Extending ABM approaches to national and continental scales

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The uptake of energy crops (miscanthus and Short Rotation Coppicing)

How quickly are climate mitigation policies adopted?

Simulation of the uptake of the bioenergy crops miscanthus and short rotation coppicing

Figure 5. Sample output maps of energy crop selection and power plant locations in 2020, 2030 and 2040.

Alexander et al. (2013). Journal of the Royal Society Interface, 10, 20130656
Time lags in adaptation - historic oilseed rape data for England and Wales, against a baseline year of 1966, and mean modelled perennial energy crop areas, using a baseline year of 2010

Modelling Adaptation to Global Change in the Swedish forestry sector

CRAFTY-Sweden Model
Modelling Adaptation to Global Change in the Swedish forestry sector

CRAFTY-Sweden Model

1 km² resolution
Forest Owner Functional Types

- Profit-oriented
  - Productionist
    - Industrial Productionist
    - Non-industrial Productionist
  - For-profit Recreationist
  - For-profit Multiobjective
- Multiobjective
- Recreationalist
- Conservationist
- Passive
  - Ecosystem Conservationist
  - Species Conservationist
  - Non-profit Multiobjective

(Blanco et al. 2015)
Competitiveness of Forest Owner Types

- **Productionist Pine-Spruce**
- **Multi-objective Pine-Spruce**
- **Recreationalist Pine-Spruce**

**Scenarios**
- Reference
- SSP1-RCP4.5
- SSP3-RCP8.5
- SSP5-RCP8.5

Year
Regional land-use changes (2010-2100)
Ecosystem Service Provision (2010-2100)

Scenarios
- Reference
- SSP1-RCP4.5
- SSP3-RCP8.5
- SSP4-RCP4.5
- SSP5-RCP8.5

Graphs showing the provision of ecosystem services over time for different scenarios.
Coping Ability:

degree to which an owner type can be at least as competitive under a global change future (defined by the scenarios) as under present conditions
Institutional Types

Conceptual model of generic institutions in the Swedish forestry sector
Institutional Action Conceptual Model

Flowchart:
- Planned Adaptation
  - (Imperfect) Environmental Monitoring
  - Service Preferences
    - Situational Service Priorities
  - Service Supply-Demand Difference
    - Perceived Effectiveness of Potential Actions
    - Action Priorities
    - Action Outcomes
      - Land
      - Land Managers
      - Other Institution
# Land planner preference weights for scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Service Supply-Demand Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIMBER PROFUSION</td>
<td>Available forest land is managed primarily for timber production while other services are treated as secondary. Timber supply is very high to the point of substantially going beyond the demand. The supply of biodiversity associated with production-oriented forests is low. Under such circumstances some recreation is provided, but it does not meet demand.</td>
<td>Timber: 0.6  Biodiversity: -0.5  Recreation: -0.1</td>
</tr>
<tr>
<td>ENVIRONMENTAL EDEN</td>
<td>A large proportion of the forest land is managed with nature conservation as a primary objective. Supply of timber does not meet demand, while biodiversity is oversupplied. Recreation, being partly associated with levels of biodiversity, is also supplied slightly beyond the demand.</td>
<td>Timber: -0.2  Biodiversity: 0.5  Recreation: 0.1</td>
</tr>
<tr>
<td>PERFECT EQUILIBRIUM</td>
<td>Forest land management seeks multi-functionality. Production levels of all three services are equal, but they do not meet the demand.</td>
<td>Timber: -0.3  Biodiversity: -0.3  Recreation: -0.3</td>
</tr>
</tbody>
</table>
Example: supply demand difference (SDD)

Institutions as emergent structures?
The CRAFTY model: continental scale applications

A1 scenario
Ways forward?

• Building the next generation of human dimensions models that are based on:
  – Better theory
  – More complete process representation, e.g. individual decision making, adaptive learning, agent evolution, institutional emergence, ...
  – Multi-scalar dynamics
  – Building from the bottom-up, rather than the top down

• Do we need typologies, or models of 8 billion agents?
## Models in a land use change inter-comparison study

<table>
<thead>
<tr>
<th>Model name</th>
<th>Key Publication</th>
<th>Spatial resolution data (model, if different)</th>
<th>Spatial extent</th>
<th>Temporal resolution data (model, if different)</th>
<th>Model type (classification)</th>
<th>Scenario descriptions (number of scenarios)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIM/GGE</td>
<td>Fujimori et al. (2012)</td>
<td>17 regions</td>
<td>Global</td>
<td>2005, 2010, 2050 and 2100 (annual)</td>
<td>CGE</td>
<td>SSP1, SSP2 and SSP3. (3)</td>
</tr>
<tr>
<td>CAPS</td>
<td>Meiyappan et al. (2014)</td>
<td>0.5 x 0.5 degree grid</td>
<td>Global</td>
<td>2005, 2030, 2050 and 2100</td>
<td>Allocation model using demand from CGE or PE model (Hybrid)</td>
<td>SSP3, SSP5, RCP 4.5 and RCP 8.5, each under estimated model parameters from historical data from Ramankutty et al. (Ramankutty et al., 2008) and HYDE (Goldewijk, 2001). (8)</td>
</tr>
<tr>
<td>CLIMSAVE-IAP</td>
<td>Harrison et al. (2015)</td>
<td>10 x 10 arc-minute grid</td>
<td>Europe (EU27+2)</td>
<td>2010 and 2050</td>
<td>Rule-based</td>
<td>SRES A1, A2, B1 and B2, each under current baseline and the socio-economic factors for the SRES scenario*. (8)</td>
</tr>
<tr>
<td>CLUMondo</td>
<td>van Asselen &amp; Verburg (2013)</td>
<td>9.25 x 9.25 km grid</td>
<td>Global</td>
<td>2000 - 2040; decadal (yearly)</td>
<td>Allocation model using demand from CGE or PE model (Hybrid)</td>
<td>FAO 4Demand, Carbon, Potential Protected Area. (3)</td>
</tr>
<tr>
<td>CRAFTY</td>
<td>Murray-Rust et al. (2014)</td>
<td>1 x 1 km grid</td>
<td>Europe (EU27)</td>
<td>2010 - 2040; decadal (yearly)</td>
<td>Agent-based model (Rule-based)</td>
<td>SRES A1 and B1. (2)</td>
</tr>
<tr>
<td>DynaCLUE</td>
<td>Verburg &amp; Overmars (2009)</td>
<td>1 x 1 km grid</td>
<td>Europe (EU27)</td>
<td>2000-2040; decadal</td>
<td>Allocation model using demand from CGE or PE model (Hybrid)</td>
<td>SRES A1, A2, B1 and B2. (4)</td>
</tr>
<tr>
<td>EcoChange</td>
<td>Dendoncker et al. (2006)</td>
<td>250 x 250m grid</td>
<td>Europe (EU25+2)</td>
<td>2010, 2020, 2050, 2080</td>
<td>Rule-based</td>
<td>Three core socio-economic scenarios, growth and globalisation, BAU, and sustainable development, and three shock scenarios, climate, energy price and pandemics. (6)</td>
</tr>
<tr>
<td>FABLE</td>
<td>Steinbuks &amp; Hertel (2014)</td>
<td>Global</td>
<td>Global</td>
<td>2005-2105; annual</td>
<td>PE</td>
<td>Baseline consistent with SRES A1B and RCP 2.6, with other scenarios adjusting population, climate to RCP 8.5, oil prices, economic growth, and more stringent GHG emission regulations. (6)</td>
</tr>
<tr>
<td>FARM</td>
<td>Sands et al. (2014)</td>
<td>13 regions</td>
<td>Global</td>
<td>2005 - 2050; five year steps</td>
<td>CGE</td>
<td>SSP1, SSP2 and SSP3, each under the current climate and climate scenario RCP 4.5, RCP 6.0 and RCP 8.5, respectively*. (6)</td>
</tr>
<tr>
<td>GCAM</td>
<td>Calvin et al. (2013)</td>
<td>32 regions</td>
<td>Global</td>
<td>2010 - 2100; decadal</td>
<td>PE</td>
<td>SSP1, SSP2, SSP3, SSP4 and SSP5. (5)</td>
</tr>
<tr>
<td>GLOBIOM</td>
<td>Havlik et al. (2014)</td>
<td>5 x 5 arc-minute grid</td>
<td>Global</td>
<td>2010 - 2100; decadal</td>
<td>PE</td>
<td>SSP1, SSP2, SSP3 (3)</td>
</tr>
<tr>
<td>IMAGE</td>
<td>Stehfest et al. (2014)</td>
<td>0.5 x 0.5 degree grid</td>
<td>Global</td>
<td>2010, 2030, 2050 and 2100 (annual)</td>
<td>Allocation model using demand from CGE model (Hybrid)</td>
<td>SSP2 reference and high bio-energy demand scenario under RCP 2.6. (2)</td>
</tr>
<tr>
<td>LandSHIFT</td>
<td>Schaldach et al. (2013)</td>
<td>5 x 5 arc-minute grid</td>
<td>Global</td>
<td>2005-2050; five year steps</td>
<td>Rule-based</td>
<td>Fuel and heat scenarios, with both BAU and regulation assumptions for each. (4)</td>
</tr>
<tr>
<td>LUISA</td>
<td>Baranzelli et al. (2014)</td>
<td>100 x 100m grid</td>
<td>Europe (EU28)</td>
<td>2010 - 2050; decadal (annual)</td>
<td>Cellular-automata and statistical model (Rule-based)</td>
<td>Reference scenario. (1)</td>
</tr>
<tr>
<td>MagPie</td>
<td>Popp et al. (2014)</td>
<td>0.5 x 0.5 degree grid</td>
<td>Global</td>
<td>1995-2100, five year steps</td>
<td>PE</td>
<td>Scenarios based on SSP2, with and without bioenergy CCS. (2)</td>
</tr>
<tr>
<td>PLUM</td>
<td>Engström et al. (2016)</td>
<td>157 countries</td>
<td>Global</td>
<td>1990-2100; annual</td>
<td>Rule-based</td>
<td>SRES A1, A2, B1 and B2 (4)</td>
</tr>
</tbody>
</table>

Notes:
* EU27 is current 28 European Union member states (EU28) less Croatia. EU25 additionally excludes Romania and Bulgaria. EU25+2 & EU27+2 includes Norway and Switzerland to EU25 and EU27, respectively.
* CLIMSAVE-IAP and FARM provided results for multiple climate models under otherwise the same scenario; the mean figure for each scenario/model combination was used.
Uncertainties in global scale land use models
Global coefficient of variation and variance components

a) Cropland

b) Pasture

c) Forest

i) Coefficient of variation

ii) Fraction of variance

Legend:
- Blue: Initial condition
- Green: Model Type
- Yellow: Model cell number
- Orange: Population
- Red: GDP growth rate
- Maroon: Global trade
- Cyan: Inequality
- Brown: Technology change
- Light blue: Residual

Year:
- 2010
- 2040
- 2070
- 2100
Land use change in a hypothetical region with global and regionalised demand

Economic model type (CGE vs PE) for cropland

Source: Peter Alexander, University of Edinburgh