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INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

Land use change modeling tools

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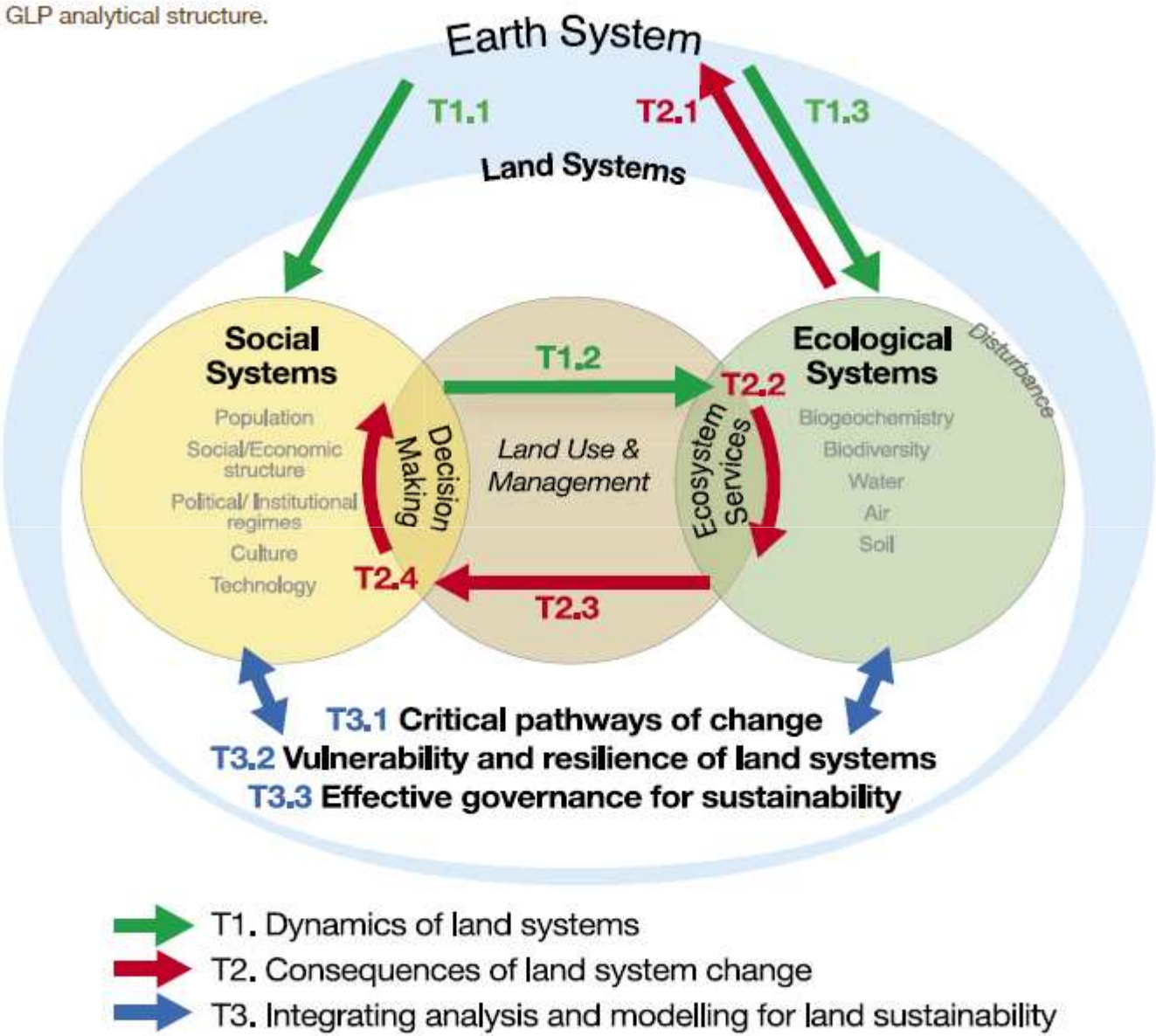
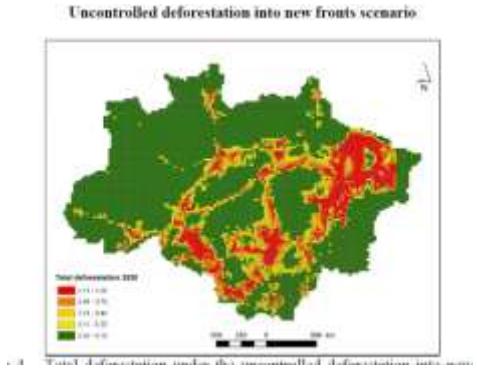
Figure 4: GLP analytical structure.



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

CCST LUCC Modeling Group



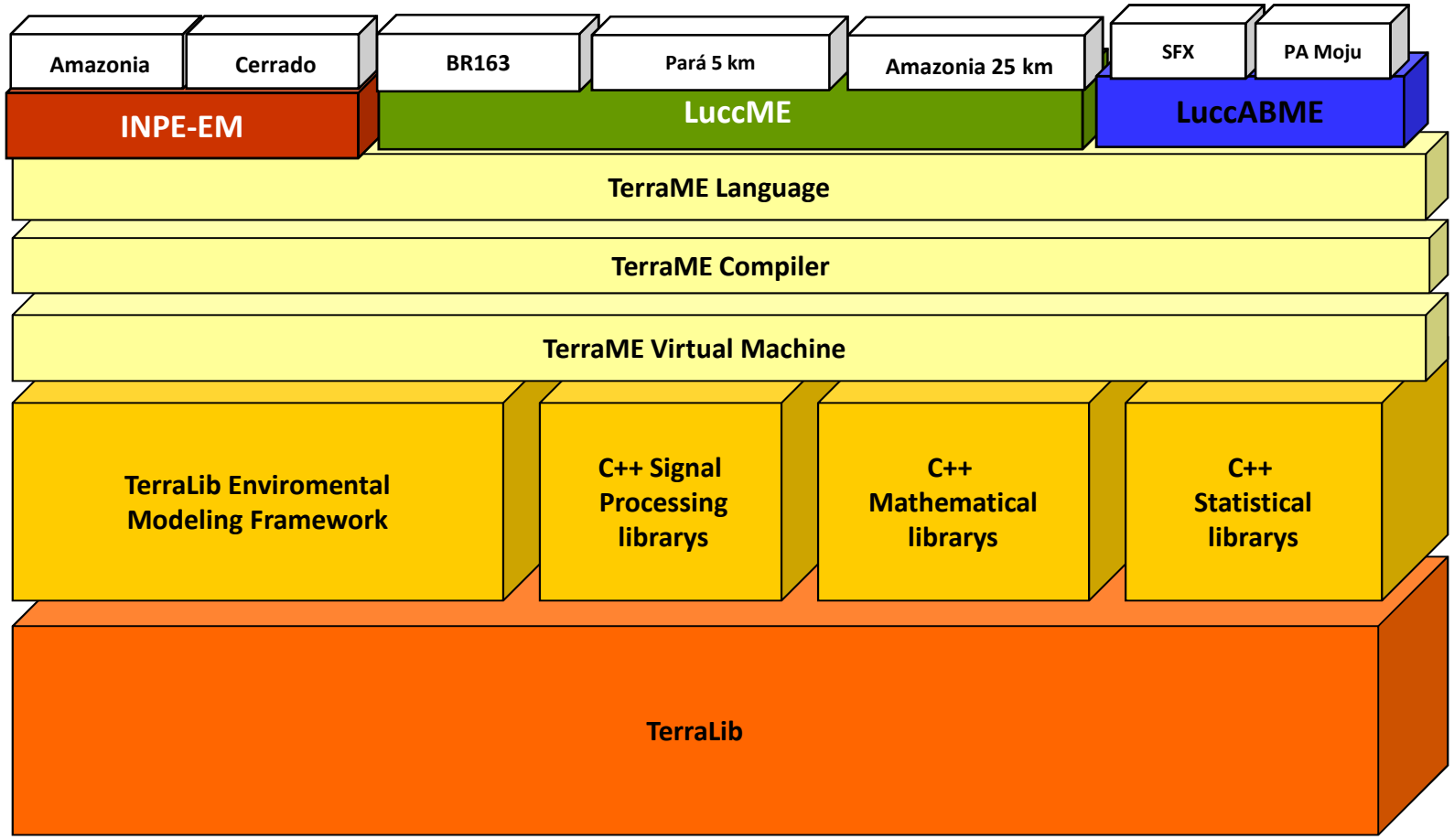
Scenarios: information to society about alternative land use change under different scenarios

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

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

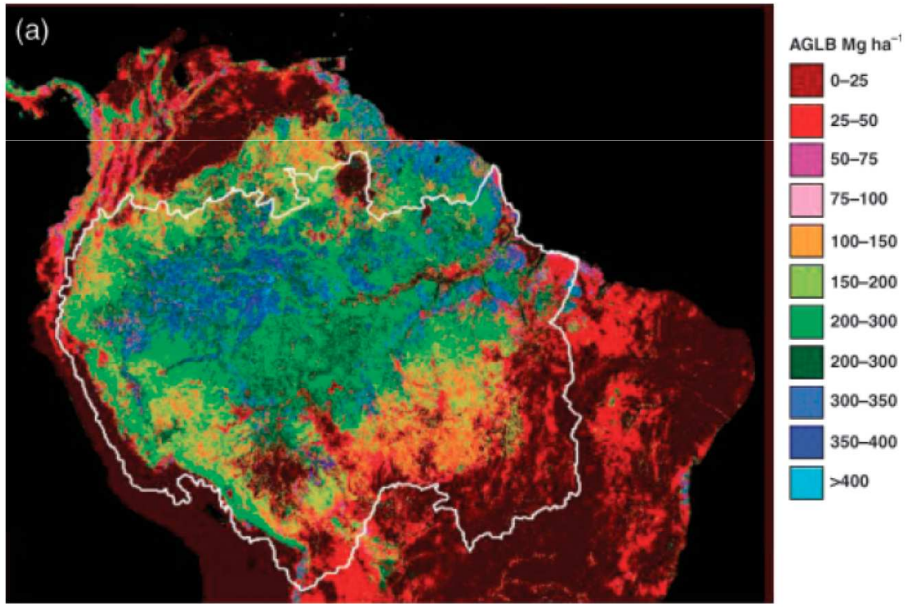
Our tools are built on top of the TerraME and they make model creation easier



www.terrame.org

INPE-EM

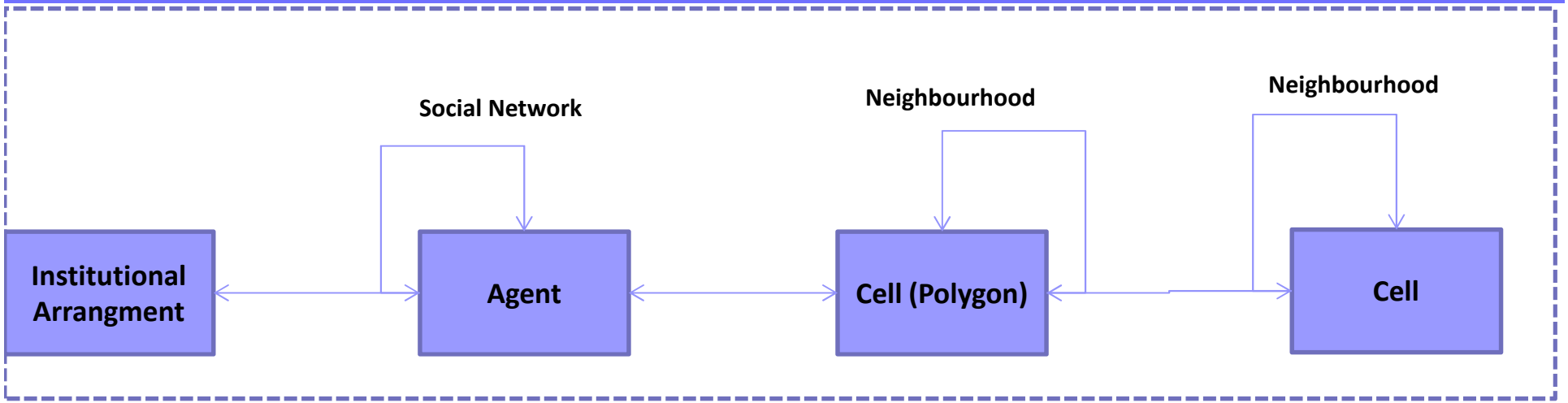
A framework to estimate greenhouse emissions derived from land cover change processes, considering the spatial and temporal heterogeneity of the region. First applied to the Brazilian Amazonia (Aguiar, Ometto et. al, forthcoming).



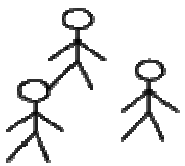
Biomass spatial distribution (source: Saatchi et al., 2007)

LuccABME

Built-in concepts to construct generic agent based models and Example



Territorial arrangements
(protected areas)
Non-territorial
(soy moratorium)

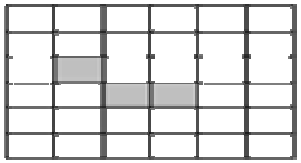


Cod_prop	Capital
1	10000
2	20000

Farmers

Cod_farm	Cod_prop	Area
1	1	100
2	1	200
3	2	300

Farms



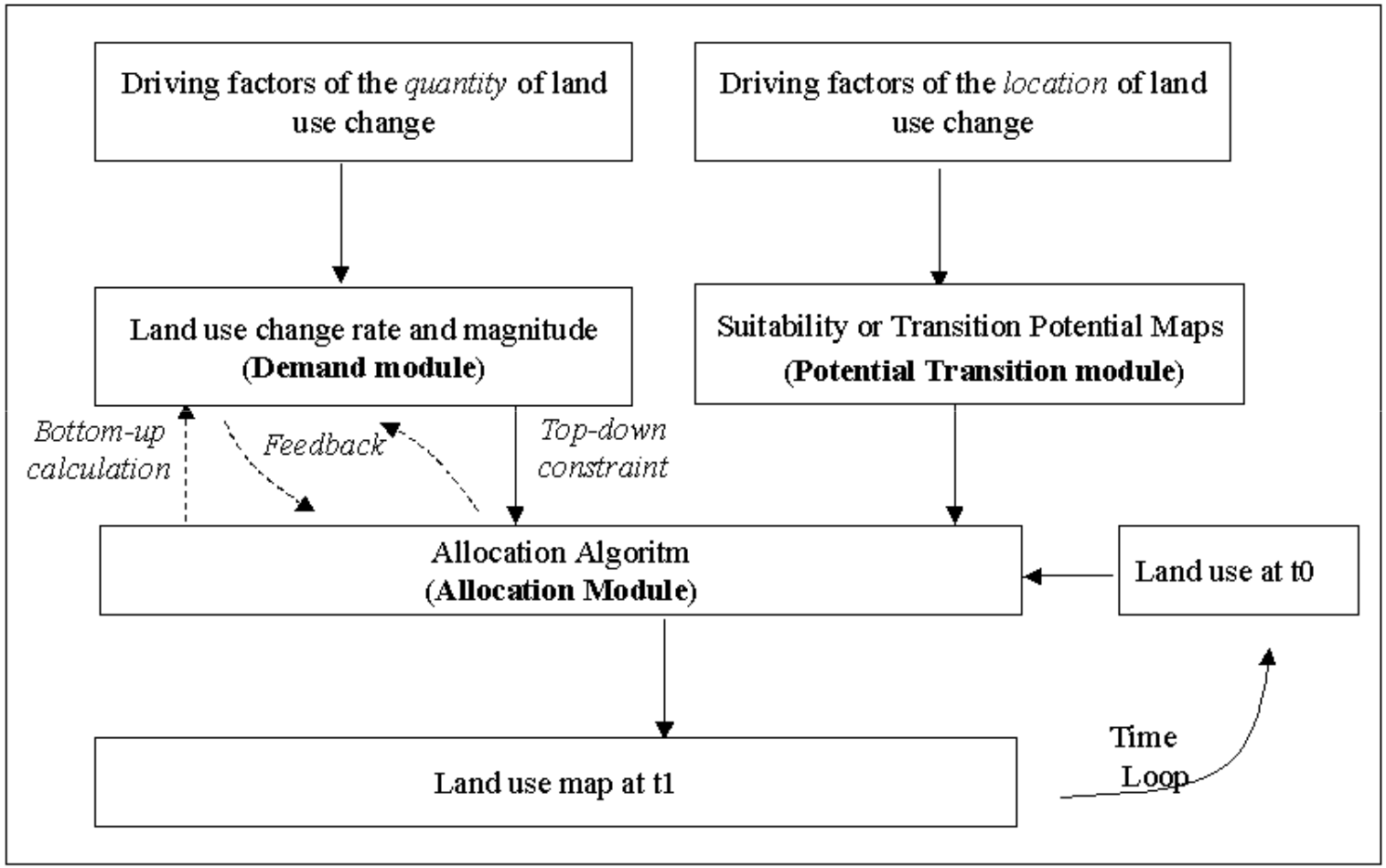
Forest	Dist_roads
1	100
	2 300
0	1500

Cells

Source: Assis et al, forthcoming (Relations), Costa et al., forthcoming (Arrangements), Andrade et al, forthcoming (TerraME agents)

Generalization of LUCC spatial explicit models

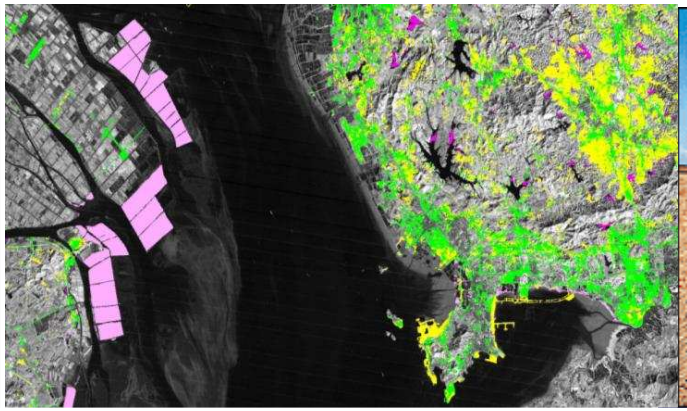
(Examples: CLUE family, Dinamica, Geomod, and others)



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?

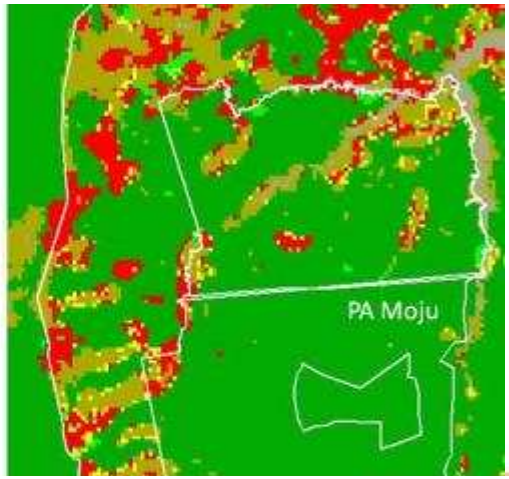
Spatial scale: Amazonia, 5 x 5 km^2
Temporal scale: 2000-2050, annual
Goal: deforestation scenarios

Spatial scale: Bauru, 500 x 500 m^2
Temporal scale: 1990-2010, bi-annual
Goal: urban expansion

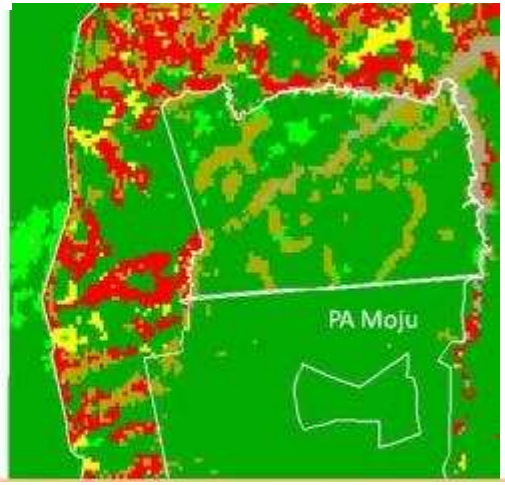
Source: Pimenta (2010)

You can compare existing components results, verify which one fits better your application, or even develop new components.

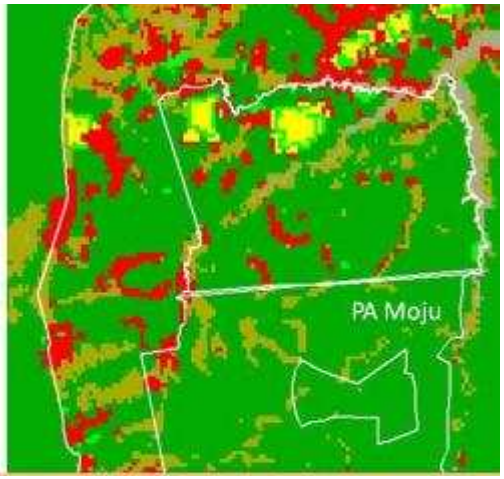
M1



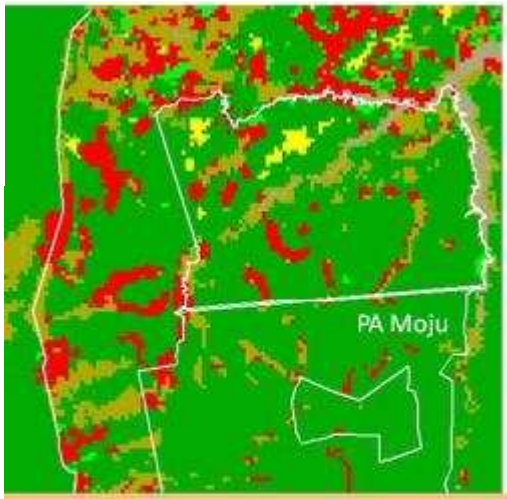
M2



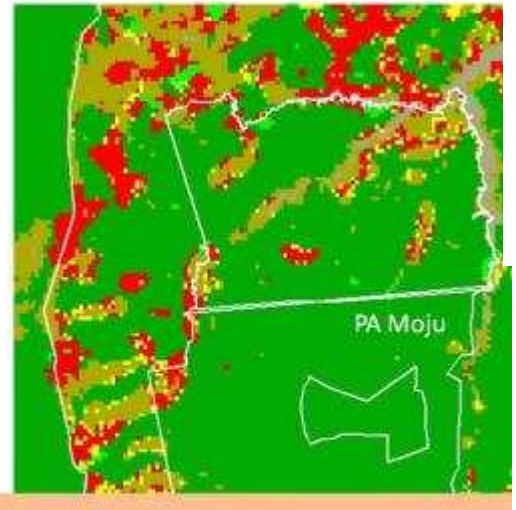
M3



Real (observed 2007)



M2 (simulated 2007)



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

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Transitional x Structural

Transitional models: input land uses at two dates

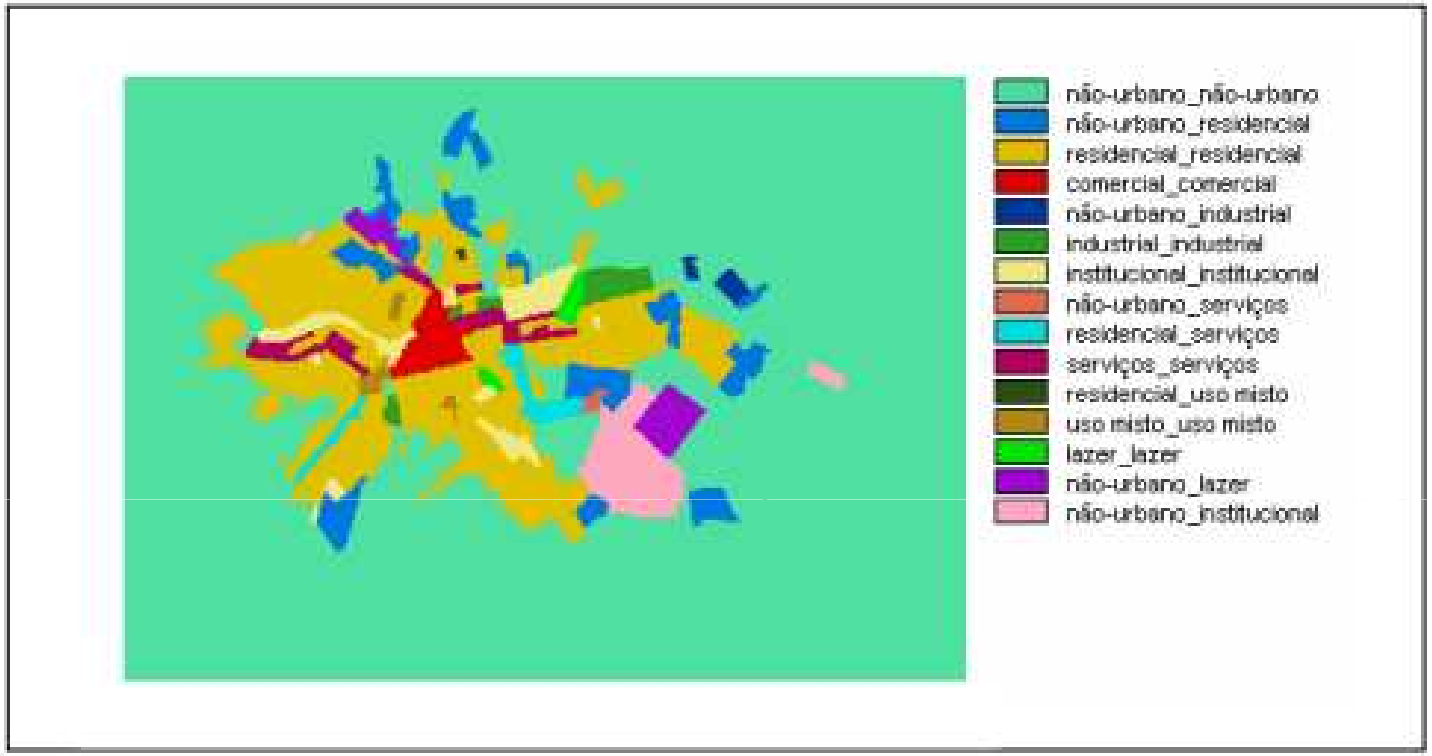


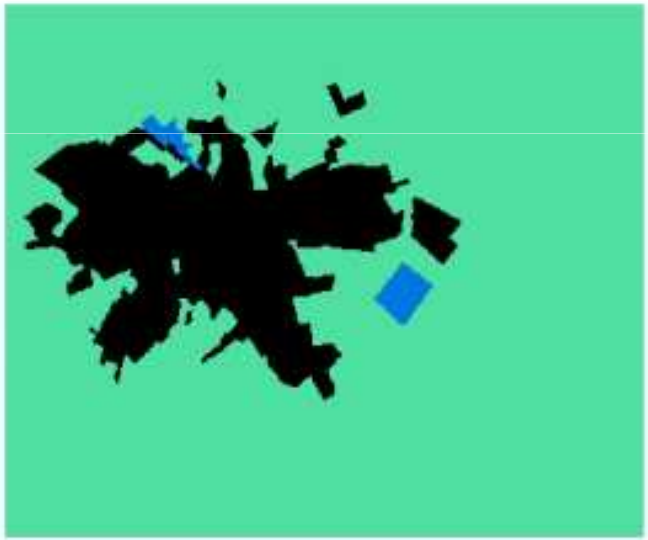
FIGURA 6.4 – Mapa de tabulação cruzada entre os mapas de uso de Bauru: 1967-1979.

Exemple of transitional tool
Dinamica

Source: Tese de Doutorado Claudia Almeida (2004)

Transitional models: differences betwen two dates

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)



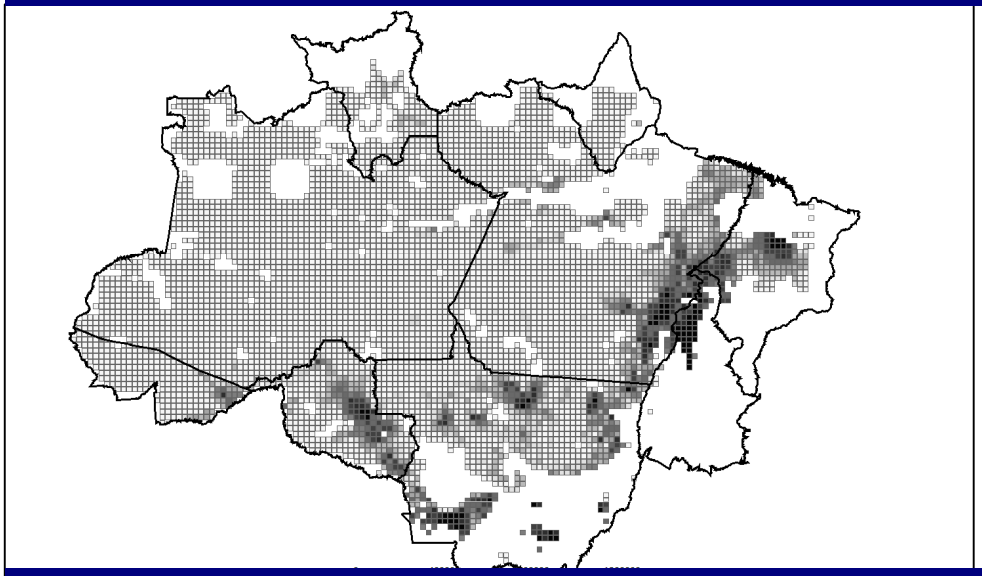
Exemple of transition
Non-urban->Urban (Recreation)

FIGURA 6.6 – Exemplo de um mapa de transição de uso do solo (não-urbano para lazer/recreação) de Bauru no período: 1967-1979.

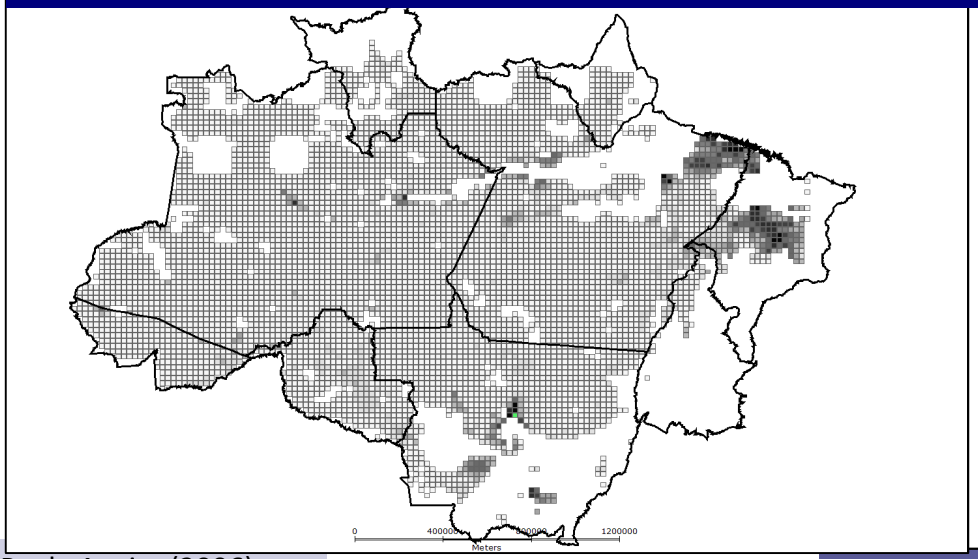
Source: Tese de Doutorado Claudia Almeida (2004)

Structural models: input land uses at one date

Pasture in 1997



Temporary agriculture in 1997

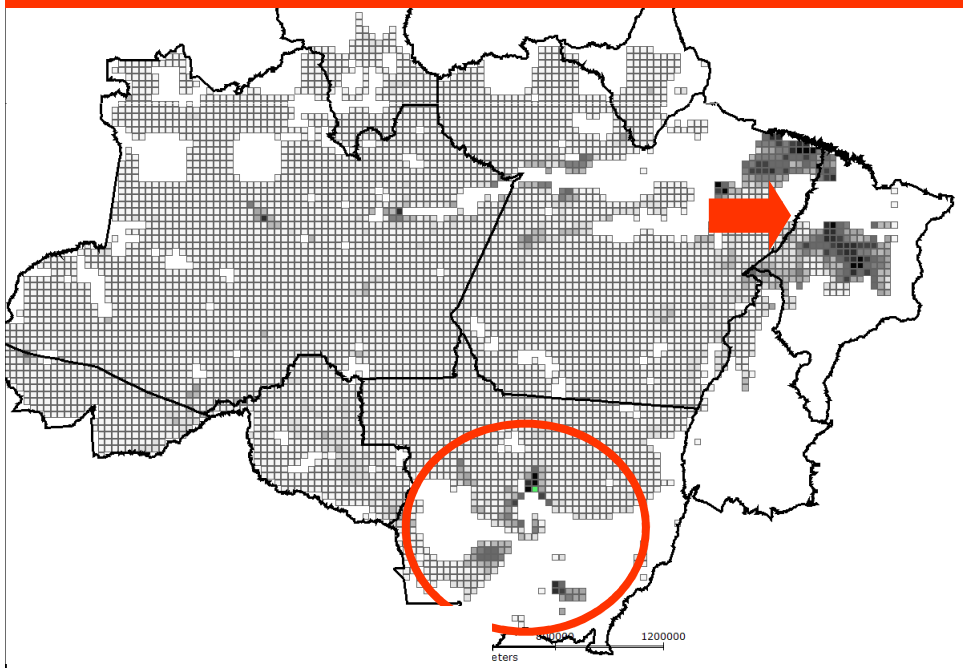


Source: Tese de Doutorado de Ana Paula Aguiar (2006)

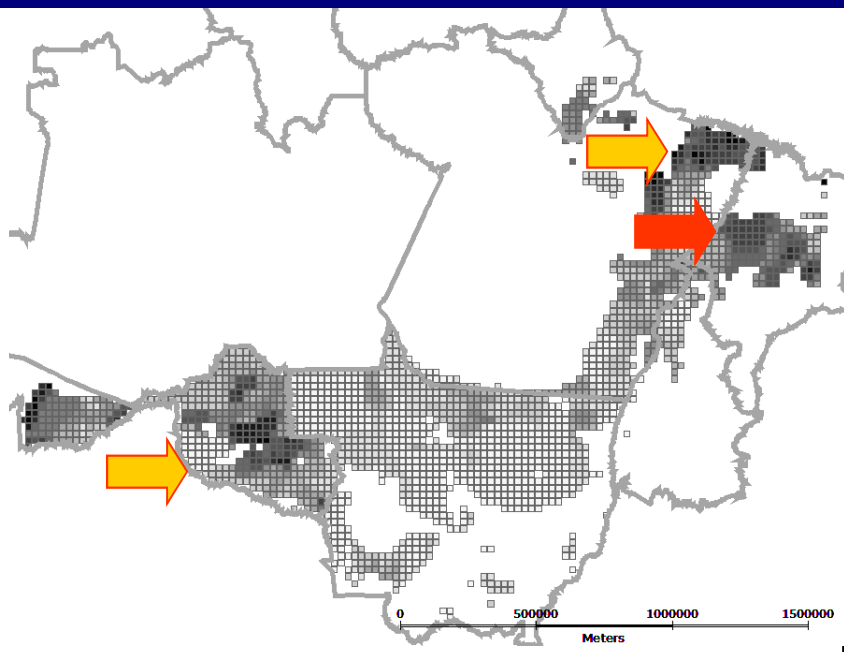
Structural models: input land uses at one date

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

Temporary agriculture in 1997



Agrarian Structure (percentage of small farms in a



Source: Aguiar et al., 2007; Aguiar, 2006.

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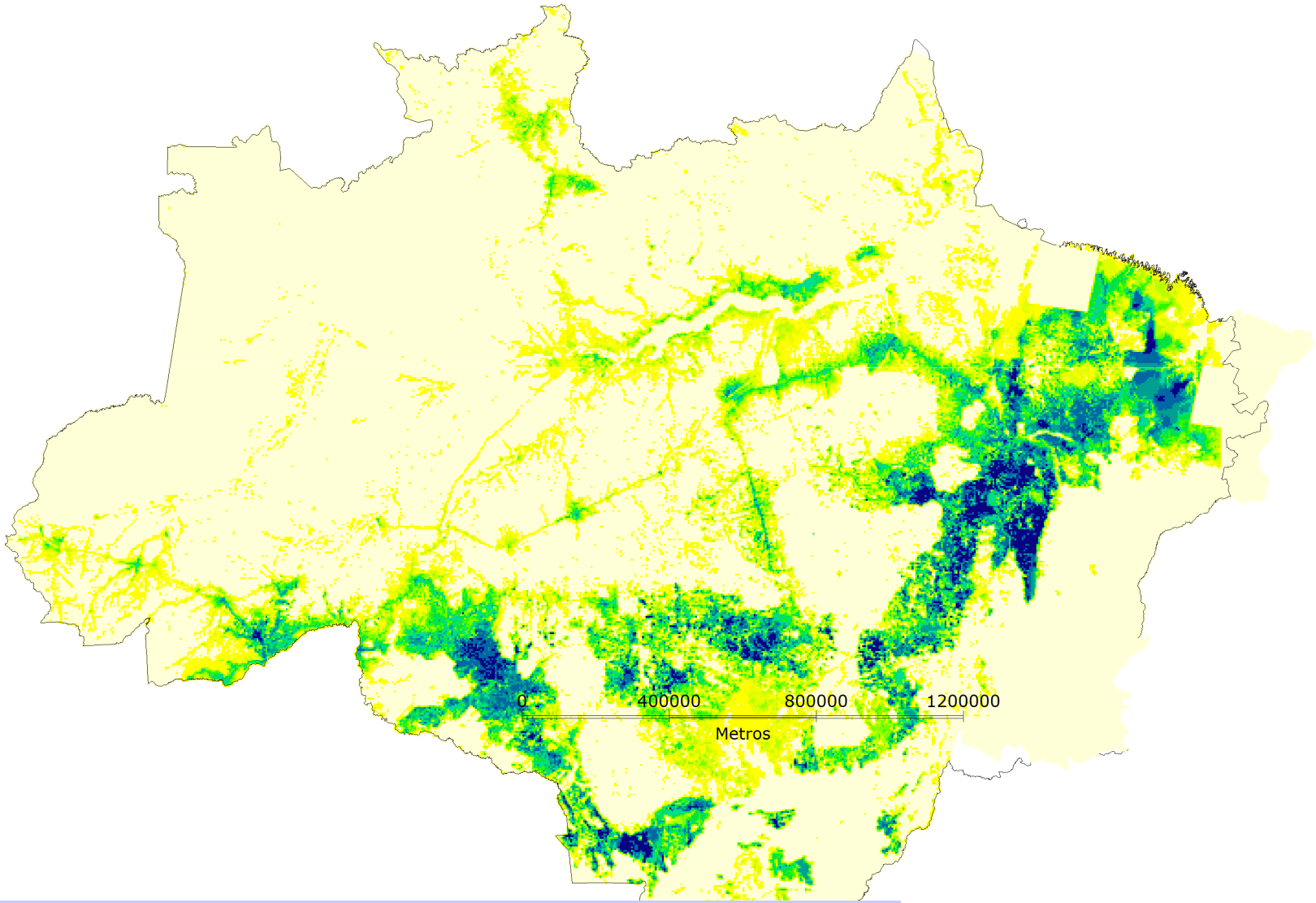
Continuos x Discrete

CONTINUOS MODELS: PERCENTAGE OF EACH USE IN THE CELLS

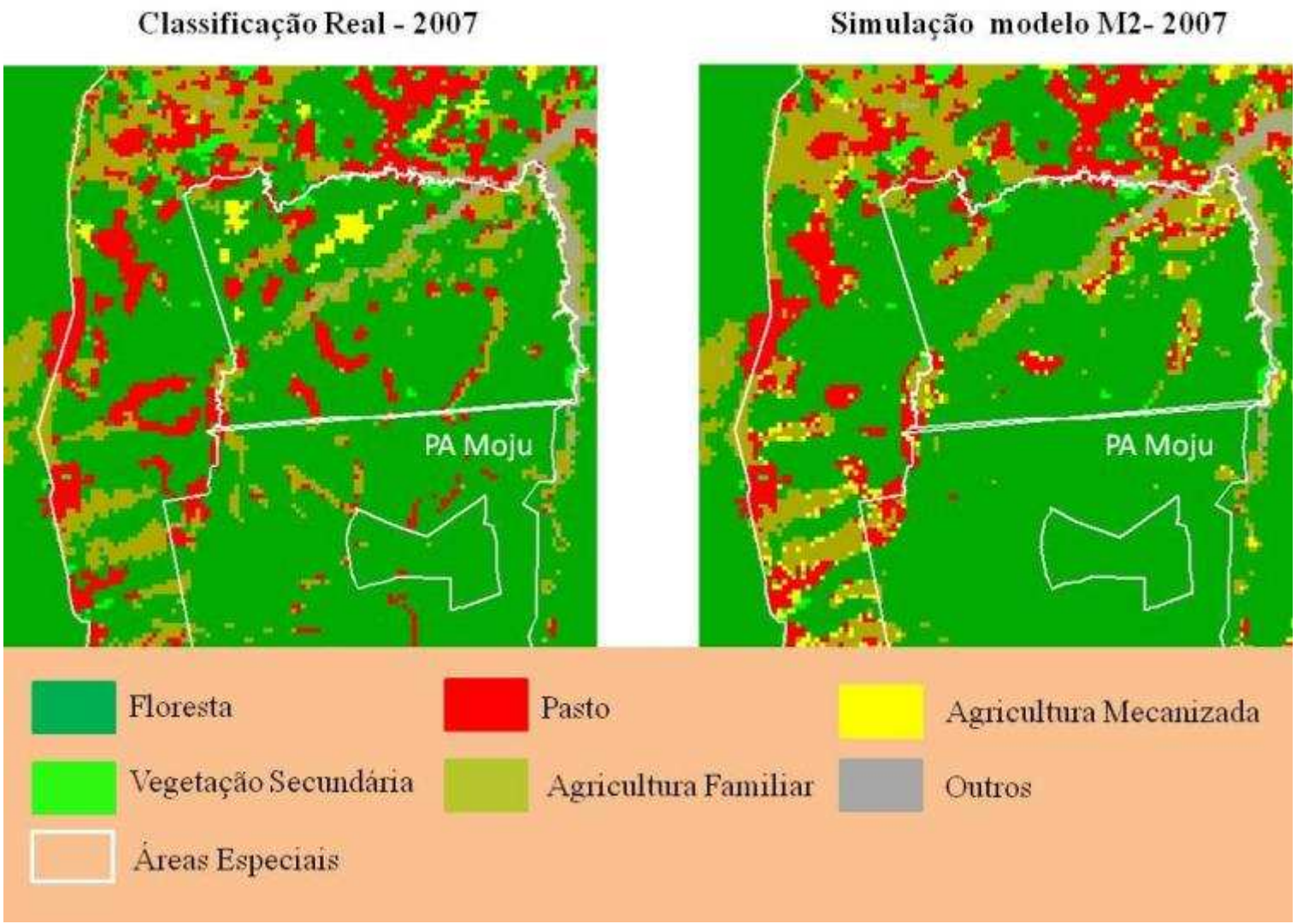
Pasture percentage in each 5x5 km^2



source: IBGE agricultural census 2006 and PRODES 2007

DISCRETE MODELS: CATEGORICAL LAND USE CLASSES

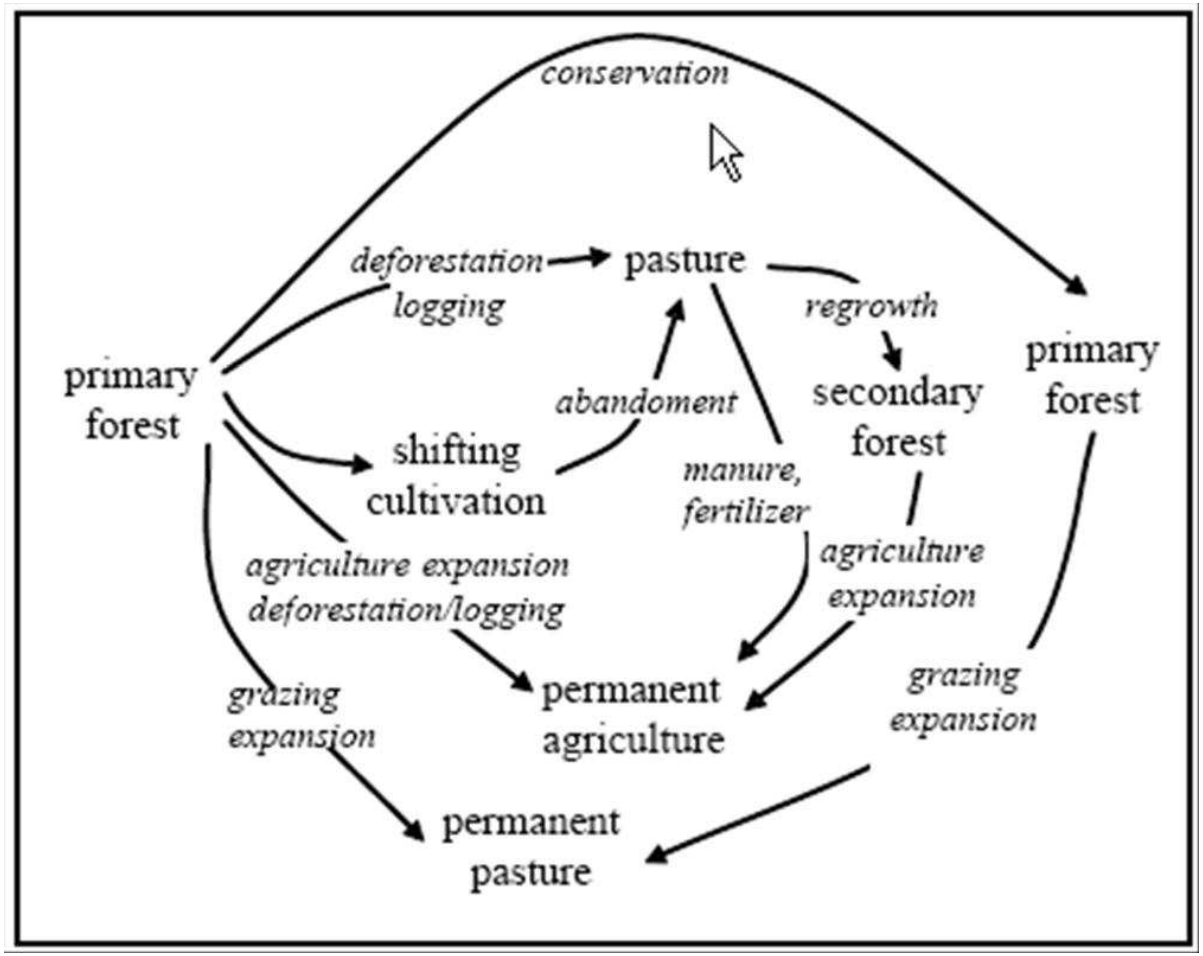
EACH CELL IS CLASSIFIED AS MECHANIZED AGRICULTURE *XOR* PASTURE *XOR* FOREST



Source: Coelho (2009), Pimenta (2010)

DISCRETE MODELS

LAND USE TRAJECTORIES EXPLICIT REPRESENTATION



Source: Fearnside (2002)

Available components (LuccME v1.0 Beta)

	Structural Approach	
	Continuos	**Discrete**
Potential	LinearRegression SpatialLagRegression	LogisticRegression NeighAttractionLogisticRegressi NeighAttractionRepulsionLogisti egression
Allocation	AllocationClueLike	AllocationCluesLike OrderedApproach
Demand	PreComputedValues ReceiveDynamicValues	PreComputedValues ReceiveDynamicValues EstimateForCalibrationValidatio

www.terrame.org/luccme

Red components being developed

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LuccME advanced features

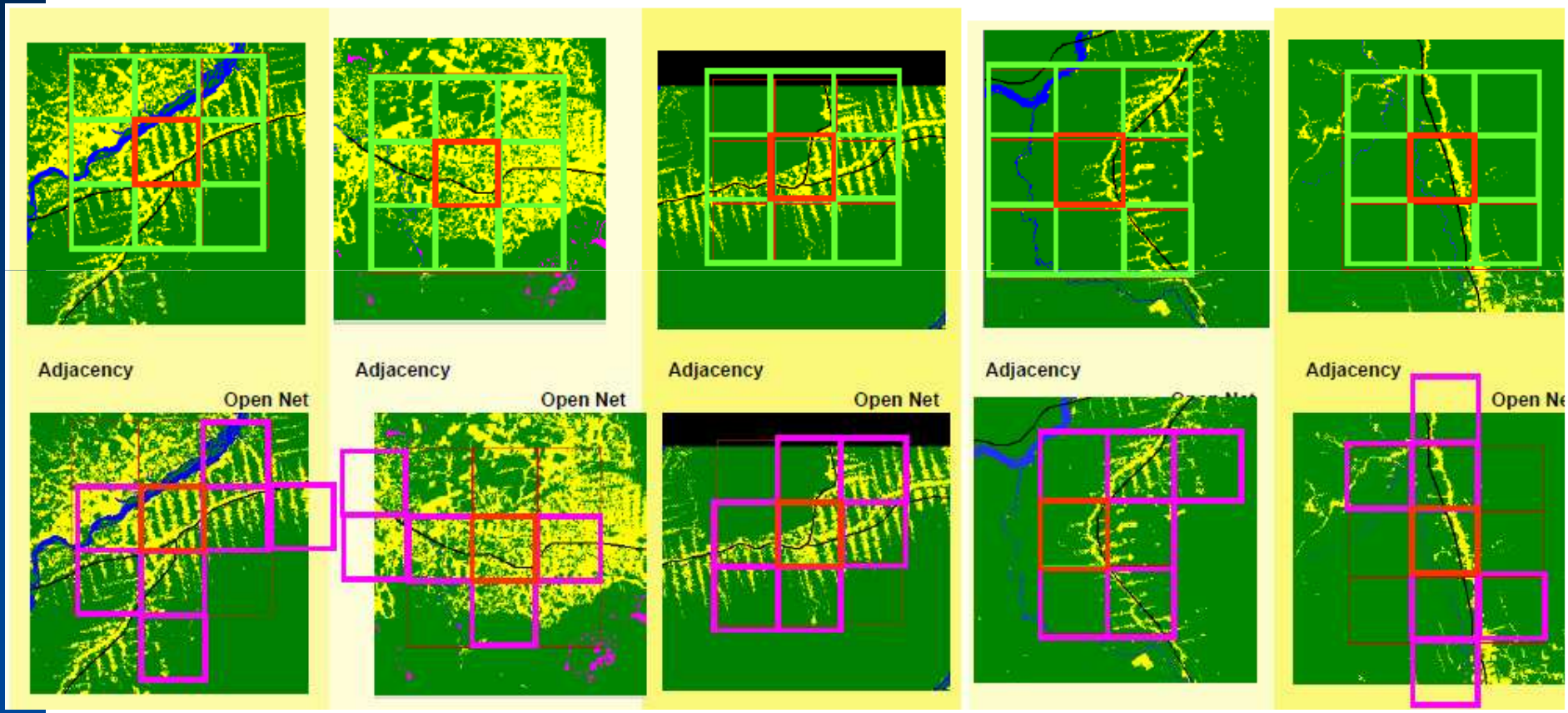
1. Advanced potential component features
2. Advanced allocation component features
3. Model coupling

1. Advanced potential component features

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

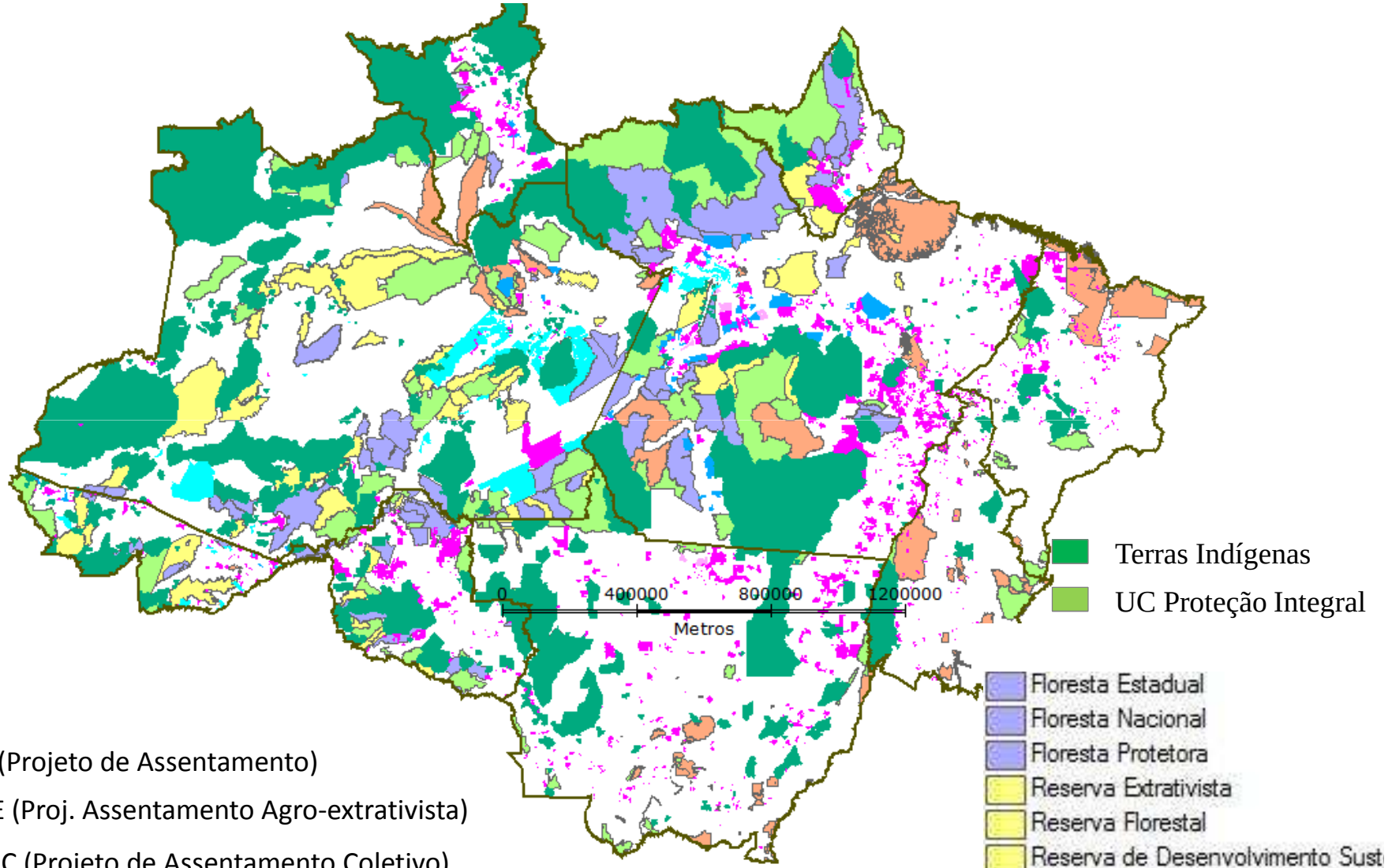
- Regionalization to represent heterogeneous rules of territory use
  - Spatial drivers/regressions
  - For discrete models, regionalization of possible transitions
  - Dynamic regionalization (space and time)

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)



PA (Projeto de Assentamento)

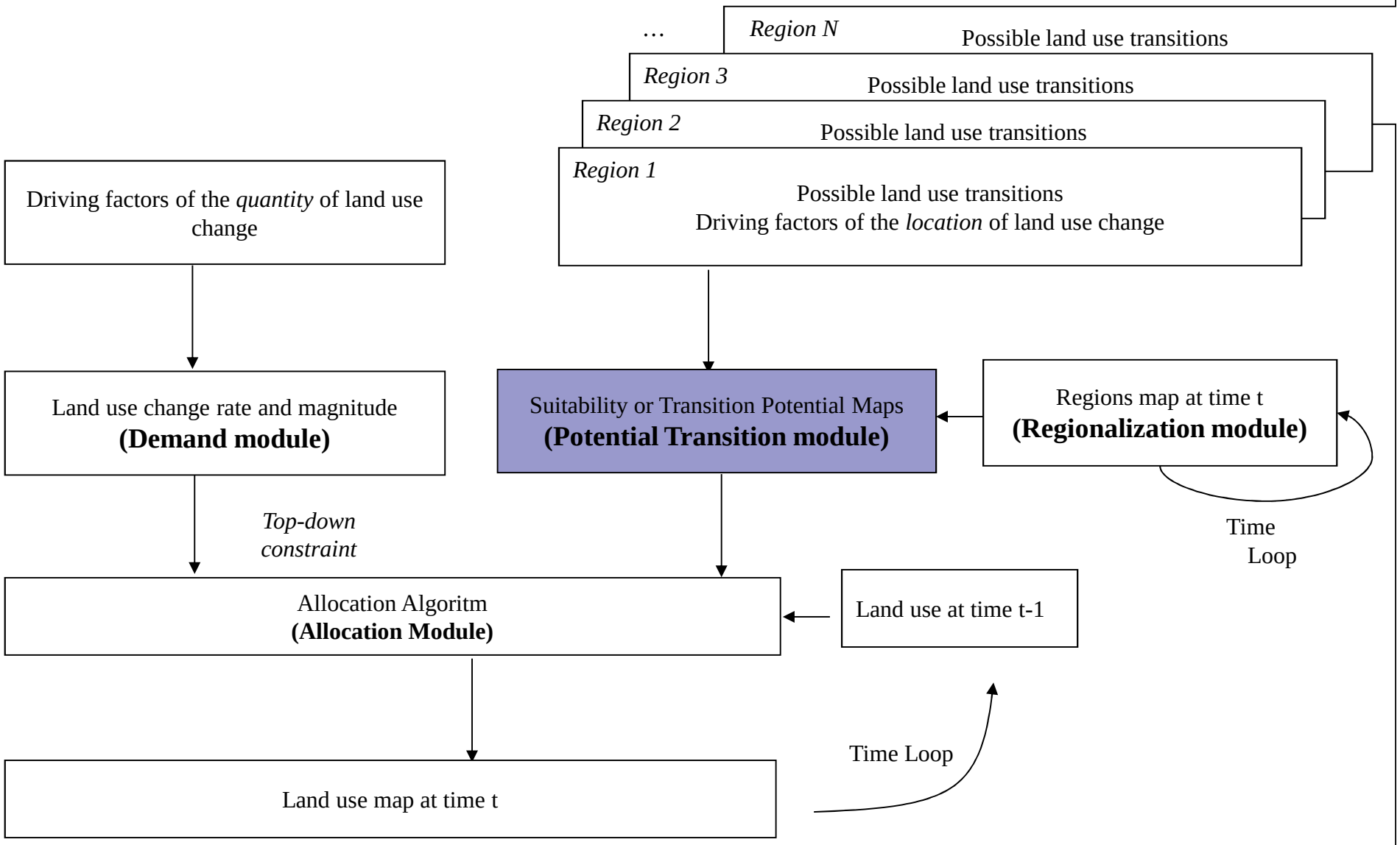
PAE (Proj. Assentamento Agro-extrativista)

PAC (Projeto de Assentamento Coletivo)

PDS (Projeto de Desenvolvimento Sustentável)

Source: INCRA, MMA, FUNAI, elaborated by Ana Aguiar (GEOMA)

Allowing multiple rules through dynamic regionalization of the potential module



Source: Pimenta et al. (2008)

2. Advanced allocation component features

- Discrete models:
  - Discrete models: optional change in block, parametrized indepentely for different land uses (block size and shape).

- Continuos 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, slown 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 sequentilally at the same time step (e.g., like Dinamica combines Expander and Patcher)

(see www.terrame.org/luccme for explanation and details about these items)

Acknowledgments

- Dr. Tom Veldkamp, Dr. Peter Verburg, Dr. Kasper Kok (CLUE model framework family) for the long time collaboration.
- Dr. Tiago Carneiro for the brilliant ideas behind TerraME
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- Dr. Carlos Nobre and Dr. Jean Ometto for promoting the CCST land use modeling activities, especially the INPE-EM mode.l

- Funding agencies: GEOMA/CNPq, LUA/FAPESP, PSI

Thanks!

- **TerraME: www.terrame.org**
- **LuccME: www.terrame.org/luccme**

"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 Ecossytem Assessment)