Land use change modeling tools

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Figure 4: GLP analytical structure.

Earth System

T1.1

T2.1

T1.3

Land Systems

Social Systems
- Population
- Social/Economic structure
- Political/Institutional regime
- Culture
- Technology

Decision Making

T2.2

Ecological Systems
- Biogeochemistry
- Biodiversity
- Water
- Air
- Soil

T1.2

Land Use & Management

T2.3

T2.4

T3.1 Critical pathways of change

T3.2 Vulnerability and resilience of land systems

T3.3 Effective governance for sustainability

T1. Dynamics of land systems

T2. Consequences of land system change

T3. Integrating analysis and modelling for land sustainability

Source: Global Land Project Scientific Plan

Ana Aguiar & colleagues, GLP Workshop, Ilhabela, Nov 2011
CCST LUCC Modeling Group

**Environmental indicators:**
Integration to greenhouse emission and secondary forests dynamics models

**Scenarios:**
Information to society about alternative land use change under different scenarios

Land use projections generated by Spatially explicit dynamic LUCC models (top-down and agent-based)

Integrated environmental models, coupling to Vegetation (INLAND) and Hydrological Models, aiming at exploring bi-directional feedbacks

Ana Aguiar & colleagues, GLP Workshop, Ilhabela, Nov 2011
Our tools are built on top of the TerraME and they make model creation easier.
INPE-EM
A framework to estimate greenhouse emissions derived from land cover change processes, considering the spatial and temporal heterogeneity of the region. First applied to the Brazilian Amazonia (Aguiar, Ometto et al., forthcoming).

Biomass spatial distribution (source: Saatchi et al., 2007)

Ana Aguiar & colleagues, GLP Workshop, Ilhabela, Nov 2011
LuccABME
Built-in concepts to construct generic agent based models and Example

Source: Assis et al, forthcoming (Relations), Costa et al., forthcoming (Arrangements), Andrade et al, forthcoming (TerraME agents)
Generalization of LUCC spatial explicit models
(Examples: CLUE family, Dinamica, Geomod, and others)

Source: Adapted from Verburg et al. (2006)
LuccME

- A generic and extensible open source framework to build spatially explicit land use and cover change models for different applications and scales.
- Based on the common structure of several well known LUCC models (Verburg et al. 2006, Eastman et al., 2005)
  - Commercial tools: ArcGIS, IDRISI
  - Academic (operational) tools: Clue family (Veldkamp et al. 1996, Verbur et al., 2002), Dinamica (Soares-Filho et al., 2002)
What is a LuccME model?

**Definition of:**
1. Spatial and temporal scale of analysis
2. Database location
3. Land use variables
4. Spatial drivers
5. Potential, Demand and Allocation components *(choice and parameterization)*
6. Output parameters
What is na LuccME model?

Model 1: Deforestation in Amazonia
- Spatial scale: Amazonia, 5 x 5 km²
- Temporal scale: 2000-2050, annual
- Goal: deforestation scenarios

Model 2: Urbanization in Bauru
- Spatial scale: Bauru, 500 x 500 m²
- Temporal scale: 1990-2010, bi-annual
- Goal: urban expansion

Source: Pimenta (2010)
You can compare existing components results, verify which one fits better your application, or even develop new components.

Source: Pimenta (2010)
Constraint to interchangeability of components

They must be *inside the same component branch*.

We defined four branches according to fundamental approach differences:

- Continuos or Discrete
- Structural or Transitional
Transitional x Structural
Transitional models: input land uses at two dates

Exemple of transitional tool Dinamica

1. Define land use transitions
2. Define drivers which explain each transition (quantity and location)
3. Compute potential for each transition
4. Compute demand for each transition
5. Perform allocation of the transitions (not the land use themselves)

Exemple of transition

*Non-urban*->*Urban (Recreation)*)

Structural models: input land uses at one date

Pasture in 1997

Temporary agriculture in 1997

1. Define land use classes
2. Define drivers which explain each land use pattern/structure (accumulated changes)
3. Compute potential for each land use
4. Compute demand for each land use
5. Perform allocation of land use classes

Source: Aguiar et al., 2007; Aguiar, 2006.
Continuos x Discrete
CONTINUOUS MODELS: PERCENTAGE OF EACH USE IN THE CELLS

Pasture percentage in each 5x5 km²

source: IBGE agricultural census 2006 and PRODES 2007
DISCRETE MODELS: CATEGORICAL LAND USE CLASSES

EACH CELL IS CLASSIFIED AS MECHANIZED AGRICULTURE XOR PASTURE XOR FOREST

Classificação Real - 2007

Simulação modelo M2 - 2007

Source: Coelho (2009), Pimenta (2010)
DISCRETE MODELS

LAND USE TRAJECTORIES EXPLICIT REPRESENTATION

Source: Fearnside (2002)
### Available components (LuccME v1.0 Beta)

#### Structural Approach

<table>
<thead>
<tr>
<th>Potential</th>
<th>Continuos</th>
<th>Discrete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LinearRegression</td>
<td>LogisticRegression</td>
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<tr>
<td></td>
<td>SpatialLagRegression</td>
<td>NeighAttractionLogisticRegression</td>
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<tr>
<td>Allocation</td>
<td>AllocationClueLike</td>
<td>AllocationCluesLike</td>
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<tr>
<td></td>
<td>OrderedApproach</td>
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<tr>
<td>Demand</td>
<td>PreComputedValues</td>
<td>PreComputedValues</td>
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<td></td>
<td>ReceiveDynamicValues</td>
<td>ReceiveDynamicValues</td>
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<tr>
<td></td>
<td>EstimateForCalibrationValidation</td>
<td></td>
</tr>
</tbody>
</table>

Red components being developed

[www.terrame.org/luccme](http://www.terrame.org/luccme)
LuccME advanced features

1. Advanced potential component features
2. Advanced allocation component features
3. Model coupling
1. Advanced potential component features

- **Alternative neighborhood** relations through the Generalized Proximity Matrix (GPM)
  - Spatial Regression analyses
  - CA-like models (attraction/repulsion)

- Regionalization to represent **heterogeneous rules of territory use**
  - Spatial drivers/regressions
  - For discrete models, regionalization of possible transitions
  - Dynamic regionalization (space and time)
TerraME incorporates the GPM concept: neighborhood based on Euclidian distance, adjacency and network relations (GPM)

Source: Aguiar et.al,(2003), Carneiro (2006)
Example of heterogeneous rules of territory use (mosaic of Territorial Units in Amazonia)

Source: INCRA, MMA, FUNAI, elaborated by Ana Aguiar (GEOMA)
Allowing multiple rules through dynamic regionalization of the potential module

- Driving factors of the quantity of land use change
- Land use change rate and magnitude (Demand module)
- Top-down constraint
- Allocation Algorithm (Allocation Module)
- Land use map at time t

Suitability or Transition Potential Maps (Potential Transition module)

Regions map at time t (Regionalization module)

Possible land use transitions
Region 1
Possible land use transitions
Driving factors of the location of land use change
Region 2
Possible land use transitions
Region 3
Possible land use transitions
...
Region N

Source: Pimenta et al. (2008)
2. Advanced allocation component features

- **Discrete models:**
  - Optional change in block, parametrized independently for different land uses (block size and shape).

- **Continuous models (features developed for the Brazilian Amazonia by Aguiar (2006), which can be useful in other contexts):**
  - Restriction of maximum magnitude change allowed in general and in each cell (to simulate heterogeneous governance levels and command and control actions)
  - Minimum percentage of a given class in a cell, slowed down in allocation speed after this limit is reached (to simulate Brazilian Forest Code enforcement)
3. Model coupling using TerraME Environment

- Multiscale/hierarchical coupling
- Regionalization of demand
- Update of dynamic variables (regions and drivers)
- Natural and social system models
- To combine potential/allocation components sequentially at the same time step (e.g., like Dinamica combines Expander and Patcher)

(see [www.terrame.org/luccme](http://www.terrame.org/luccme) for explanation and details about these items)
Acknowledgments

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“The essence of sustainability is to harmonize economic development with social goals and environmental preservation. At its core is the moral imperative that current generations should pass along an undiminished world to their descendants. To a large degree, sustainability is a challenge to think about the long-range future and, in so doing, to rethink the present. Sustainable development brings the question of the future to the strategic forefront of scientific research, policy deliberation, forward-thinking organizations, and the concerns of citizens.”

(Raskin et al., 2005 – Millenium Ecossystem Assessment)