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Methodological Abilities of Integrated Models to Support Agricultural Landscape Resilience: Current Status and Research Perspectives

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Abstract: It is important to increase the resilience of rural landscapes in the face of global changes. It is widely recognized that integrated modeling is often a methodological choice to study landscape resilience because the task is often beyond the ability of direct, empirical studies. However, so far there has not yet been a systemized, critical review on methodological abilities current modeling approaches can have for supporting management for agricultural landscape resilience. This review study (i) highlighted the methodological abilities of integrated system modeling ideally needed for agricultural landscape management for resilience, (ii) reviewed strengths and weakness of common integrated modeling methods with respects to these required methodological abilities, and (iii) discussed perspectives of modeling research toward meeting these abilities. Based on common frameworks of socio-ecological systems, we identified nine methodological abilities that would be ideally needed for integrated modeling for supporting agricultural landscape resilience: (1) representing social-ecological complementariness, (2) anticipating multiple performances in a distributed way, (3) explaining behavioral change of multiple human actors, (4) representing flexible, multi-scale feedbacks, (5) capturing intra- and inter-farm heterogeneity, (6) explaining farm's structural changes, (7) being sensitive to key drivers, (8) managing uncertainty, and (9) mediating effective participation. Seven common integrated modeling approaches selected for our review are: (a) material flow analysis, (b) system dynamics, (c) Bayesian network, (d) bio-economic optimization, (e) coupled components, (f) cellular automata, and (g) multi-agent systems (agent-based model). The results are the matrices of concise narrative assessments with references to published examples, rather than abstract scores, of each modeling approach against the nine methodological criteria. The matrices can serve as methodological maps that help citizen scientists, with own context, to position themselves and wherefrom identify relevant modeling directions towards meeting the required methodological criteria better. We demonstrated the potential usage of the reviewed matrices with different typical use cases.

***Keywords**:* agricultural landscape, integrated modeling, methodological abilities, review, socio-ecological resilience, sustainability

RESEARCH PROGRAM ON Dryland Systems

Food security and better livelihoods for rural dryland communities

Methodological Abilities of Integrated Models to Support Agricultural Landscape Resilience: Current Status and Research Perspectives

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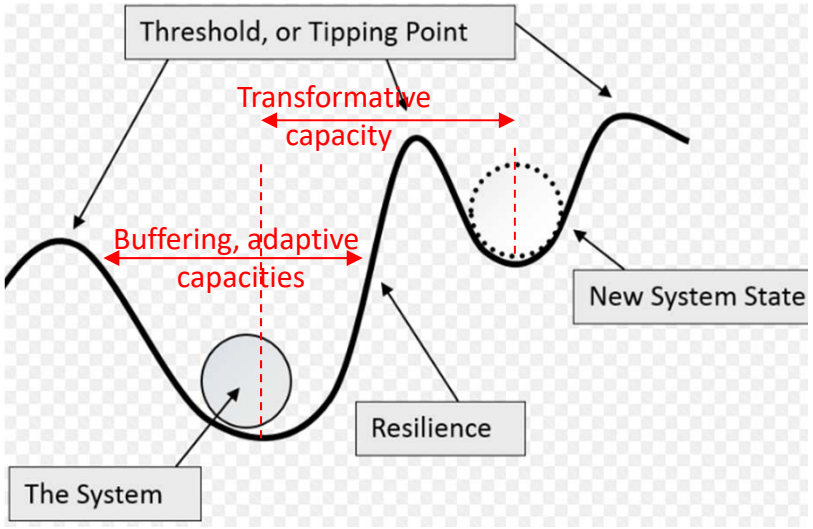
Motivation

- Needs to increase the resilience of rural landscapes in the face of global changes.
  - **Buffering** and **adaptive capacities** (maintain current stability regime)
  - **Transformability** (implement innovations to transit to a better stability regime).
  - **Social equity** (in both benefits and responsibilities)

- Integrated modeling as a methodological choice
  - Understand, measure, assess landscape resilience often beyond the ability of direct, empirical studies

- Lacking of systemized, critical review on methodological abilities of current modeling approaches for rural landscape resilience research



Objectives

This review study aims to

- **highlight the methodological abilities** of integrated system modeling (ISM) ideally needed for agricultural landscape management for resilience,

- **review strengths and weakness of common ISM methods** with respects to these required methodological abilities, and

- discuss **perspectives of modeling research** toward meeting these abilities.

From what bases were the criteria of methodological abilities drawn?

Method: review of key literature on theories, conceptual frameworks, mini-reviews of socio-ecological systems' sustainability (including resilience) → key criteria/principle being needed to understand and/or managed → methodological abilities of ISM ideally needed

- The Ecosystem Services (ES) framework (e.g. de Groot et al. 2002)
- The Coupled Human and Nature System (CHANS) framework (e.g. Liu et al. 2007; Reynolds et al. 2007)
- The Socio-ecological System (SES) framework (Ostrom 2007, 2009)
- The Management and Transition Framework (MTF) (e.g. Pahl-Wostl 2009)
- The Human-Environment System (HES) framework (Scholz et al. 2011)
- The mini-review of HES-like frameworks (Binder et al., 2013)

Methodological abilities ideally needed

System aspect being important landscape sustainability (incl. resilience)	Methodological ability of ISM
Landscape sustainability involves the dynamics of **coupled SES or HES**	▪ Represent **social-ecological interactions, inter-disciplinarity***
Crossing **threshold of "slow/controlling"** variables → shifts in system's stability domain	▪ Explain **changes in slow/controlling parameters** or **structural features**

* Discussed in Boulanger and Blanchet (2005), otherwise be new

What integrated systems modeling methods were reviewed against the methodological abilities?

Method: adapted from the common ISM methods discussed in previous reviews - i.e. Boulanger and Brechet (2005), Kelly et al. (2013)

- Material Flow Analysis (MFA)
- System Dynamics (SD)
- Bayesian Belief Network (BBN)
- Bio-economic optimization modeling (BOM)
- Coupled components systems (CCS)
- Cellula automata (CA)
- Multi-agent System/Agent-Mased Modeling (MAS/ABM)

with application cases in rural/agricultural landscape studies

Matrices of concise narrative assessments

A simplified, subset of whole evaluation matrix (**no** – weak/difficult –possible/medium – **strong**)

Methodological ability	MFA	SD	BBN
Socio-ecological interactions	weak	**strong**	**strong**
Changeable slow/controlling/structural parameters	**no**	**no**	**no**
Flexible, multi-scale feedbacks	**no**	**no**	**no**
Heterogeneities (s= social, b= biophysical)	**no**	**no**	possible
Human behavior changes	**no**	possible	**strong**
Uncertainty measurement	possible	possible	**strong**
Multi-dimensional outputs	**strong**	**strong**	weak
Distributed outputs	**no**	**no**	possible
Participation mediation	**strong**	**strong**	**strong**

Narrative reviews are not showed.

Matrices of concise narrative assessments

A simplified, subset of whole evaluation matrix (**no** – weak/difficult – possible/medium – **strong**)

Methodological ability	BOM	CCS	CA	MAS/ABM
Socio-ecological interactions	medium	medium - **strong**	medium	**strong**
Changeable slow/controlling/structural parameters	**no**	**no**	possible	possible
Flexible, multi-scale feedbacks	**no** - weak	**no** - weak	**strong**	**strong**
Heterogeneities (s= social, b= biophysical)	**no** - weak	(s): **no** –weak; (b): possible - **strong**	(s): weak; (b): **strong**	**strong**
Human behavior changes	possible - **strong**	**no** - **strong**	weak - possible	**strong**
Uncertainty measurement	**no** - weak	**no** - possible	**strong**	**strong**
Multi-dimensional outputs	medium - **strong**	medium - **strong**	medium	**strong**
Distributed outputs	**no**	**no** - possible	**strong**	**strong**
Participation mediation	weak	weak	weak	weak - **strong**

Narrative reviews are not showed.

Discussions

- The matrices can serve as **methodological maps** that help citizen scientists, with **own contexts**, to position themselves and wherefrom identify relevant modeling directions towards meeting the required methodological criteria better

- The “cost” of using a method was not reviewed as it is specific to users’ context
  - Research goal - driven
  - Availability of current expertise
  - Learning potentials: connected expert network, own background, personal preferences/comportabilities
  - Data requirement vs. availability

- Singular method or hybrid approach: also context-specific
  - “Thin” ,or “thick” modeling project
  - Etc.

Thank you