



MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

TerraME - A modeling Environment for non-isotropic and non-homogeneous spatial dynamic models development

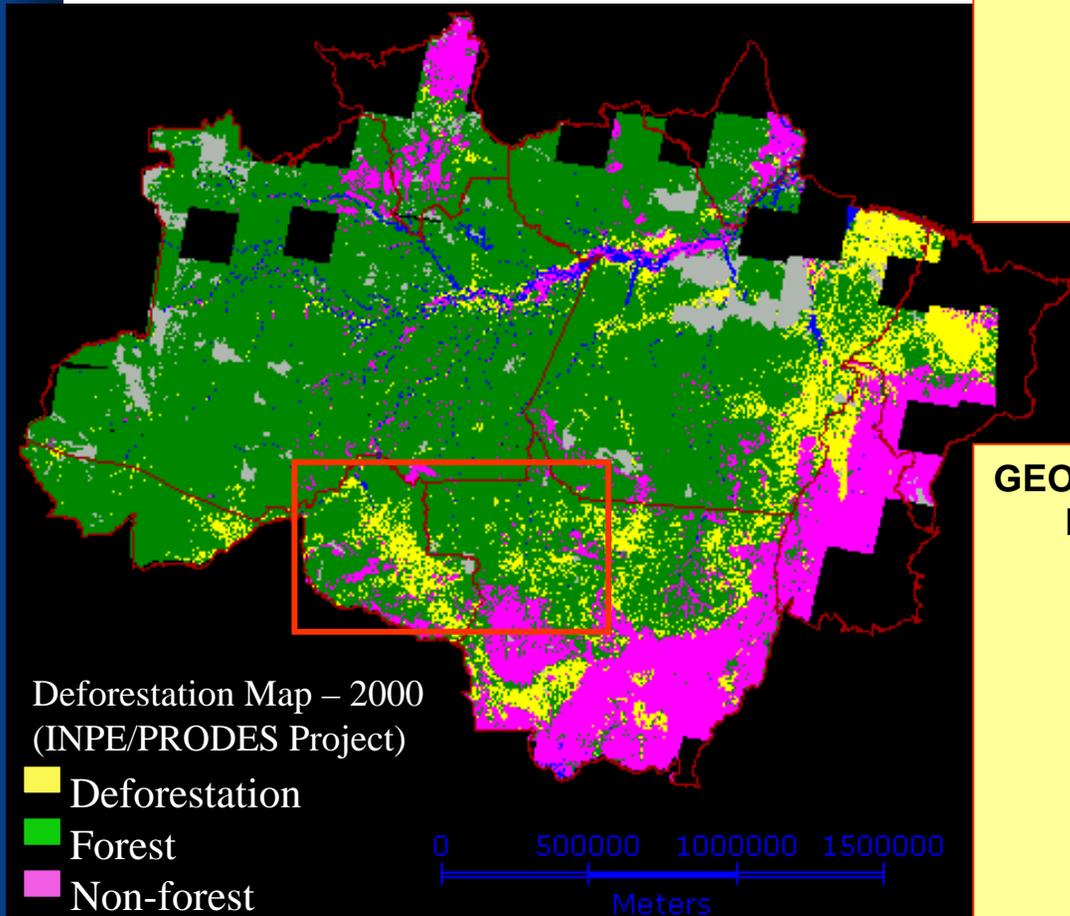
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LUCC Workshop
Amsterdam, October 2004

Introduction: TerraME goal

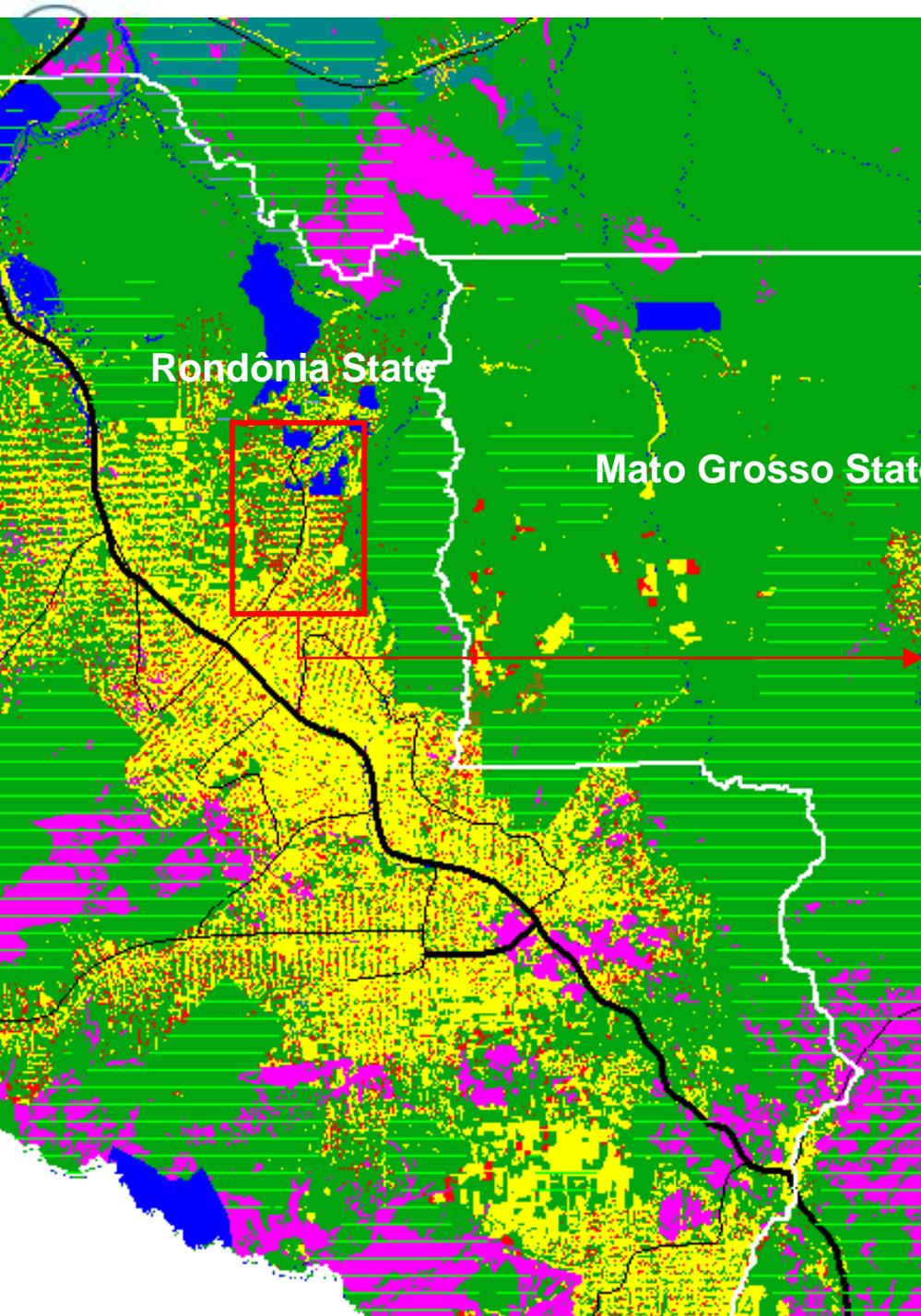
Provide computational modeling support for GEOMA research areas:

- Environmental Physics
- Wetlands
- Biodiversity
- LUCC**
- Population Dynamics**
- Climate



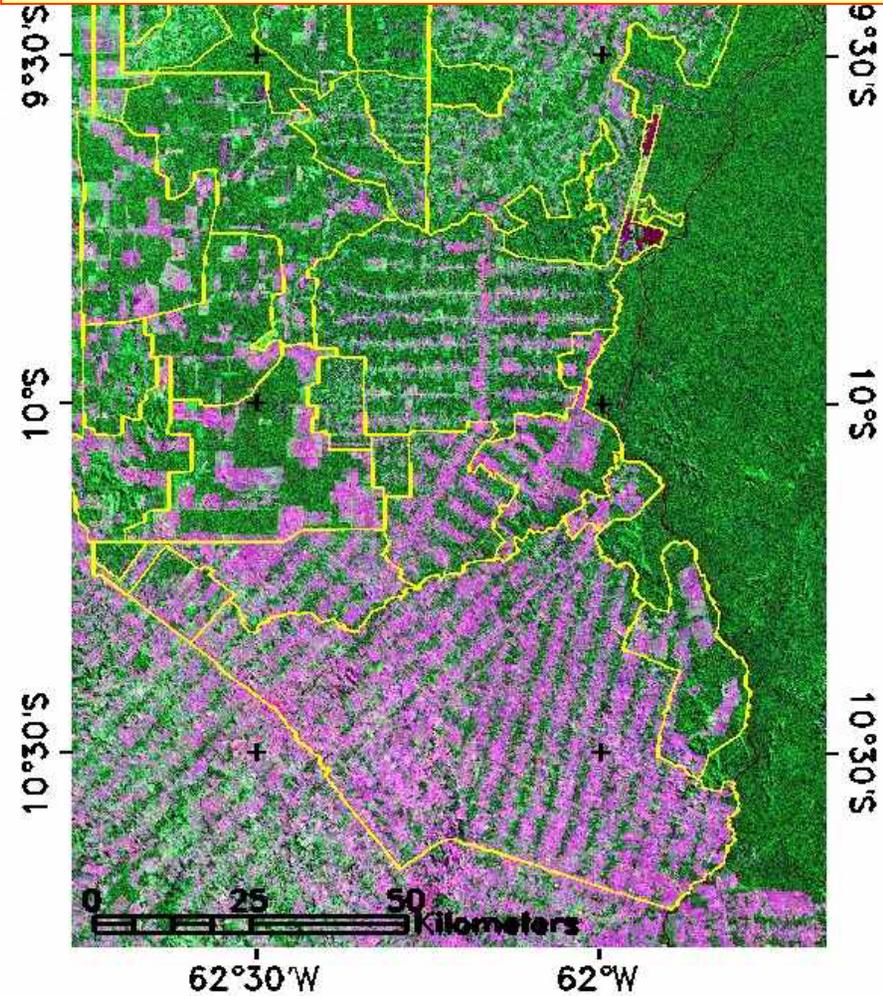
GEOMA network Science and Technology Ministry institutions:

- LNCC**-Laboratório Nacional de Computação Científica
- MPEG**-Museu Paraense Emílio Goeldi
- INPE**-Intituto de Pesquisas Espaciais
- IDSM**-Instituto de Desenvolvimento Sustentável Mamirauá
- IMPA**-Instituto de Matemática Pura e Aplicada
- CBPF**-Centro Brasileiro de Pesquisas Físicas



Main requirement: represent and model Amazon region space-time diversity of:

- Actors
- Processes
- Speedy of change
- Connectivity relations

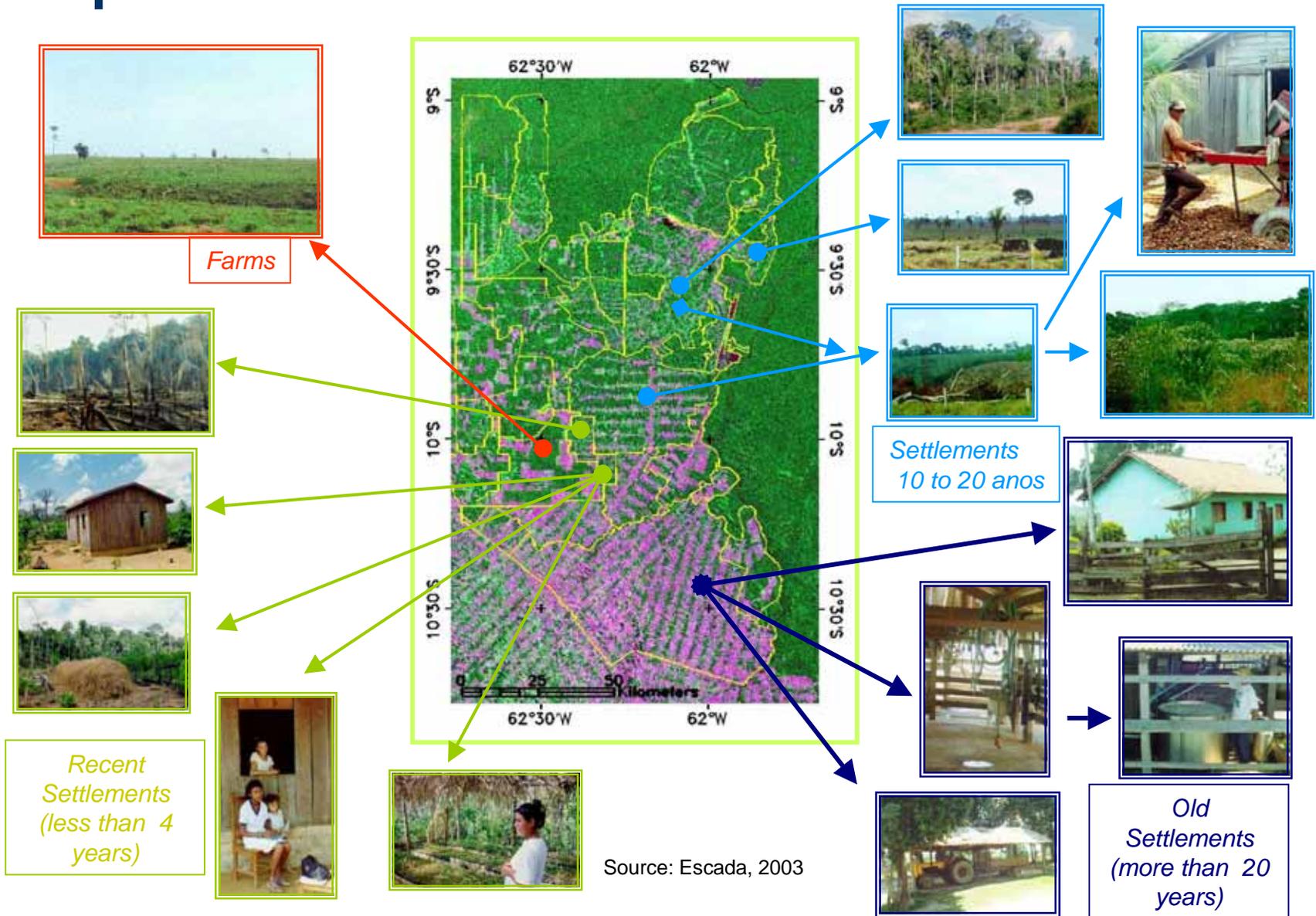




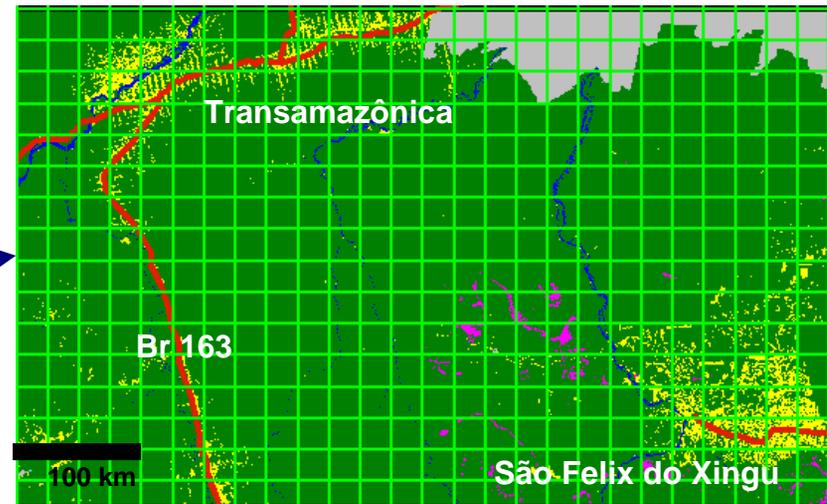
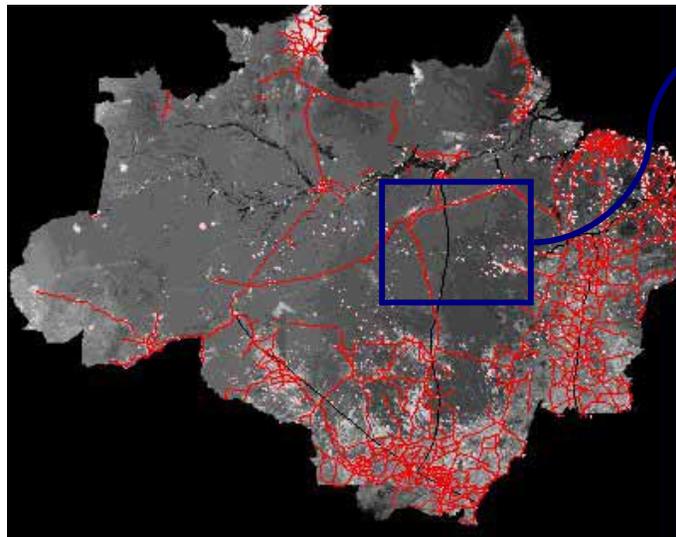
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Part I – TerraME main characteristics

Behavior can be heterogeneous in space and time in TerraME

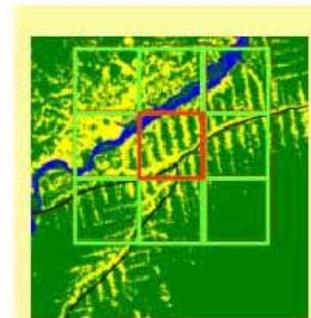


Space can be non-isotropic in TerraME

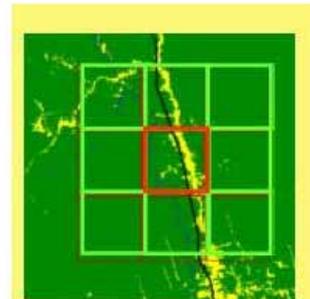


- Forest
- Deforested
- No data
- Non-forest
- Water
- Roads

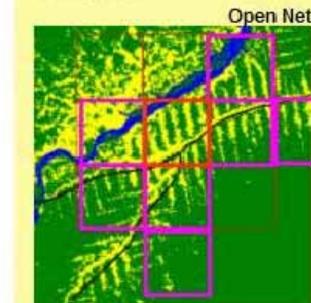
Source:
Prodes/INPE



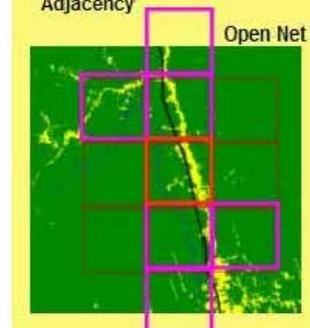
Adjacency



Adjacency

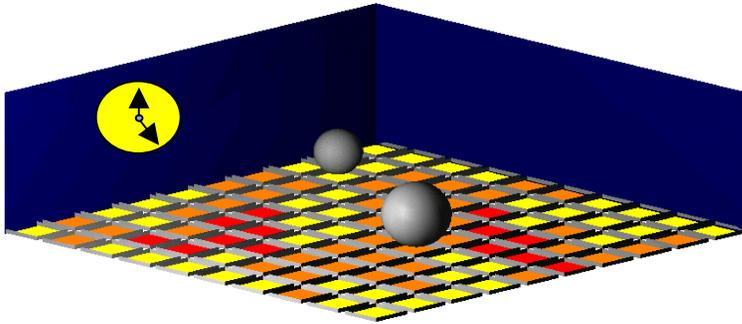


Open Net

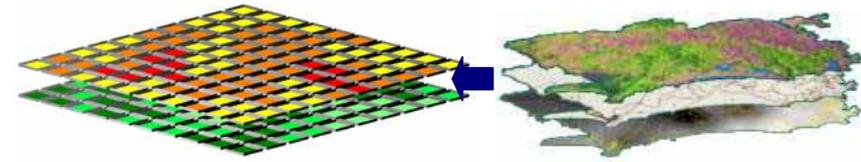


Open Net

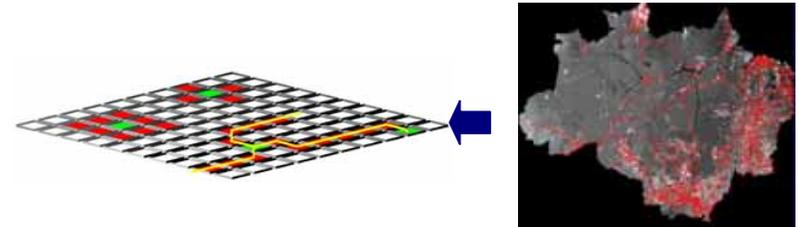
Environments in TerraME



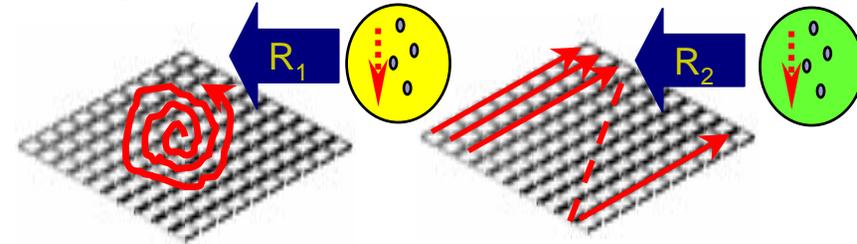
Cellular space



Absolute and relative space proximity relations



Regions are maps of ordered indexes to cells



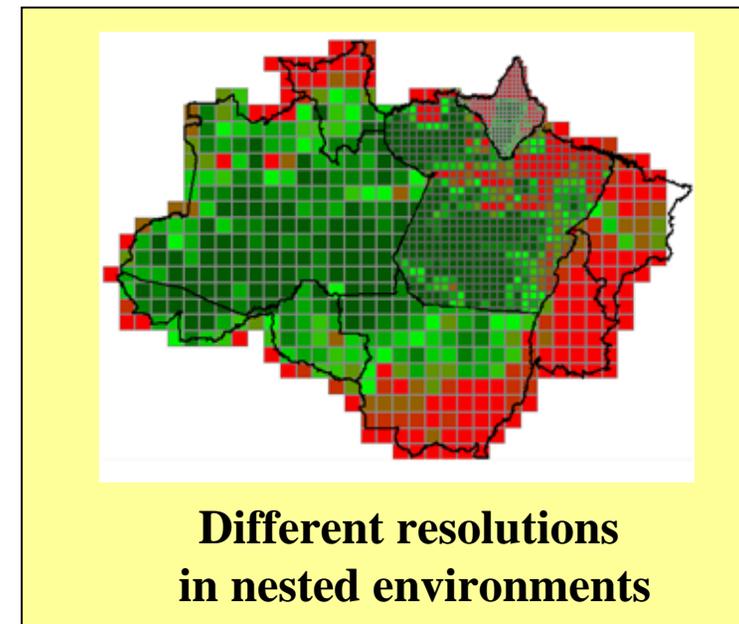
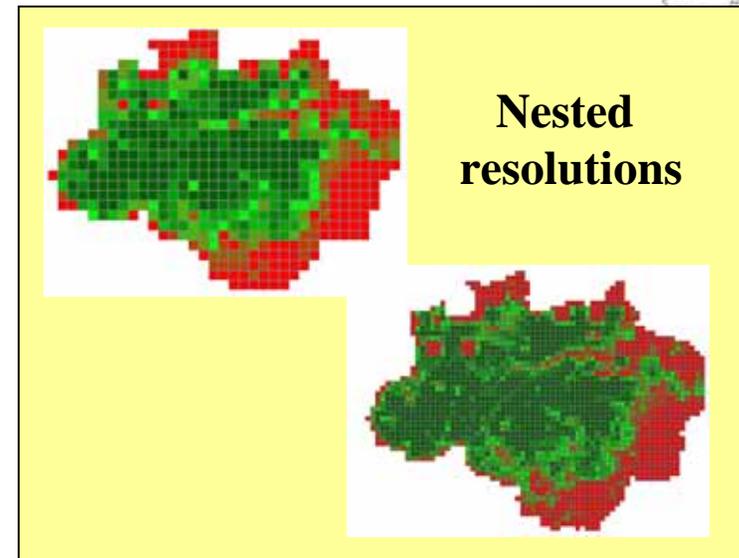
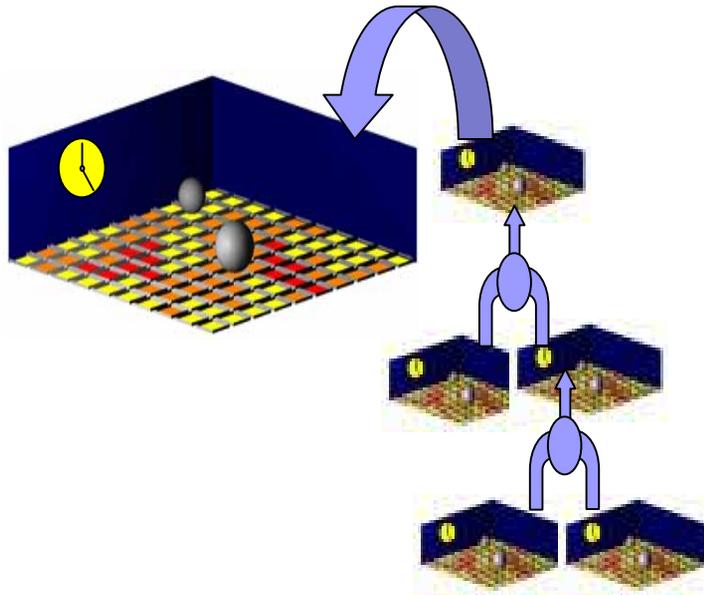
An **environment** has 3 kinds of sub models:

- Spatial Model:** cellular space + region + GPM (Generalized Proximity Matrix)
- Behavioral Model:** hybrid automata + situated agents
- Temporal Model:** discrete event simulators

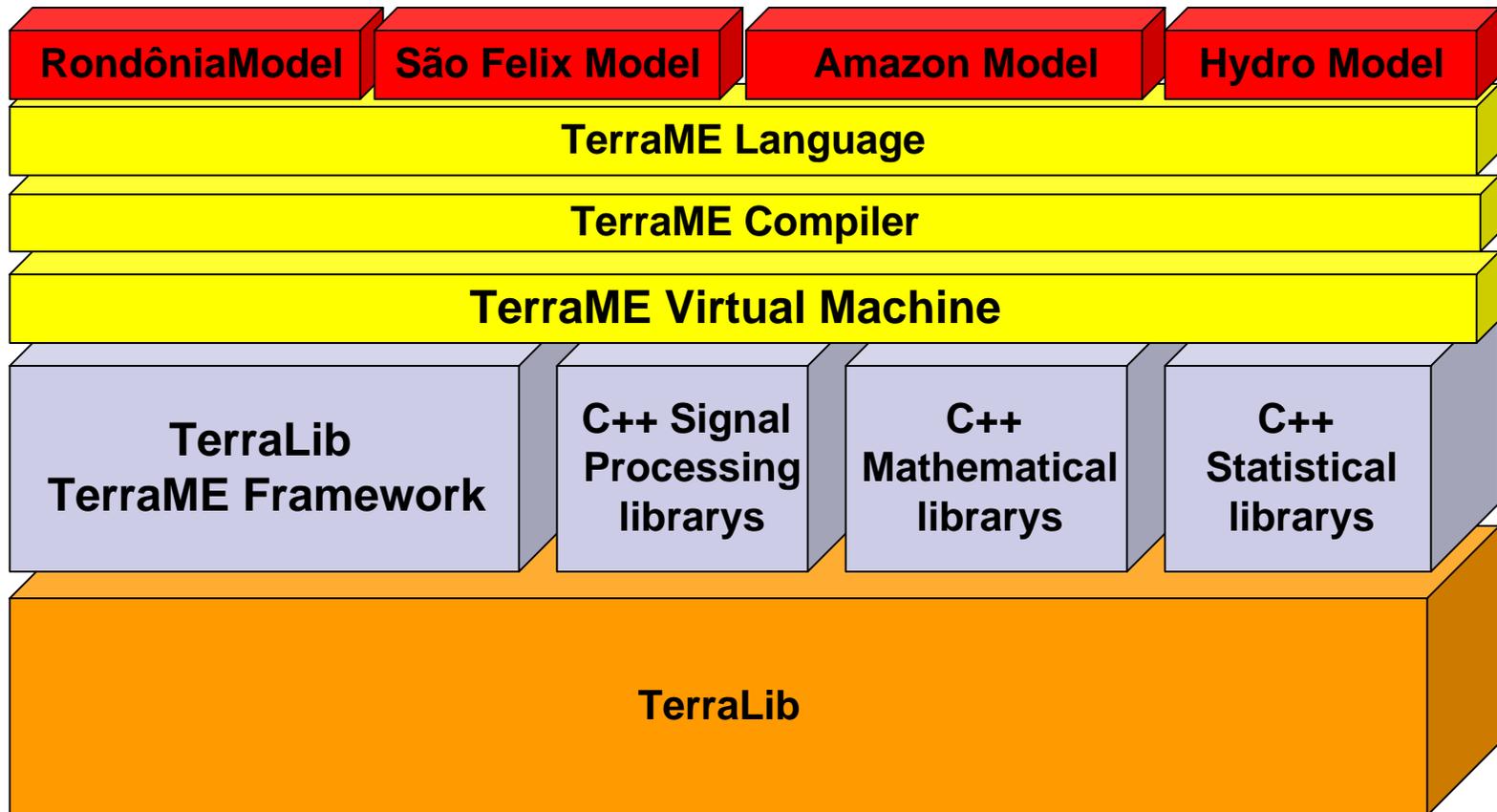
The **spatio-temporal structure** is shared by several communicating agents

TerraME supports multi-scale model construction

Using
Nested Environments



Software Architecture

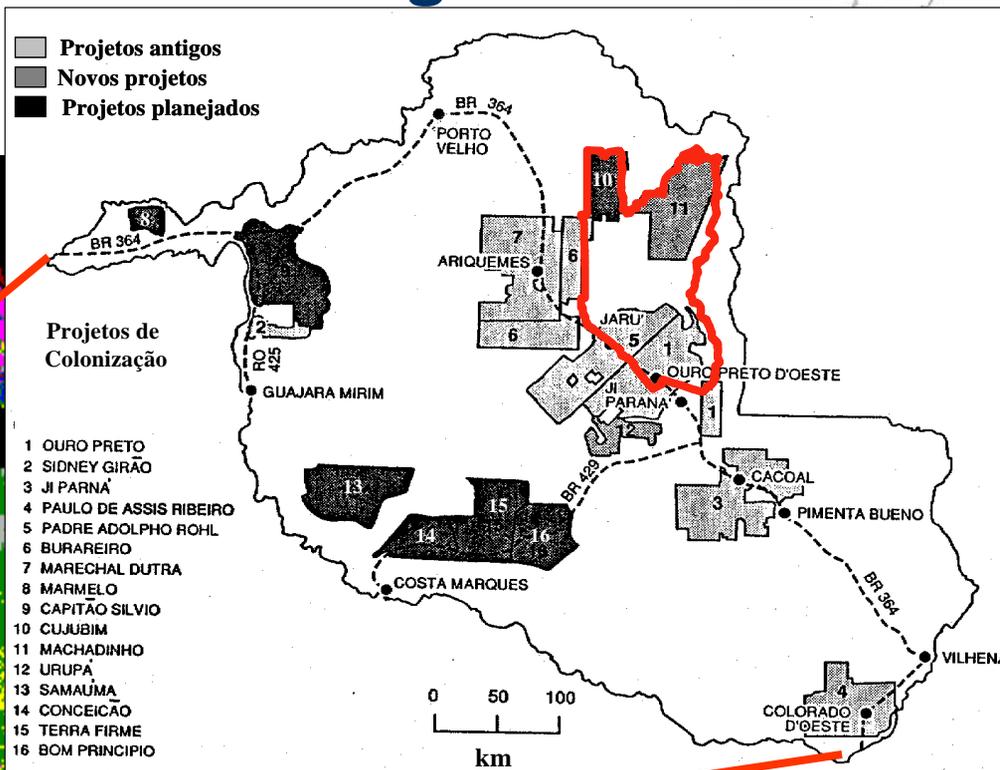
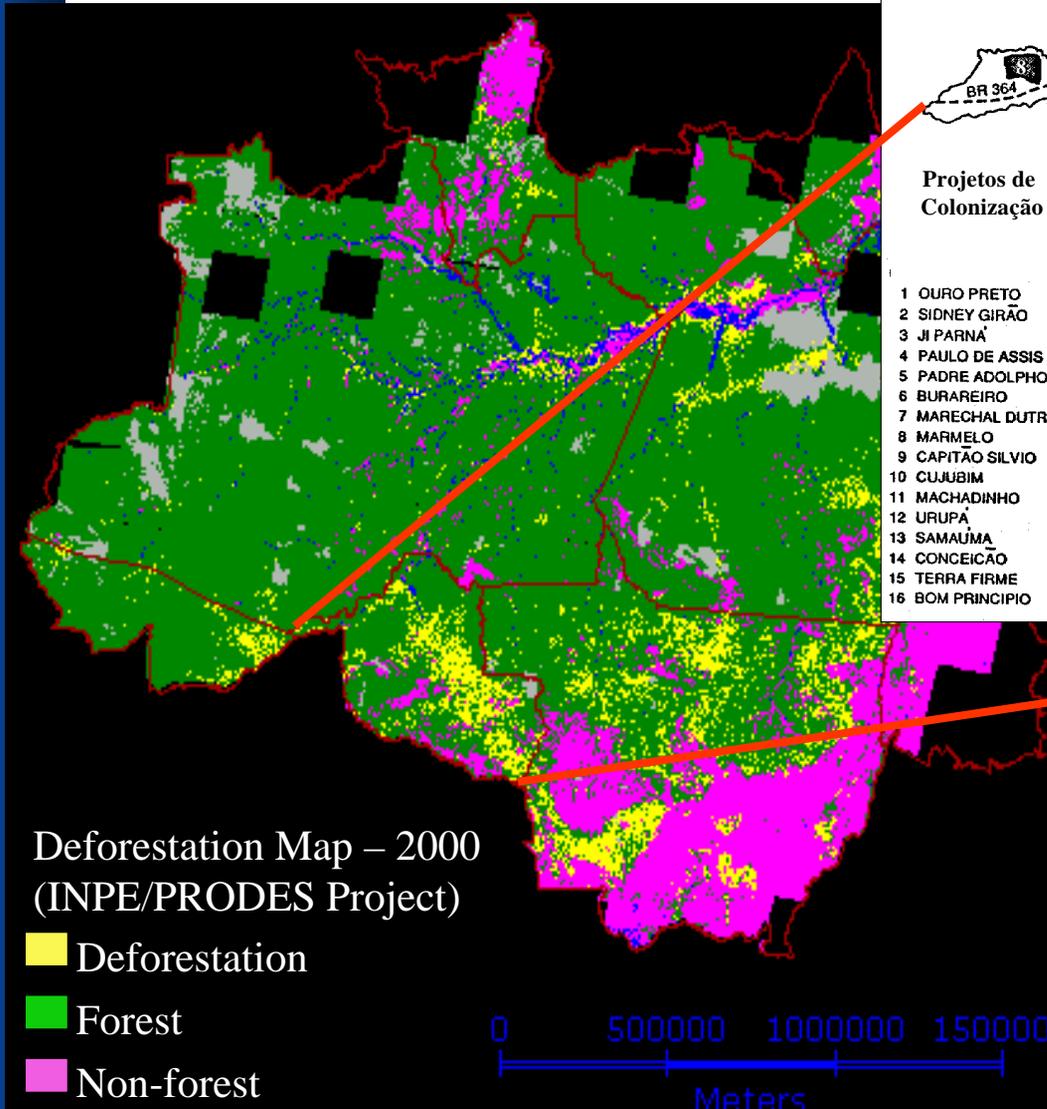




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Part II: Modeling Exercise

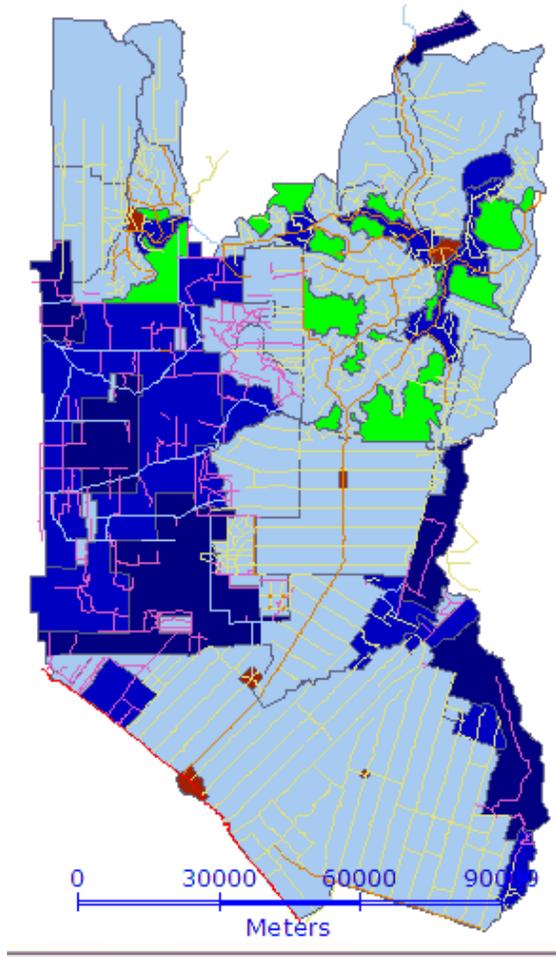
Introduction: Rondônia modeling exercise study area



Federal Government induced colonization area (since the 70s):

- Small, medium and large farms.
- Mosaic of land use patterns.
- Definition of land units and typology of actors based on multi-temporal images (85-00) and colonization projects information (Escada, 2003).
- Intersects 10 municipalities (~100x200 km).

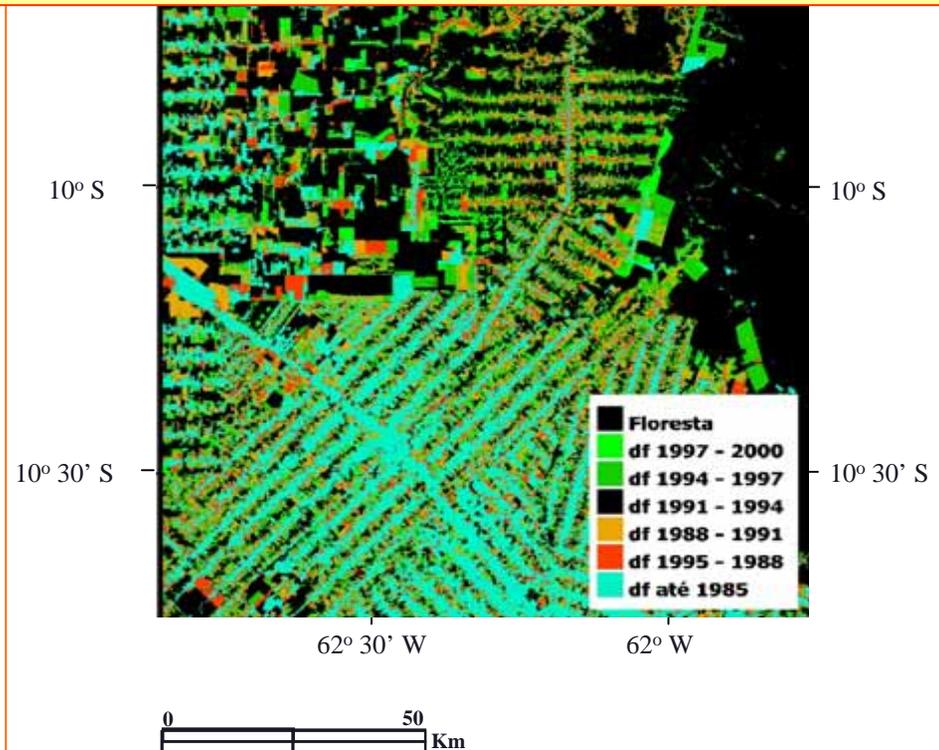
Actors and patterns



- Large farms
- Medium farms
- Urban areas
- Small farms
- Reserves

Model hypothesis:

- Occupation processes are different for Small and Medium/Large farms.
- Rate of change is not distributed uniformly in space and time: rate in each land unit is influenced by settlement age and parcel size; for small farms, rate of change in the first years is also influenced by installation credit received.
- Location of change: For small farms, deforestation has a concentrated pattern that **spreads** along roads. For large farmers, the pattern is not so clear.



Model overview

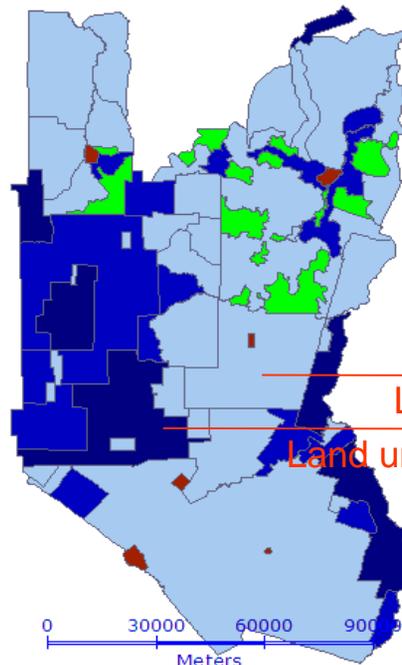
Deforestation Rate Distribution from 1985 to 2000 - Land Units Level:

- Large/Medium Rate Distribution sub-model
- Small Farms Distribution sub-model

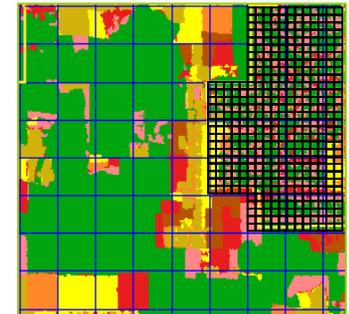
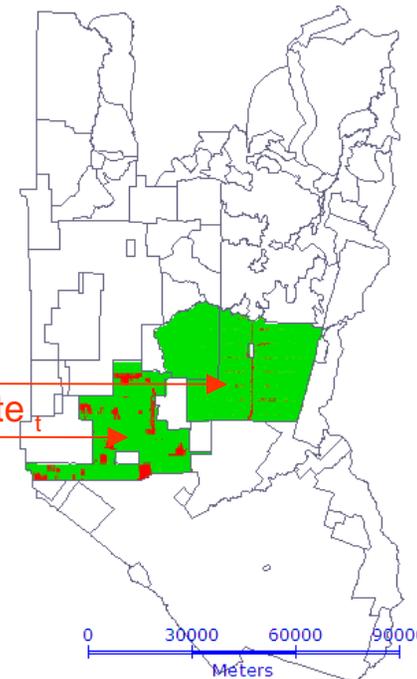
Allocation of changes - Cellular space level:

- Large/Medium allocation sub-model
- Small allocation sub-model

Global study area rate in time



Land unit 1 rate t
Land unit 2 rate t



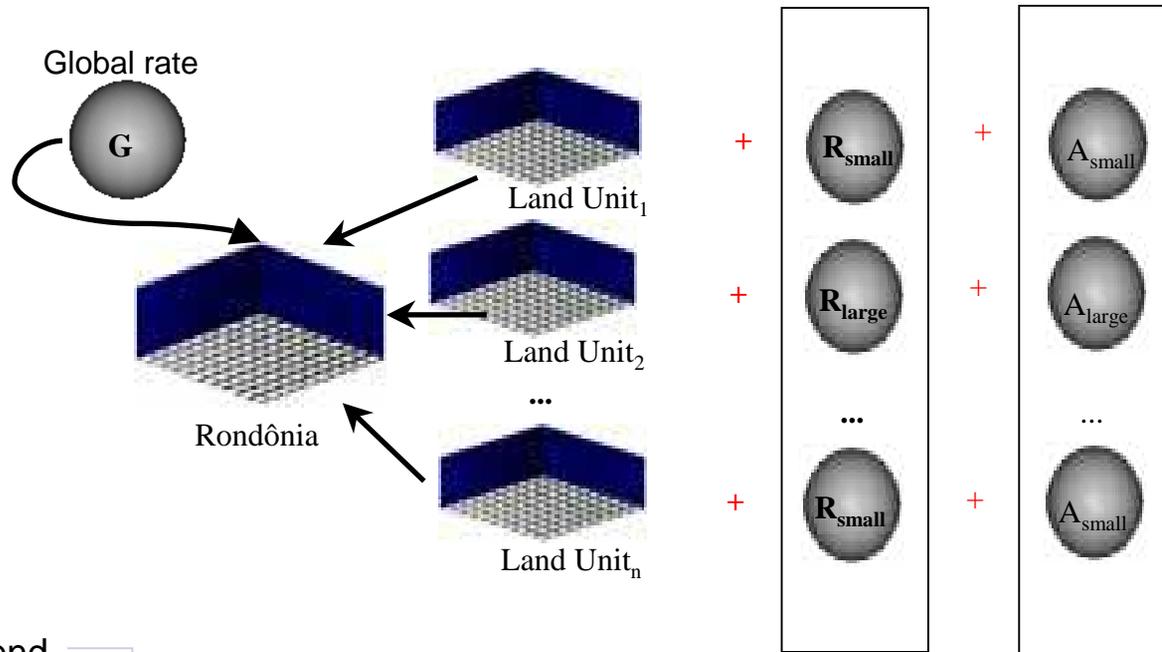
2.500 m (large and medium)

500 m (small)

- Large farms
- Medium farms
- Urban areas
- Small farms
- Reserves

Model implementation in TerraME

Each Land Unit is an **environment**, nested in the Rondônia **environment**.



Legend



Environment



Agent

Deforest Rate Distribution

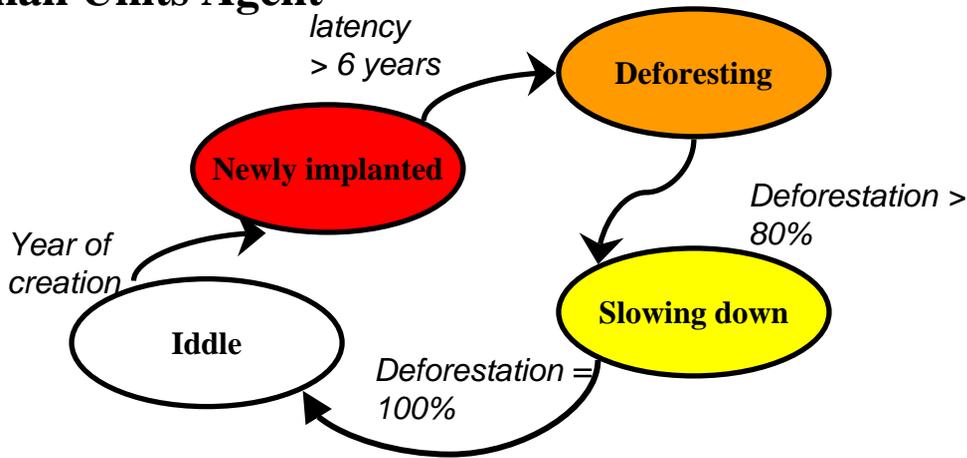
(two types of agentes R_{small} and R_{large})

Deforest Allocation

(two types of agentes A_{small} and A_{large})

Deforestation Rate Distribution Module

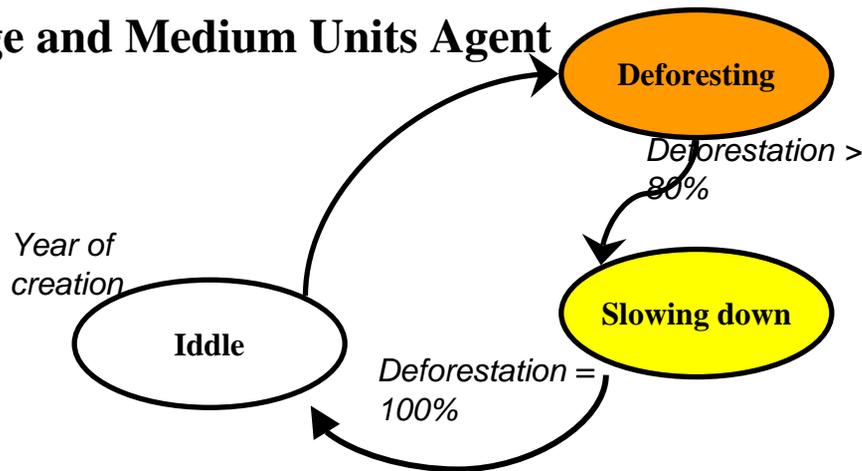
Small Units Agent



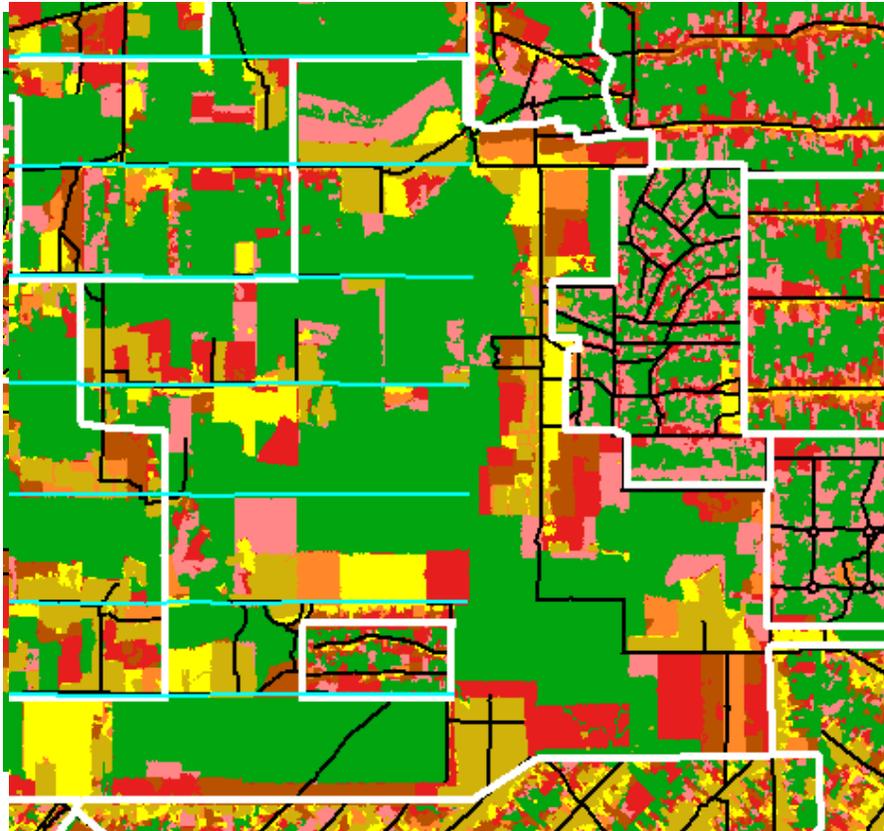
Factors affecting rate:

- Global rate
- Relation properties density - speedy of change
- Year of creation
- Credit in the first years (small)

Large and Medium Units Agent



Allocation Module: different factors and rules



Factors affecting location of changes:

Small Farmers (500 m resolution):

- Connection to opened areas through roads network
- Proximity to urban areas

Medium/Large Farmers (2500 m resolution):

- Connection to opened areas through roads network
- Connection to opened areas in the same line of ownerships

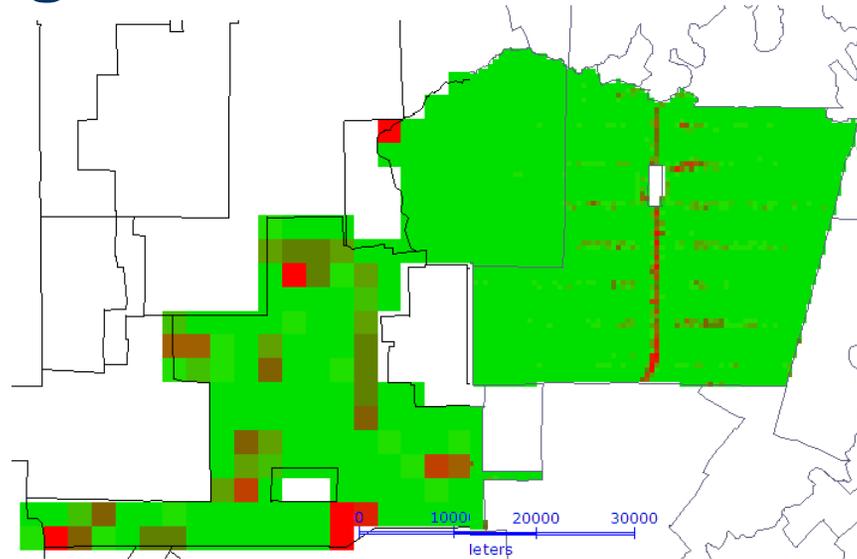
Allocation Module: different resolution, variables and neighborhoods

Small farms environments:

500 m resolution

Categorical variable:
deforested or forest

One neighborhood relation:
• connection through roads



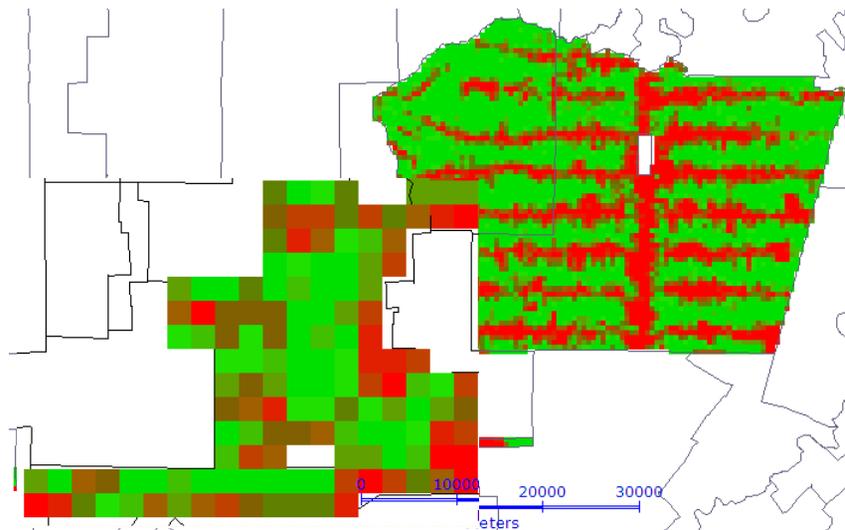
1985

Large farm environments:

2500 m resolution

Continuous variable:
% deforested

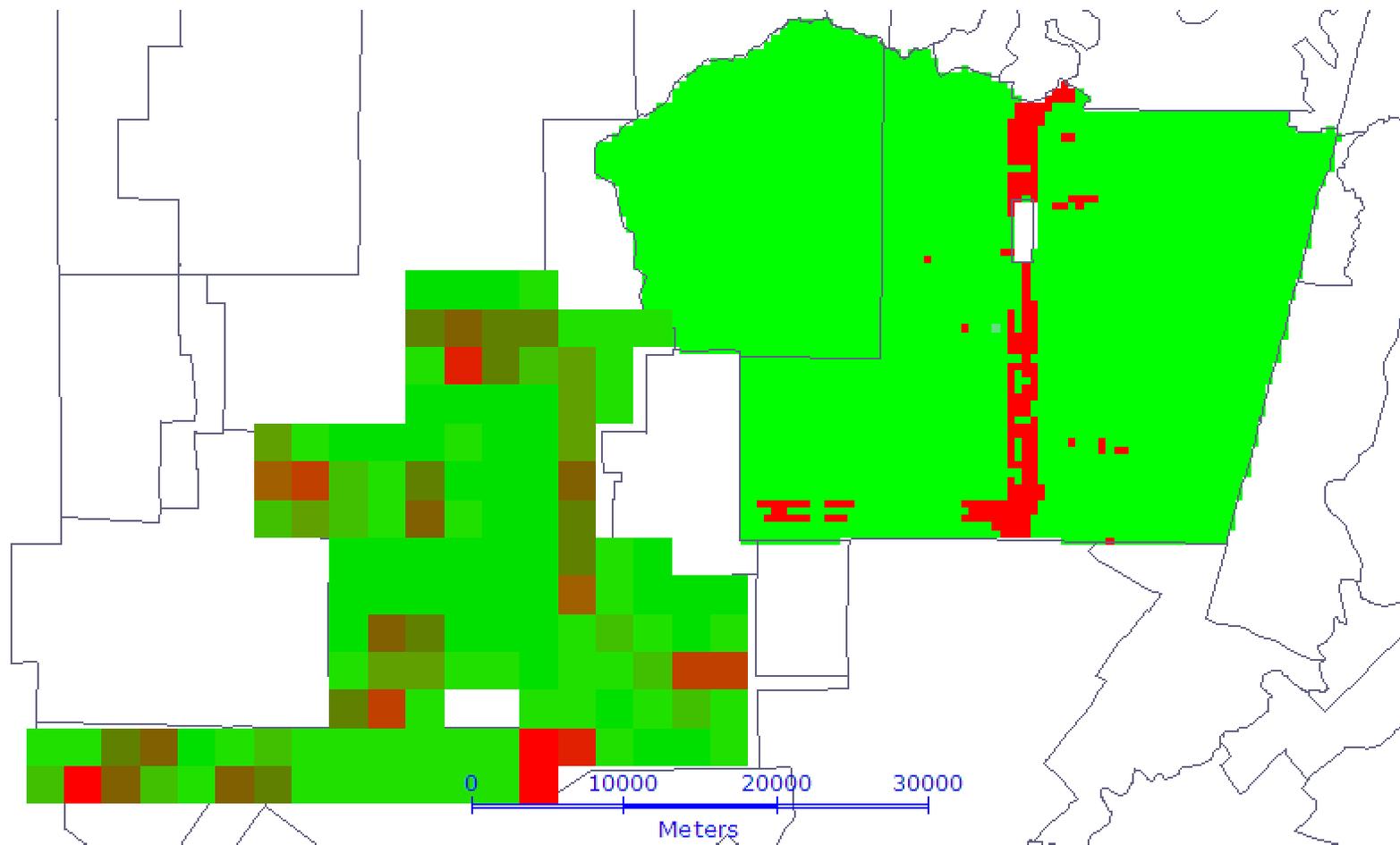
Two alternative neighborhood relations:
• connection through roads
• farm limits proximity



1997

Simulation Results

1985 to 1997



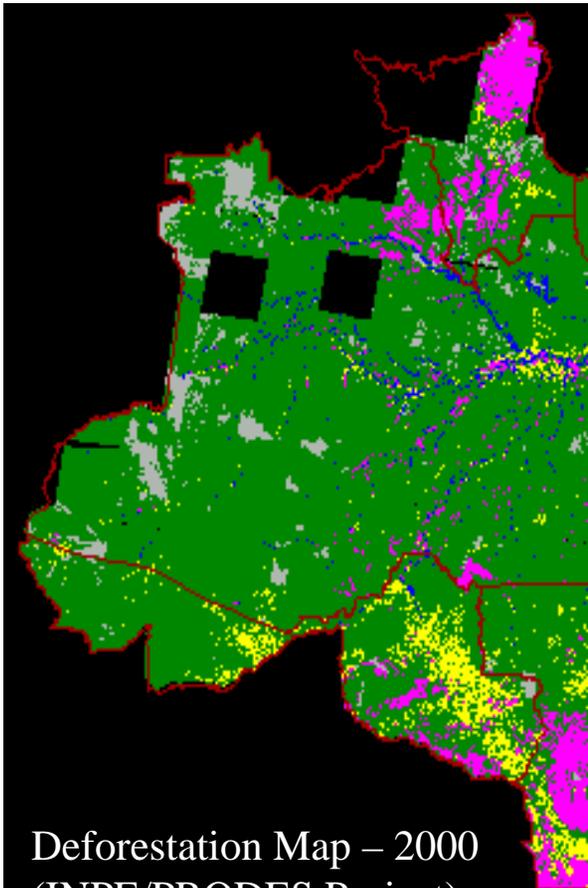
Contributions

- Framework allows to model many aspects of spatial and temporal Rondônia study area complexity combining:
 - Multiple scales
 - Multiple actors and behaviors
 - Multiple time events and asynchronous processes
 - Alternative neighborhood relationships
 - Continuous and discrete behavior

- Further work:
 - TerraME programming language;
 - Calibration and validation tools.

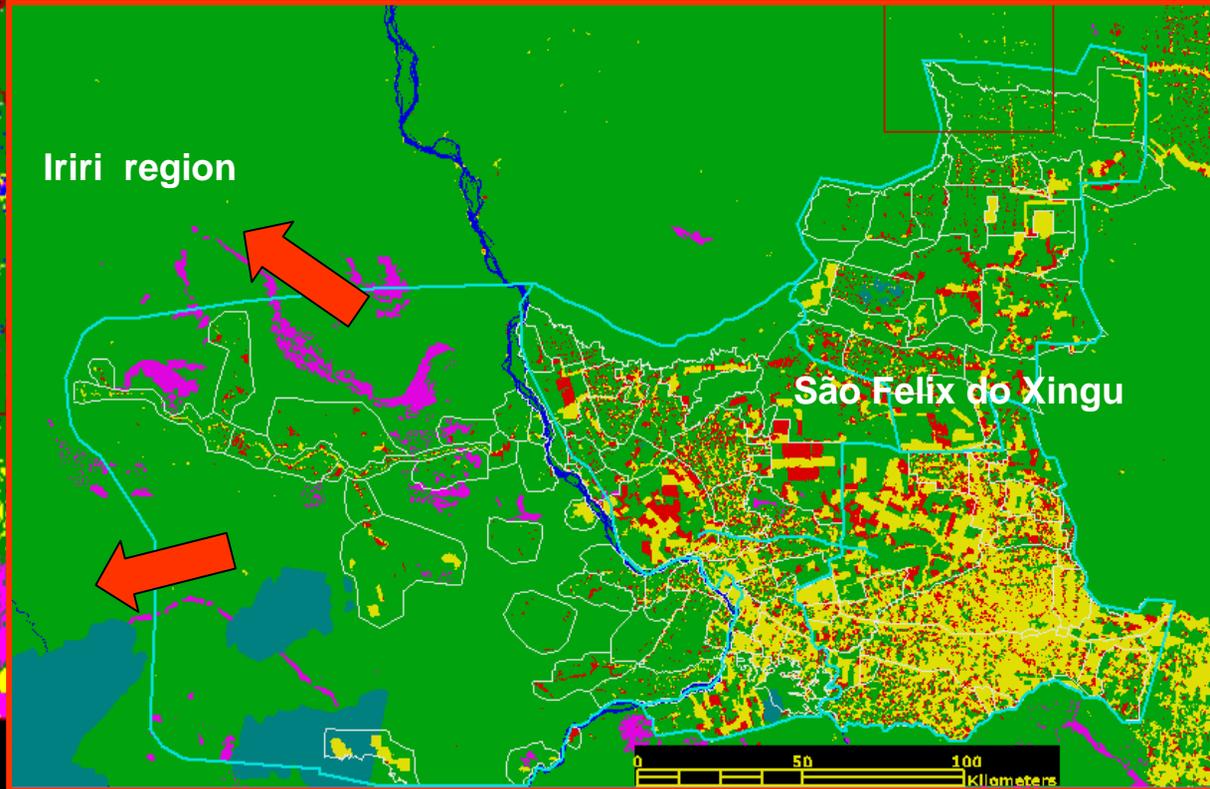
GEOMA study area: new Pará frontiers

Our challenge is to construct models to non-structured spaces such as Amazon new frontiers...



Deforestation Map – 2000
(INPE/PRODES Project)

- Deforestation
- Forest
- Non-forest



Links/References

- GEOMA Network: <http://www.geoma.Incc.br/>
- Terralib (open source GIS library): <http://www.terralib.org/>
- INPE - Image Processing Division: www.dpi.inpe.br
- Rondônia qualitative work developed at INPE:
 - ESCADA, M.I.S. Evolução dos Padrões de Uso da Terra na região centro-Norte de Rondônia. **Tese de Doutorado**. Instituto Nacional de Pesquisas Espaciais. Defendida em março de 2003, p.155.
- Generalized proximity matrix paper:
 - Aguiar, A.P.D., Câmara, G., Monteiro, A.M.V., Cartaxo, R. Modelling Spatial Relations by Generalized Proximity Matrices. **V Simpósio Brasileiro de Geoinformática**, Campos do Jordão, Novembro 2004.