMENTS



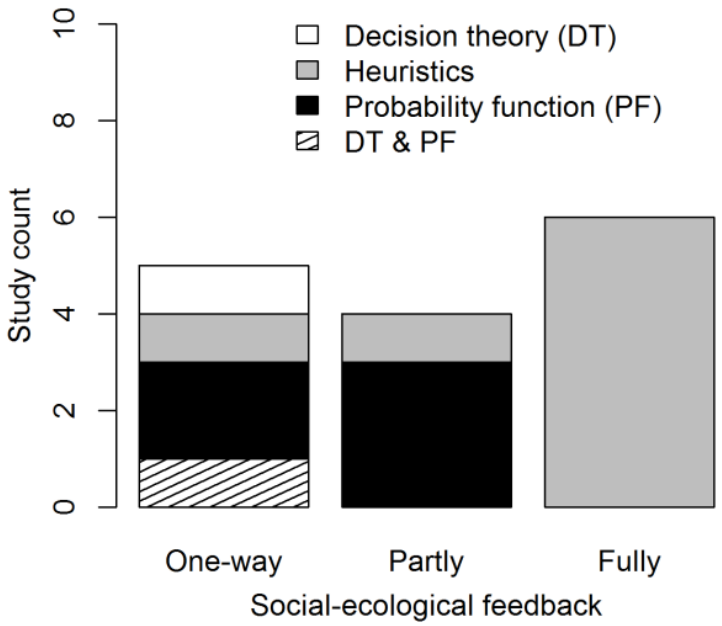
- Some elements of our conceptual framework receive more attention than others
  - Most reviewed ABMs consider out-migration from one system & return
  - Few ABMs consider migration out of and into the system
  - Few ABMs consider situation in destination system

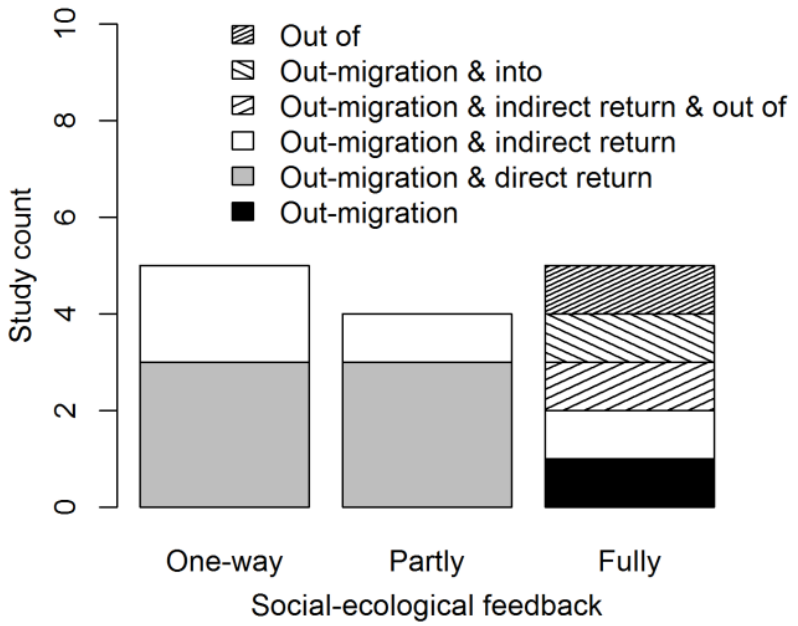
RESULTS
SOCIAL-ECOLOGICAL FEEDBACKS

Type of coupling	**Number of ABMs**	**Examples of causal chain**
One-way linkage	5	Rainfall -> *Migration decision* (Kniveton et al. 2011, 2012)
		Climate warming -> Caribou numbers -> Hunting success -> *Migration decisions* (Berman et al. 2004)
Partly integrated	4	Rainfall + *Rice planting* -> Rice growth -> Income -> *Migration decision* (Naivinit et al. 2010)
		Slope -> *Land use selection* -> Assets -> *Migration decision* (Mena et al. 2011)
Fully integrated	6	Soil quality + Rainfall -> Harvest level -> *Migration decision* -> Population density -> Soil quality (Janssen 2010)
		Resource availability -> *Migration decision* -> Resource availability (Rogers et al. 2011)

→ Potential of ABMs for studying environmental migration is not fully exploited

RESULTS
THE CHALLENGE OF MATCHING THE FRAMEWORK

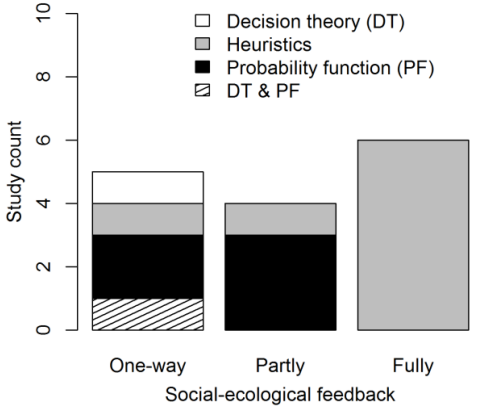




→ Focus either on representing human decision-making or on representing fully integrated social-ecological feedbacks and all relevant migration flows

KEY FINDINGS AND WAYS AHEAD

1. None of the reviewed ABMs explicitly analyzed non-migration
2. Fully-integrated ABMs are not the majority
3. Focus either on decision-making or on migration flows and fully-integrated social-ecological feedbacks



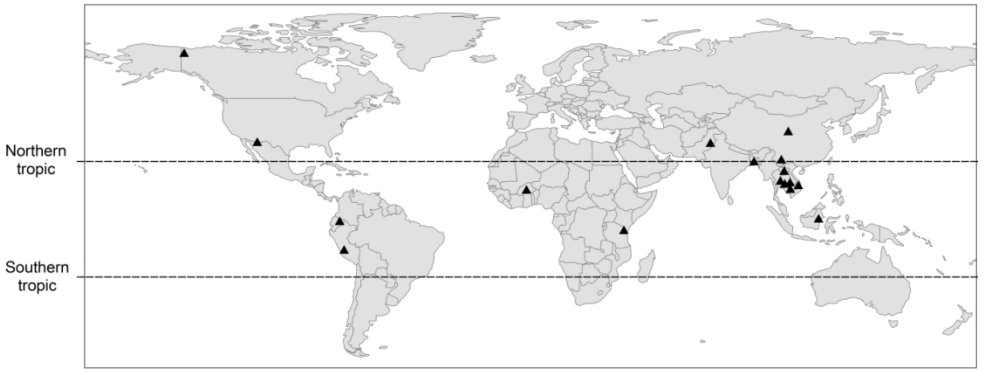
→ **Changing this will increase model complexity leading to reduced model transparency or difficulties regarding parameterization & model analysis**

Ways ahead

1. Standards for developing and analyzing ABMs are needed
2. More interdisciplinary work between social and natural scientists, modelers and empiricists

THANK YOU FOR YOUR ATTENTION!

Photo: Lisa Garbe



This study has been conducted in the frame of the BMBF- and UFZ-funded junior research group MigSoKo (https://www.ufz.de/migsoko/).

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APPENDIX
DEFINITIONS

Duration of migration (seasonal/permanent): Migration is defined as "being absent from the place of origin for more than three months" (Liehr et al. 2016, page 153). Additionally, we differentiate between seasonal and permanent migration. Seasonal migration is characterized by short-term absence (i.e. less than a year) from the place of origin whereby the return is already planned at the time of migration. In the context of natural resource use, this type of migration is often aligned to harvest cycles. In the case of permanent migration, migrants leave with the intention to stay abroad for long-term periods. However, it is not precluded that they move on or return after a short-term due to changing conditions.

Direct/indirect environmental influence factors: Regarding the environmental factors we analyzed whether these are conceptualized as direct (e.g. agents consider amount of precipitation when deciding to migrate or not) or indirect drivers (e.g. rainfall affects income which agents consider when deciding whether to migrate or not).

Social network: Social networks are explicitly modeled social linkages (e.g. remittance, information exchange, dependents). Just considering the situation of others without an explicit network is not yet a social network effect (e.g. comparing your own situation with that of others or considering the impact a decision has on others).

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DEFINITIONS

Social-ecological feedbacks (one-way linkages/partly integrated linkages/fully integrated linkages): For one-way linkages, agents are influenced by the environment but do not influence the ecosystem. In the case of partly integrated linkages, agents can alter for example land use and are in turn influenced by harvest success. Finally, for fully integrated linkages also environmental consequences of natural resource use and migration decisions are considered within the model (e.g. resource depletion or soil degradation).

Migration decision (probability function/decision theory/heuristics/optimization): Here, we classify according to the techniques used in the decision model. "Probability function" can be any function that includes a stochastic factor to determine the migration decision (e.g. random destination, logistic regression function). Based on "decision theory" are those decision models that are based on an existing decision theory from economics, psychology or other fields (e.g. Theory of Planned Behavior). "Heuristics" are simple decision rules or rules of thumb (e.g. if-then rule). "Optimization" includes any form of maximization of a certain indicator (e.g. income, fitness, happiness).

Migration flows: We differentiate between out-migration of a system and return migration: systems can be characterized by out-migration from system A to system B and return-migration from system B to system A. Here, agents can move directly back (direct return) to the origin or do so via multiple stops (indirect return). Furthermore, humans can in-migrate from outside the two systems into system A and/or B and humans can out-migrate from system A and/or B to somewhere outside the overall system.

APPENDIX
STANDARDIZED PROTOCOL

General aspects:
- Model purpose (understanding, decision support, theory development …)
- Case study
- Spatial & temporal scale

Migration processes:
- Migration flow (out-migration, return, out of system, into system)
- Duration

Influence factors:
- Environmental influence factors (number, type, direct/indirect)
- Economic & social influence factors

Decision-making:
- Methodology (probability function, decision theory, heuristics, optimization)

Social-ecological feedback:
- Type of coupling (one-way linkage, partly integrated, fully integrated)

RESULTS
ENVIRONMENTAL INFLUENCE FACTORS (EFs)

In general:

- ABMs include between **1 to 5 EFs**
- Majority of ABMs consider <= 2 EFs
- Most often as **indirect factors**

Influencing environmental factors		**Availability of natural resources**	
	Number of ABMs		Number of ABMs
Rainfall	7	Crop yield	4
Climate shock (e.g. flood)	4	Food resource availability	4
Soil quality	2	Wildlife availability	3
Temperature	2	Water availability	2
Increasing weather variability	1	Timber	1
Sunlight luminosity	1	Livestock stock	1
Glacier albedo	1		
Glacier melt	1		
Slope	1		
Brackish water	1		

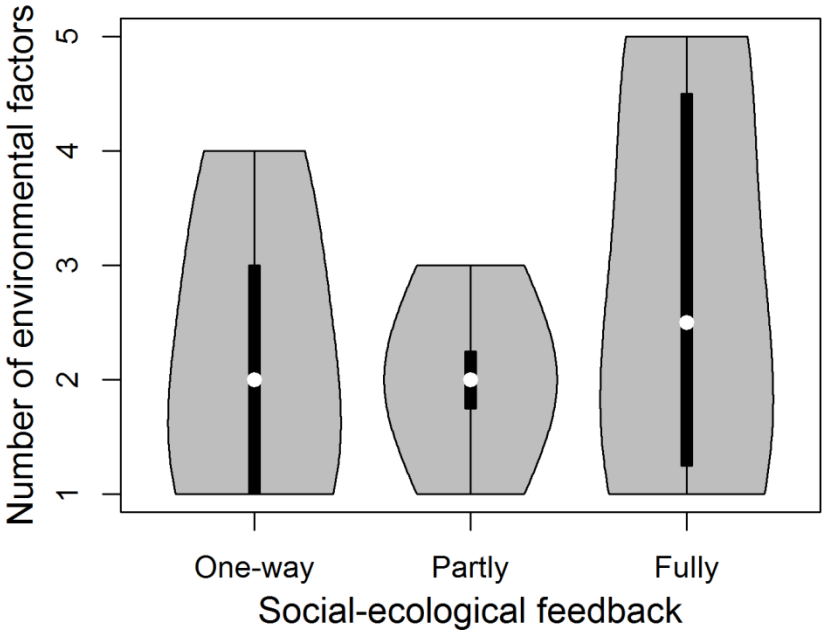
APPENDIX
RESULTS – ECONOMIC AND SOCIAL FACTORS

- Most of the 15 ABMs consider economic & social factors
- Only four ABMs explicitly model social networks
- **Most frequently considered economic influence:** distance to nearest road, market or to the destination system, assets, income
- **Most frequently considered social influence factors:** age, influence by peers, gender, population size, migration experience, social ties and education

→ **In general, these correspond with identified influence factors in empirical studies of human migration**

→ **But:** class of political influence factors is underrepresented in ABMs

APPENDIX
RESULTS – LINKING EFS & COUPLING



- number of EFs is slightly higher for ABMs with fully-integrated feedback
- higher number of EFs is needed in order to represent fully-integrated feedbacks

→Hindrance of the consideration of fully-integrated feedbacks due to a lack of knowledge or data?