Representing Human Agency in Land Use Models

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Methods and approaches to modelling the Anthropocene

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Highlights

- Socio-ecological system dynamics of the Anthropocene require novel modelling approaches.
- Models need to capture emergent properties, regime shifts and feedbacks between system components.
- Human decision making and responses are essential components of Anthropocene.
Including and representing human behavior

....many uncertainties in the abiotic and biotic system remain....

....But, human systems are in integrated models often much more poorly represented as compared to biophysical processes.....

....while humans are the main driver of environmental change...
Conceptualisations of land systems drivers

Conceptual models after Hersperger et al, 2010
‘Classical’ synthesis: count of most important drivers

- Settlement expansion (39)
- Industrial development (34)
- Infrastructure construction (47)
- Agricultural development (82)
- Peat extraction (13)
- Wood extraction (15)

Institutional factors (24)
Population density (63)
Economic growth (73)
Technological innovations (18)
Little environ. awareness (10)
Cultural/Recreational (8)

(82) number of times mentioned as cause (total number of cases = 105).
(52) number of times an underlying force drives a proximate cause.
(19) sole proximate cause or underlying force.

Two-factor causation.
Three-factor causation.
Conceptualisations of land systems drivers

I
Driving forces

II
Driving forces
Actor
Land change

III
Driving forces
Actor
Land change

IV
Driving forces
Actor
Land change

Conceptual models after Hersperger et al, 2010
Intensification
- Increase in agricultural land area
- Removal of landscape elements
- Increase in management intensity
- Change in agricultural land use activities
- Specialization

Extensification
- Land abandonment
- Increase in landscape elements
- Decrease in management activities
- Change in agricultural land use activities
- On farm diversification

Land manager’s decisions

Farm(er) characteristics
- Farmer characteristics
- Farm characteristics
- Personal attitudes

Demographic drivers
- Population density
- Migration

Economic drivers
- Globalization
- Labour markets
- Local demand

Technological drivers
- Mechanization
- Land improvement (drainage, irrigation)

Institutional drivers
- Subsidies
- Tenure
- Governance shifts (post-socialism)

Social and cultural drivers
- Tourism and recreation
- Public attitudes

Location factors
- Topography
- Accessibility
- Climate

Van Vliet et al., 2014
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### Agent typology

**Agent population**

- **No**
  - **Farm diversification**
    - **Hobby**
    - **Non-expansionist conventional**
  - **Non-expansionist diversifier**
  - **Expansionist conventional**
  - **Expansionist diversifier**

- **Yes**
  - **Farm expansion**
    - **Farm diversification**
      - **Hobby**
      - **Non-expansionist conventional**
      - **Non-expansionist diversifier**
      - **Expansionist conventional**
      - **Expansionist diversifier**

### Agent type parameterization: production strategies

<table>
<thead>
<tr>
<th>Agent type</th>
<th>Stop farming</th>
<th>Increase production</th>
<th>Decrease production</th>
<th>Diversify farm practices</th>
<th>Compensation schemes</th>
<th>Tourism and recreation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hobby farm</td>
<td>+</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>+</td>
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<tr>
<td>Non-expansionist conventional</td>
<td>+</td>
<td>−</td>
<td>+</td>
<td>+/−</td>
<td>+/−</td>
<td>+</td>
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<tr>
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<td>+</td>
<td>−</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Expansionist conventional</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Expansionist diversifier</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>+</td>
<td>+</td>
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</tr>
</tbody>
</table>
Conceptualisations of land systems drivers

I
Driving forces

II
Driving forces

III
Driving forces

IV
Driving forces

Actor

Land change

Conceptual models after Hersperger et al, 2010

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the Von Thünen model

- Economic theory:
  - People optimize profit
  - Land rent is determined by the market price, land quality and transport costs
  - Land use is therefore determined by market conditions and the distance to the market
Implementation of decision making in models

- Hierarchical allocation: allocating ‘highest land rent’ locations to specific land uses following a hierarchy (urban > agriculture > grassland/forest > rest/nature)

- Equilibrium/partial equilibrium/optimization approaches optimizing total land rent (competition amongst land uses)

- Rule-based allocation (often using land rent based rules or cost-benefit analysis)
Agents’ decision-making

Internal factors
- Ability
- Willingness

Options → Decisions → Actions

External factors
- Policies & subsidies
- Demand
- Advice

Social networks & institutions

Feedback

Land-use pattern

Farm scale

Regional scale

Valbuena et al., Landsc. Ecol., 2010
Agent-objectives influencing land use decisions

- Environmental objectives
- Economic objectives
- Security objectives
- Self-realization objectives
- Prestige objectives
<table>
<thead>
<tr>
<th>Role</th>
<th>Security</th>
<th>Environmental</th>
<th>Economic</th>
<th>Prestige</th>
<th>Self-realization</th>
<th>Mode: constraints</th>
<th>Mode: trade-off factors</th>
<th>Gross domestic product (US $)</th>
<th>Upfront capital index</th>
<th>Social power rank</th>
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<td>0.8</td>
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<td>0.2</td>
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<td>[ 1 2 ]</td>
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<td>1</td>
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<tr>
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<td>0.2</td>
<td>0</td>
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<td>[ 0 ]</td>
<td>[ 1 2 ]</td>
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<td>10</td>
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<td>Commercial mega company</td>
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<td>Transformed collective</td>
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<td>Poor self-sufficient</td>
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<td>[ 0 1]</td>
<td>[ 2 ]</td>
<td>10000</td>
<td>0</td>
<td>8</td>
</tr>
</tbody>
</table>
Meta-analysis of land use decision making

- Natural capital
- Social capital
- Human capital
- Financial capital

Ability

Decision-making actor

Willingness

- Attitudes
- Objectives

Land-use decision
Meta-analysis of land use decision making

- 212 articles suitable out of >5000 screened
- 251 cases
<table>
<thead>
<tr>
<th>Cluster</th>
<th>Objective</th>
<th>Attitude</th>
<th>Ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster 1</td>
<td>Livelihood security, moderate economic growth</td>
<td>High biospheric values, progressive</td>
<td>High land tenure security, social safety nets</td>
</tr>
<tr>
<td>Cluster 2</td>
<td>Lifestyle, environment and economic</td>
<td>High environmental values, progressive, law obedient</td>
<td>High financial, natural and social capital</td>
</tr>
<tr>
<td>Cluster 3</td>
<td>Economic, environment and social prestige</td>
<td>Progressive, law obedient</td>
<td>Highest financial, natural and social capital</td>
</tr>
<tr>
<td>Cluster 4</td>
<td>Economic and livelihood security</td>
<td>progressive</td>
<td>Moderate financial capital, land size, land tenure security</td>
</tr>
<tr>
<td>Cluster 5</td>
<td>Livelihood security and economic</td>
<td>Progressive, biospheric values</td>
<td>Low financial and natural capital, high social capital</td>
</tr>
<tr>
<td>Cluster 6</td>
<td>Survival</td>
<td>Conservative</td>
<td>Lowest financial, natural and social capital</td>
</tr>
</tbody>
</table>
Conceptualisations of land systems drivers

I  II  III  IV

Driving forces  Driving forces  Driving forces  Driving forces

Actor

Land change  Land change  Land change  Land change

Conceptual models after Hersperger et al, 2010
Feedbacks

- Adaptation and mitigation strategies to environmental change
- Telecoupling (feedbacks across a distance/scales: markets, governance, people, conflict)
- Learning and developing (innovation, scale enlargement) towards different decision making strategies

➡️ Behavior and land use decision making are not static and constant as our models assume…

➡️ The rules of the game are changing….
Representing multi-scale interactions and feedbacks
The future of land use modelling

- High uncertainties inherent to modelling socio-ecological processes
- Similarities between current assessment models in representation of human dimensions are likely to underestimate the real uncertainty
Decomposition of variation

Prestele et al., GCB 2016
The future of land use modelling

- High uncertainties inherent to modelling socio-ecological processes

- Similarities between current assessment models in representation of human dimensions are likely to underestimate the real uncertainty

- Alternative ways of representing human dimensions in land use modelling is critical

- Agent-based modelling is NOT the only way forward (as many agent-based models start resembling pixel-based models)
The future of land use modelling

Ways forward:

- empirical work in ‘measuring’ and ‘characterizing’ land use decision making to underpin model algorithms

- move away from: one size fits all, vary decision making in space and time (adapt model rules ‘on the go’)

- new land use representations in large scale models accounting for land management: a land systems approach
Land cover map of Laos
Results

Ornetsmeuller et al., in prep

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Regime shifts in land systems and landscapes

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What does it take?

- Respect the variation in land use models (move away from a fixed set of IPCC IAM models and MIP type of exercises that lead to convergence of models)

- Bring modelers and case-study scientists together:
  - SIMPLIFY THE COMPLEXITY OF THE REAL WORLD
  - REPRESENT THE DIVERSITY OF THE REAL WORLD

- Invest in model building rather than in model application