GEOINFO 2008
X Brazilian Symposium on GeoInformatics

Spatial relations across scales in land change models

08 – 10 of December, Rio de Janeiro - RJ - Brazil

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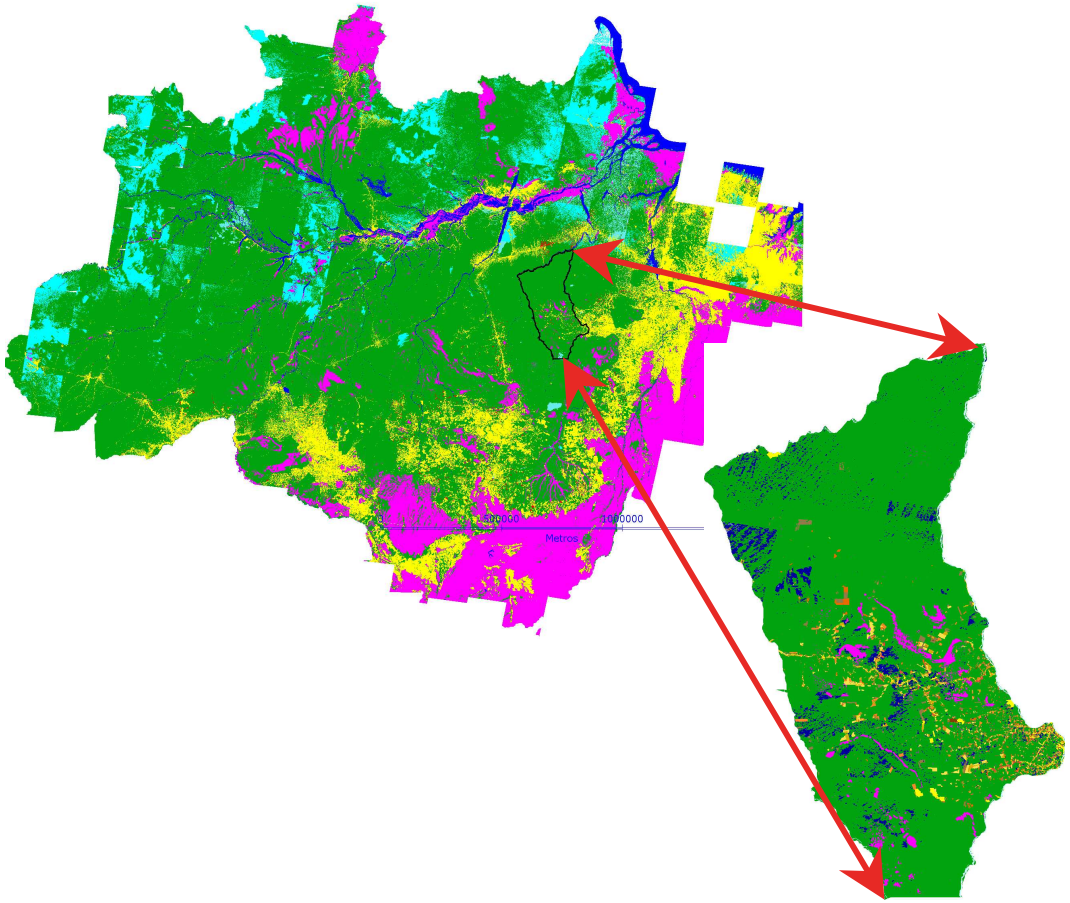
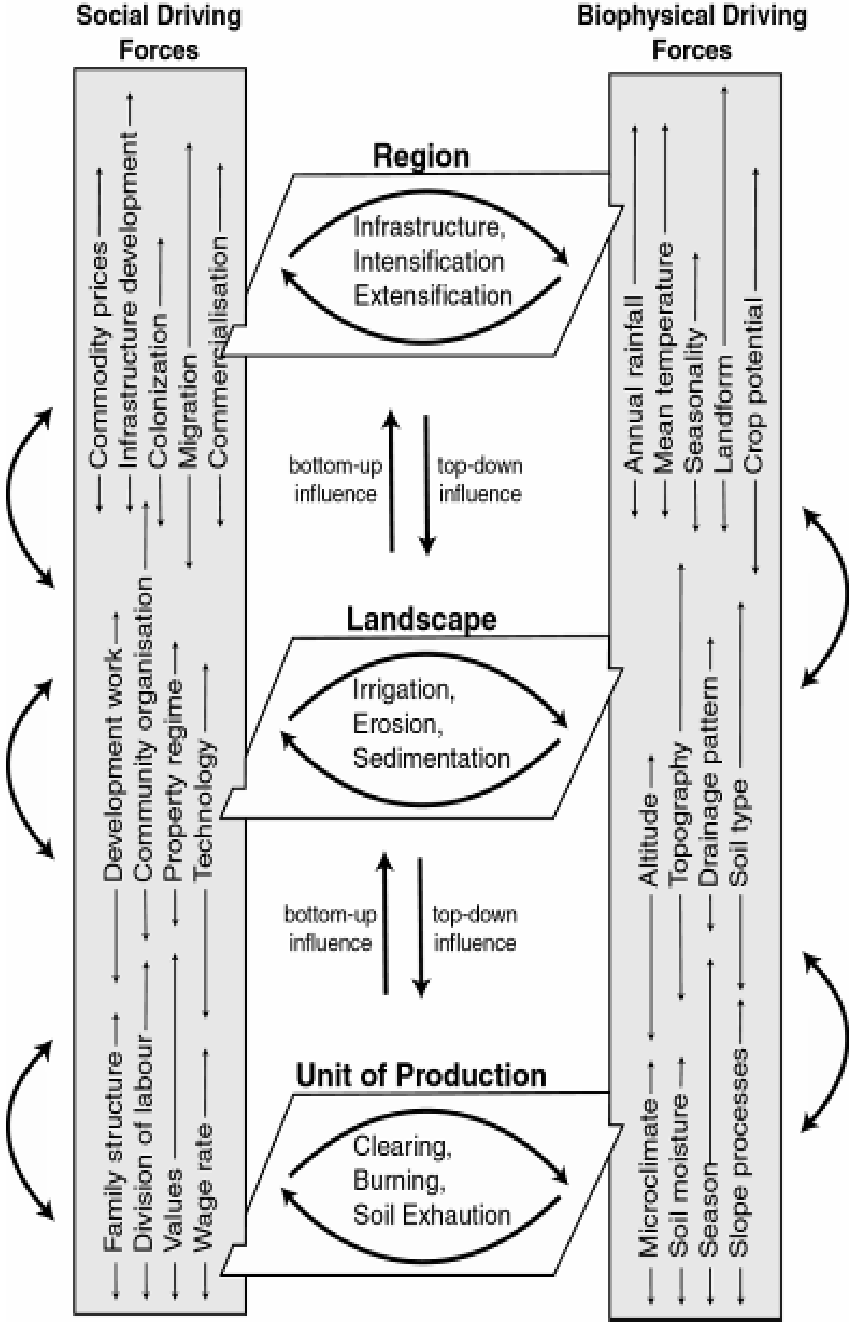
Land changes

Introduction





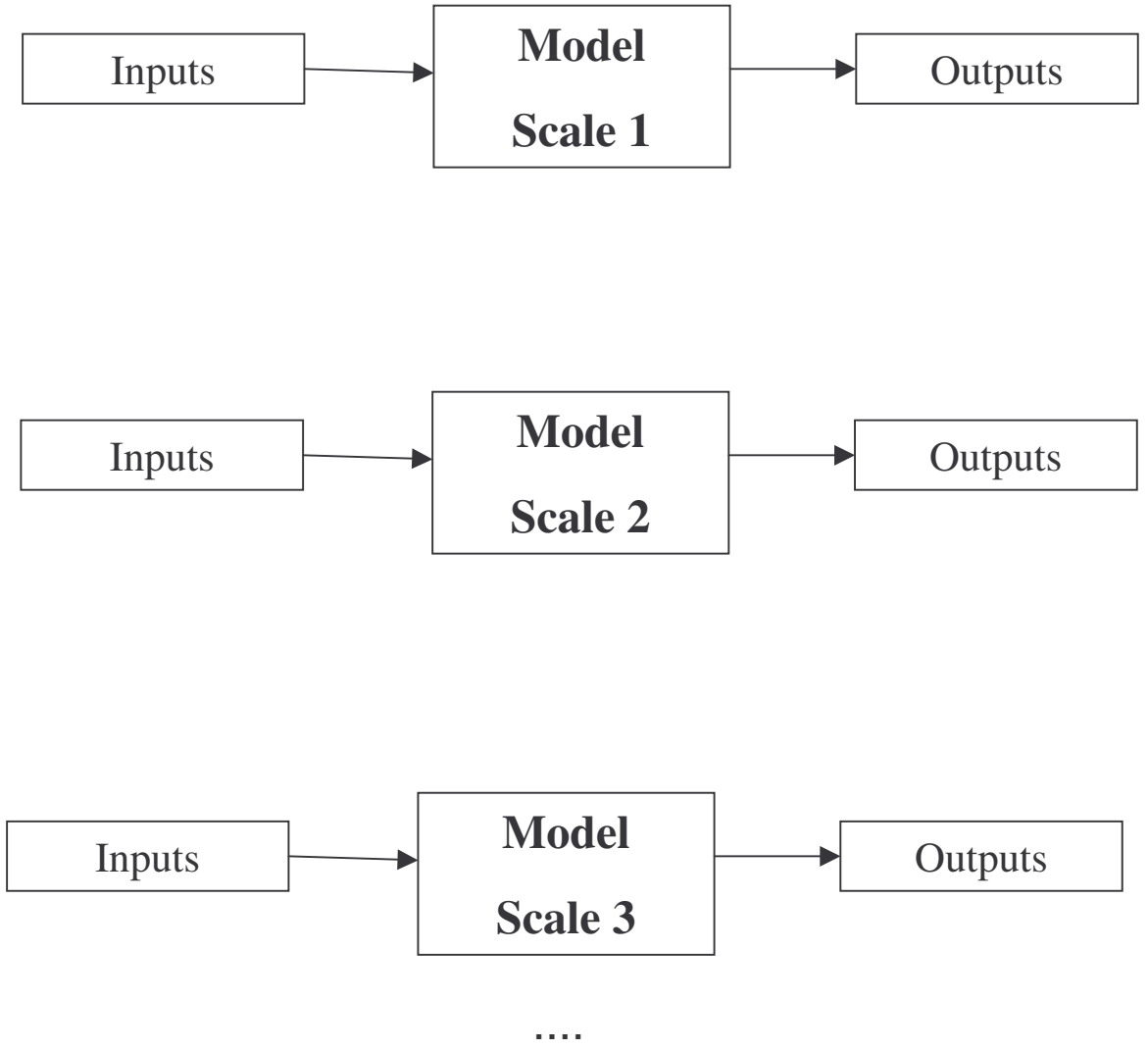
Regional dynamics impact and are impacted by local dynamics through *top-down* and *bottom-up* interactions

[Verburg, Schot, Dijst et al. 2004]

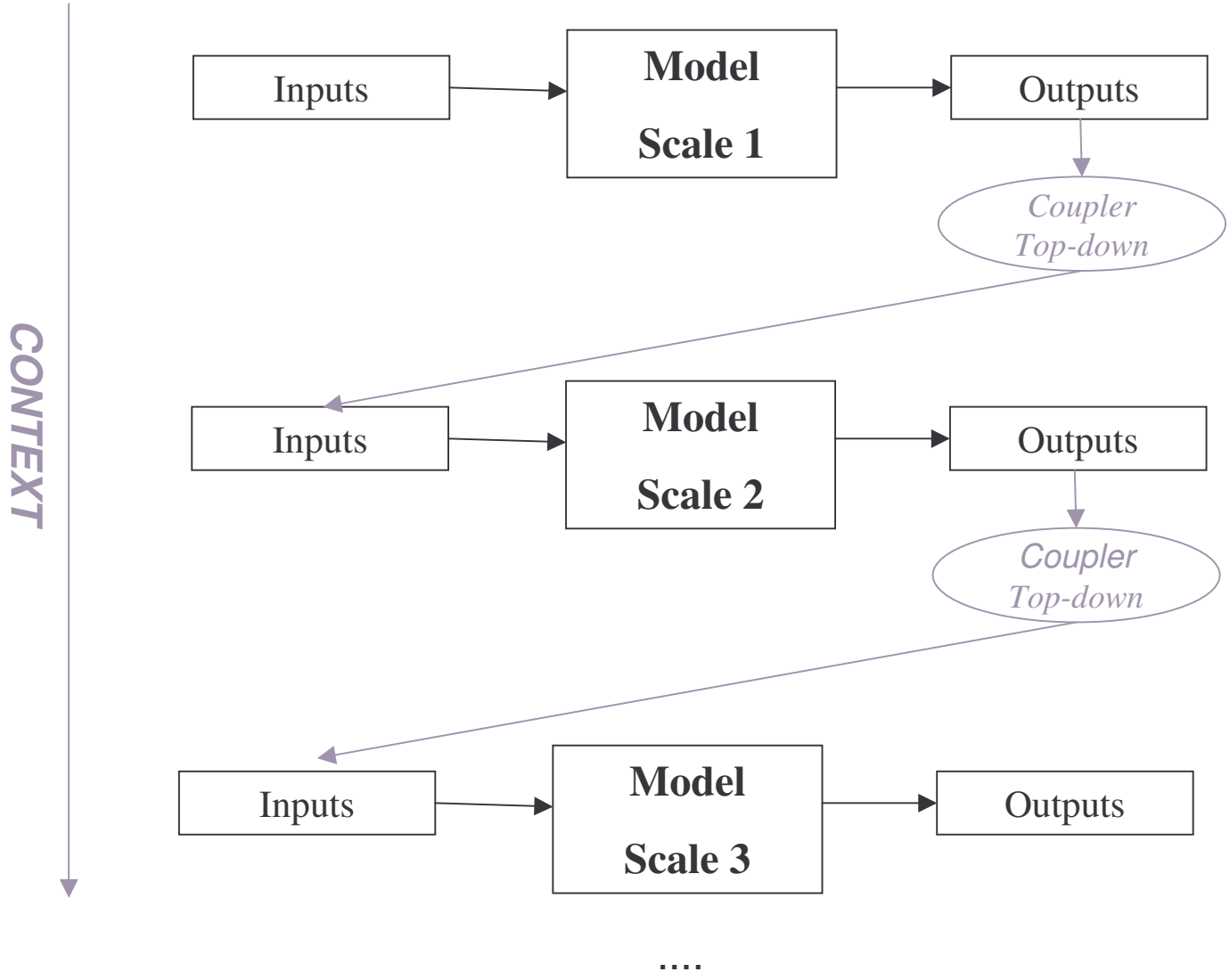
Multi-scale land change models

"it is impossible today, more than ever, to understand what happens in one place without considering the interests and conflicting actions at different geographical scales"

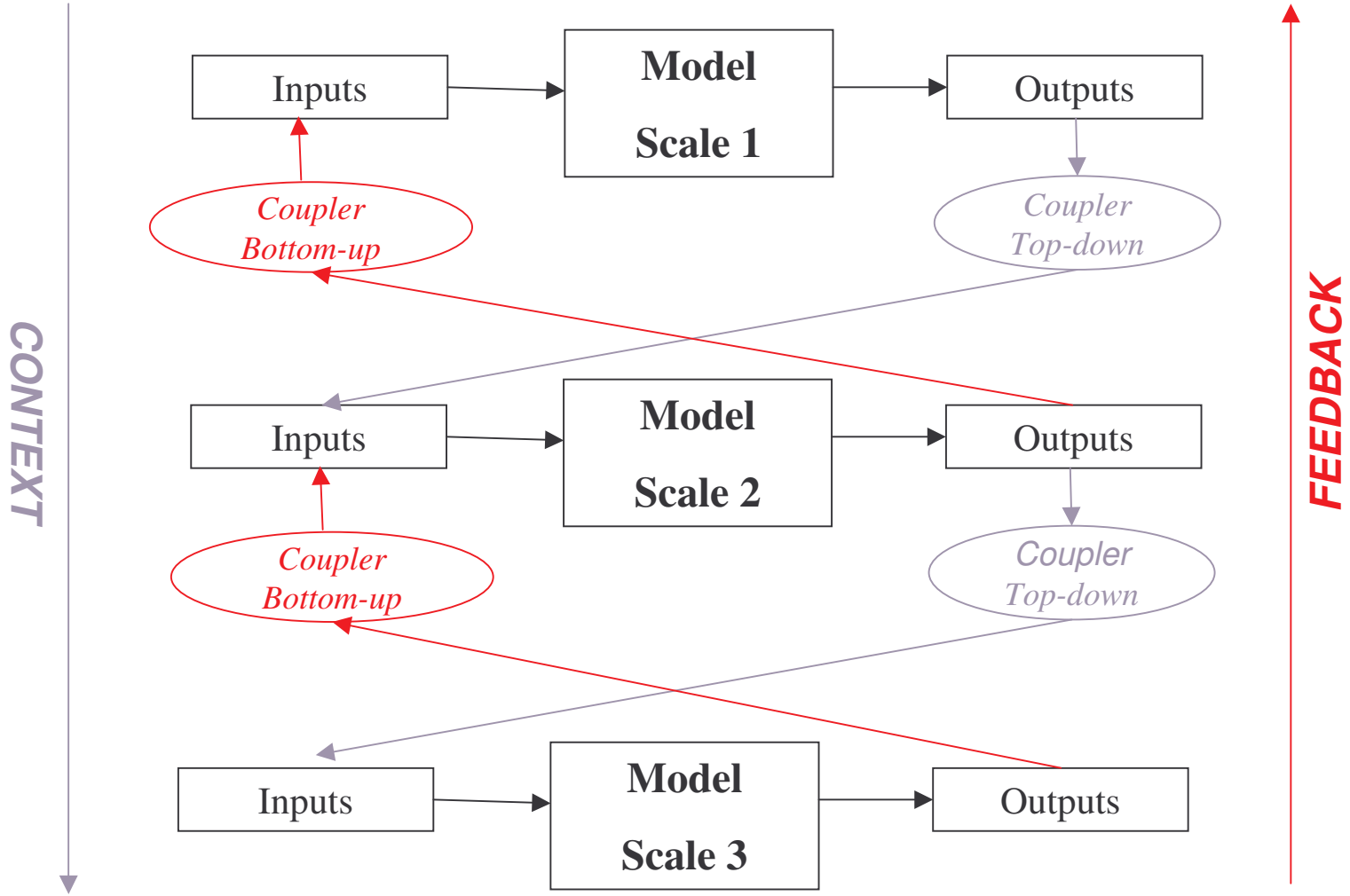
Becker [2005]



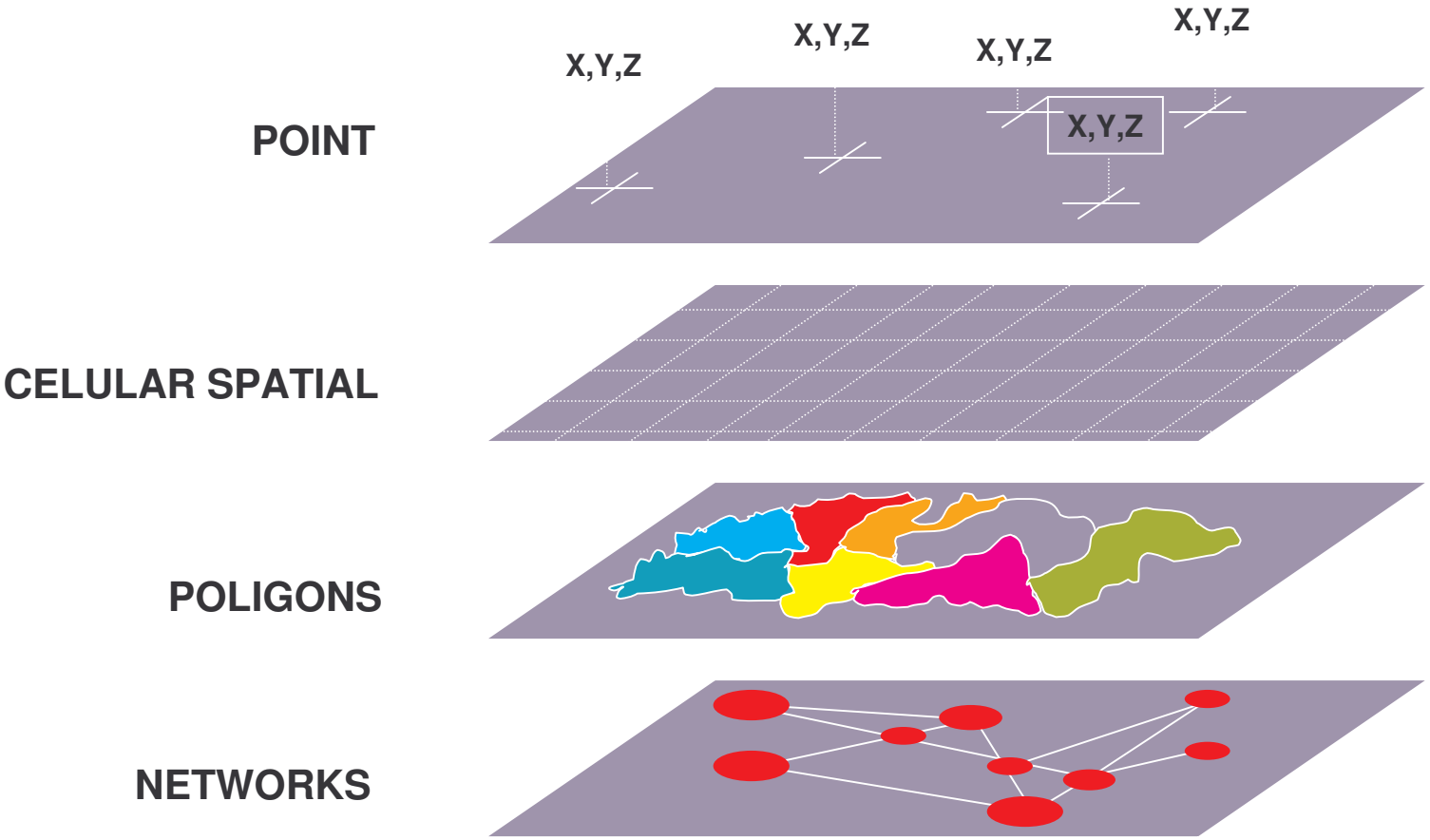
Multi-scale land change models



Multi-scale land change models

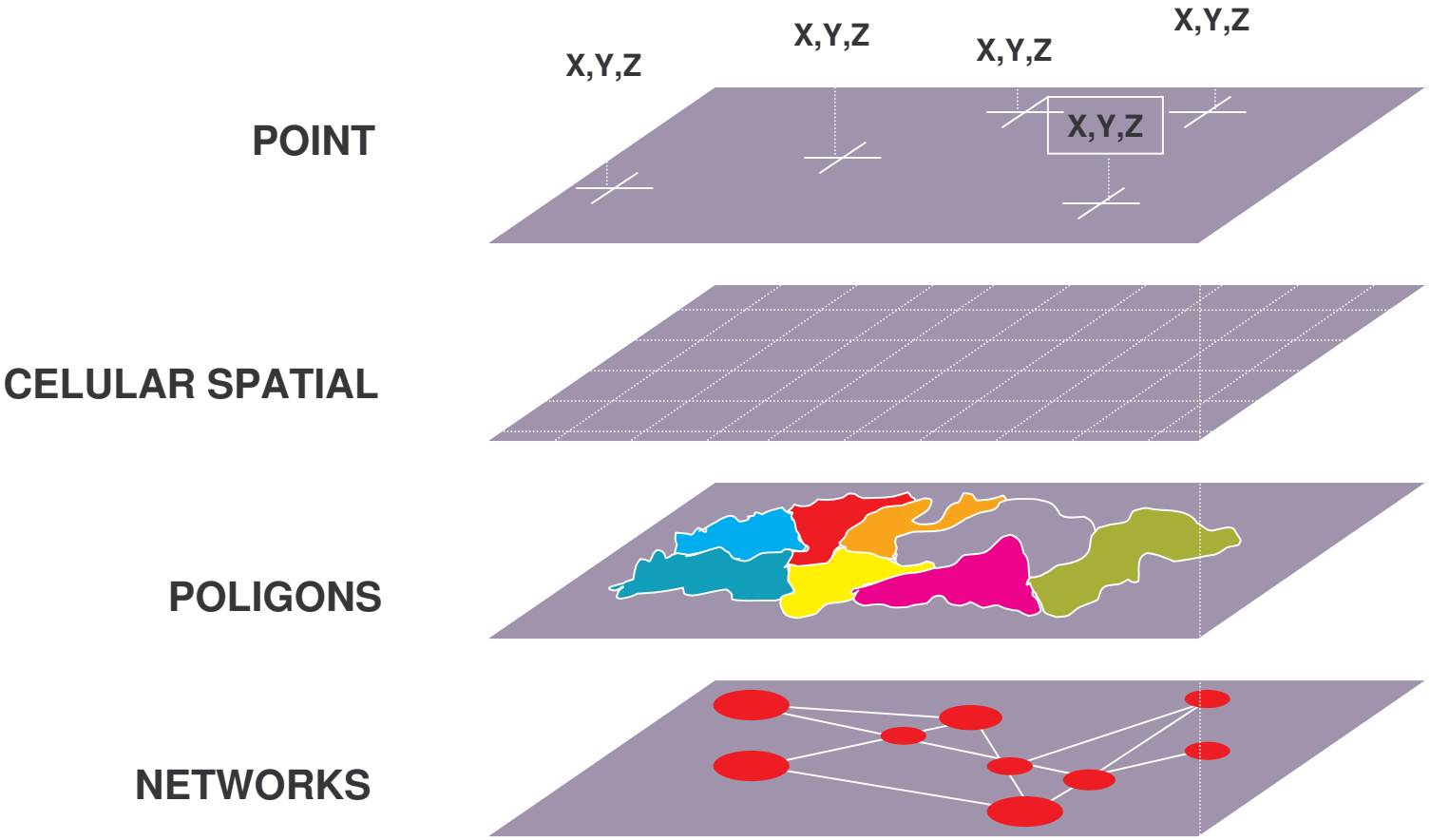


Spatial scale geographic objects represented



Adapted from Câmara [2004_]

Spatial scale geographic objects represented



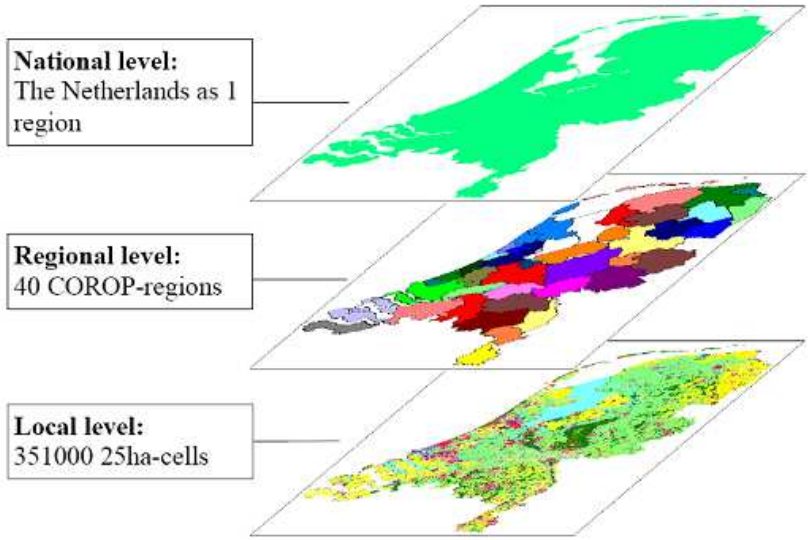
Adapted from Câmara [2004_]

Objective

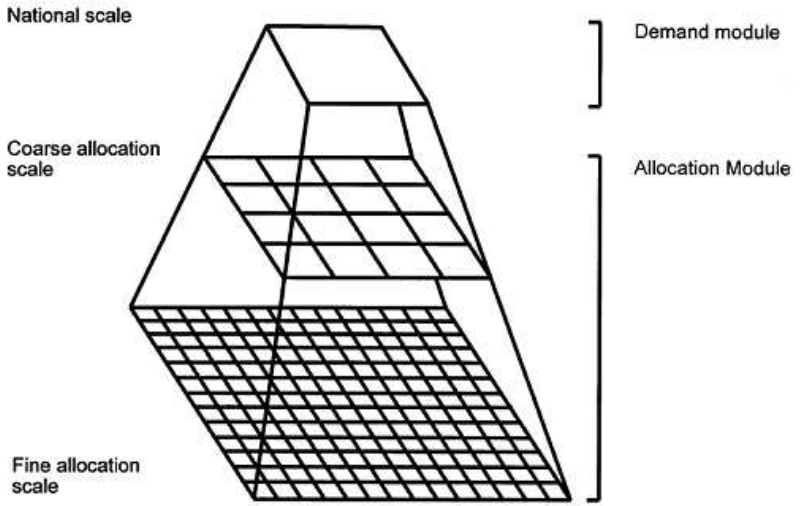
To conceptualize the spatial relations between pairs of *Entities* at different scales to allow a broad representation of *top-down* and *bottom-up* interactions in land change models

Spatial relations across scales in land change models

A) Hierarchical spatial relations

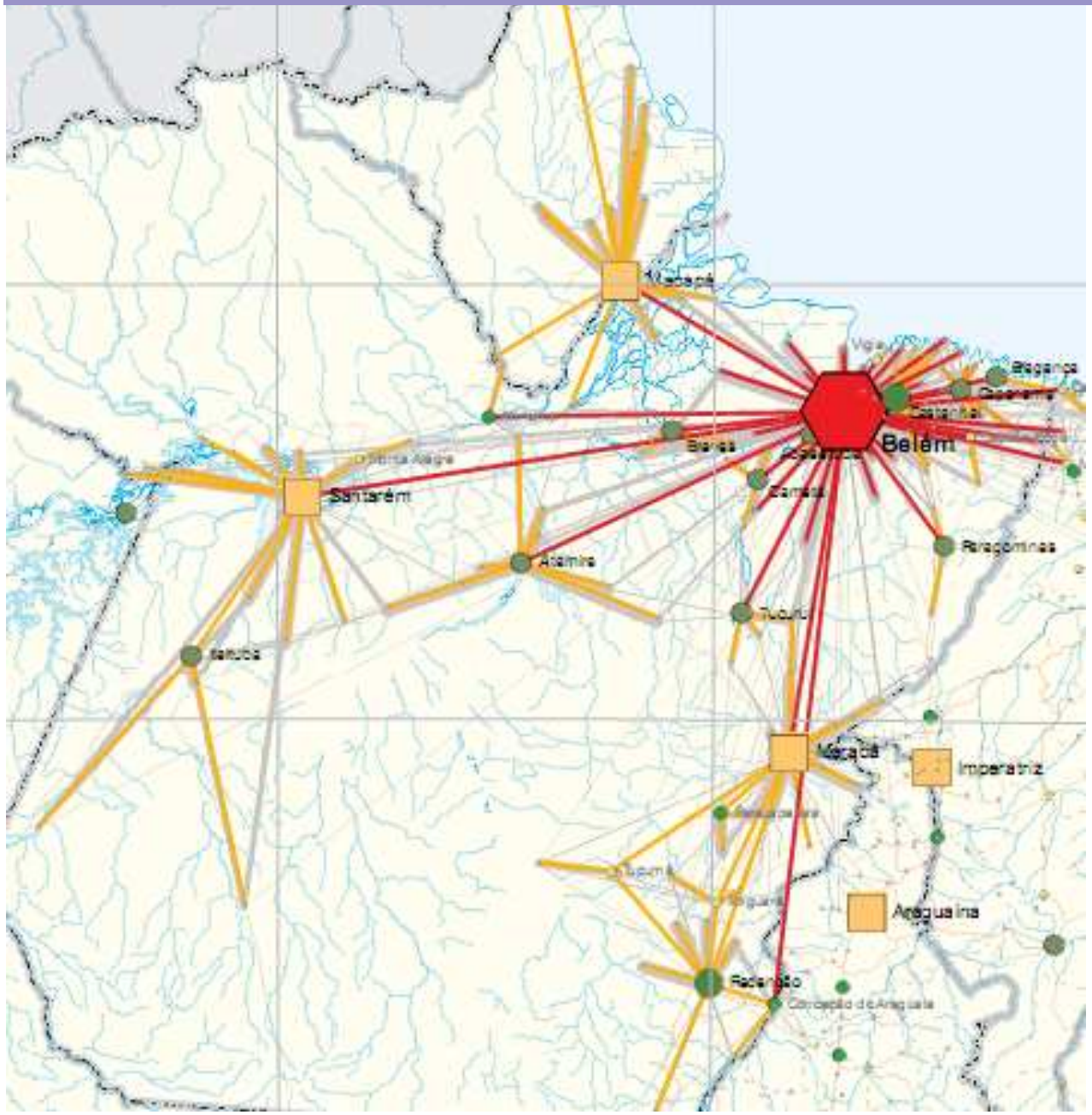


(a) Environmental Modeler
[Engelen, White and Nijs 2003]

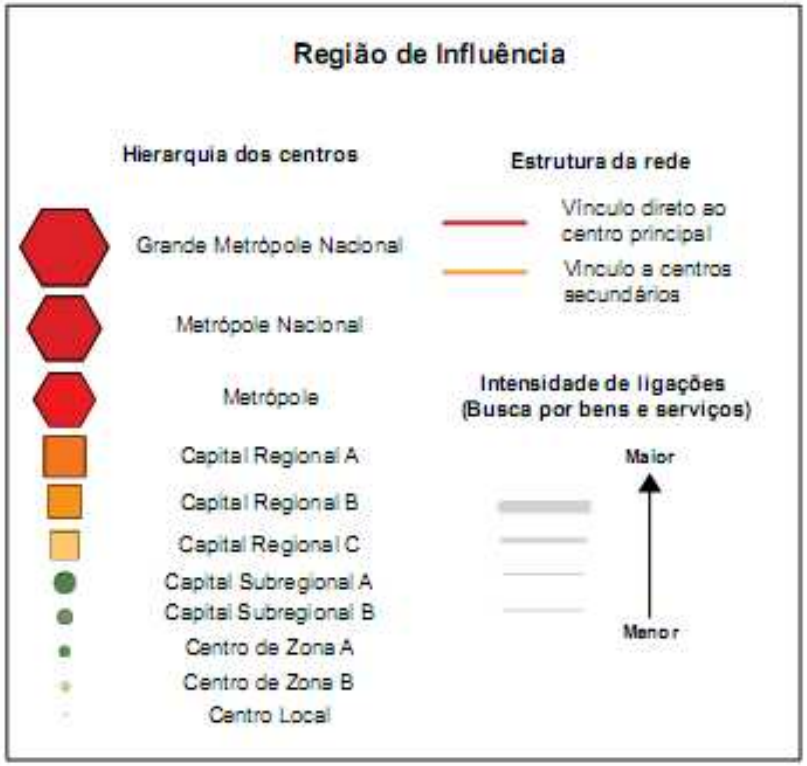


(b) CLUE model
[Veldkamp and Fresco 1996]

Spatial relations across scales in land change models



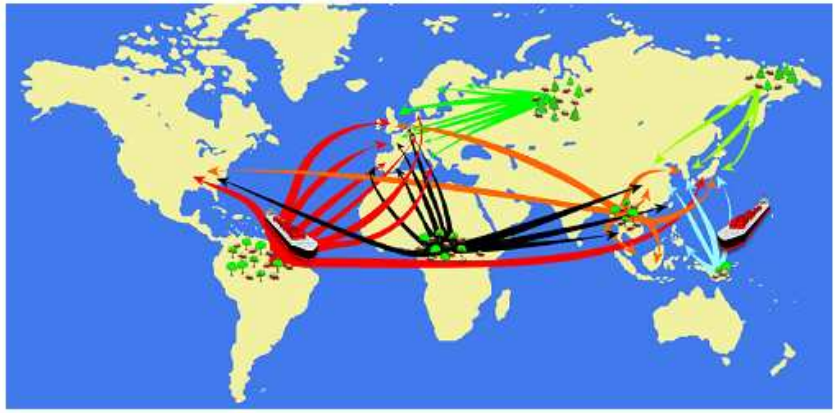
B) Hierarchical networks relations



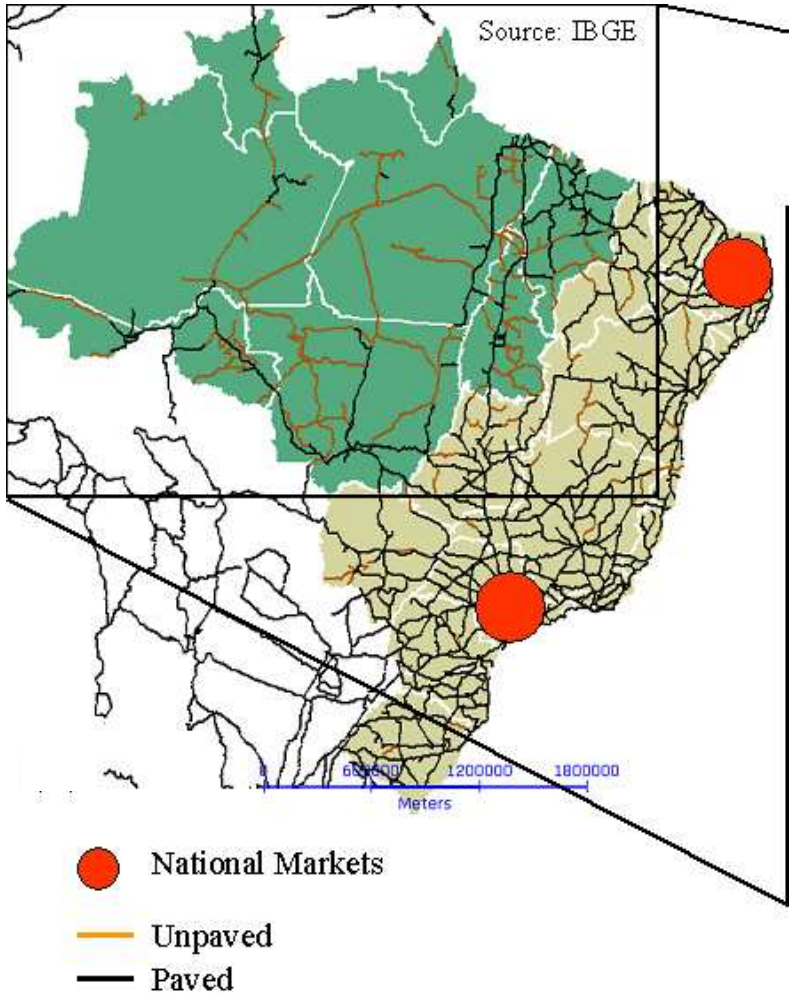
Source: IBGE (2008)

Spatial relations across scales in land change models

C) Networks-based relations



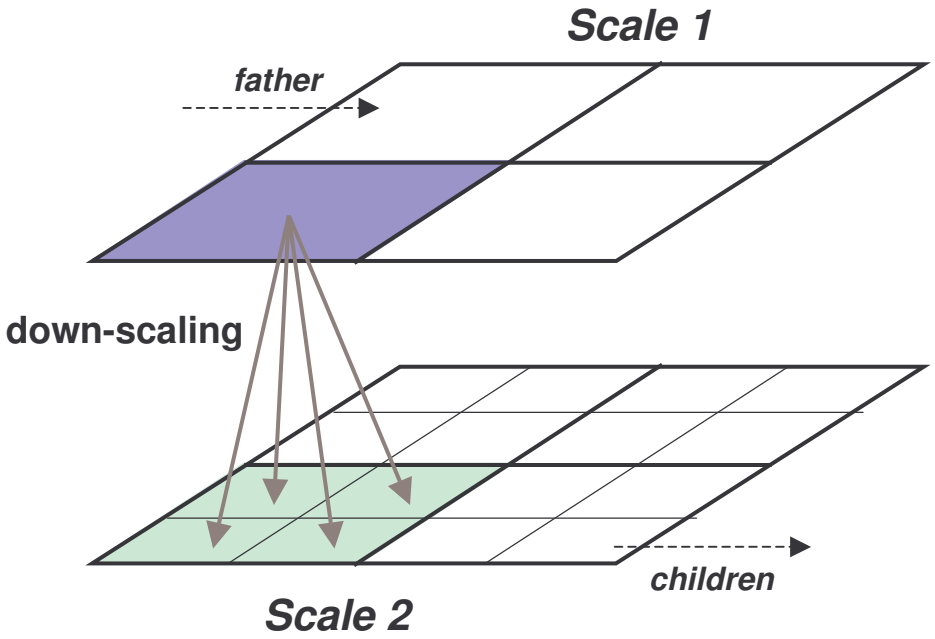
Links to global and continental markets:
International flow of wood from Amazonia
(source: Greenpeace, www.greenpeace.org)



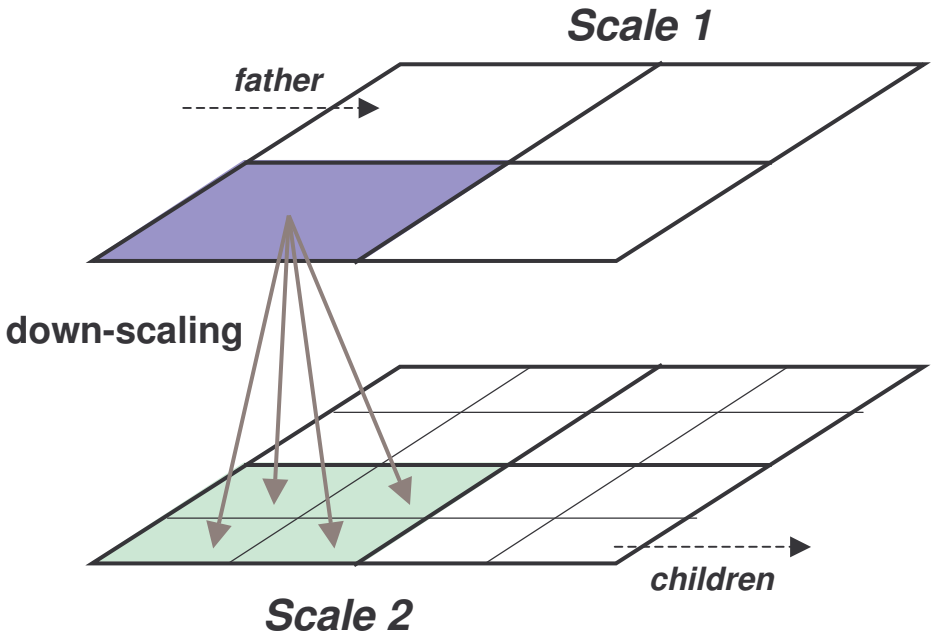
"Land change processes are also intimately linked to processes of globalization" Verburg et al. [2004]

Conceptualize the spatial relations

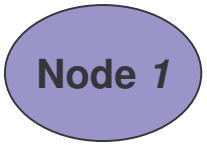
Hierarchical spatial relations



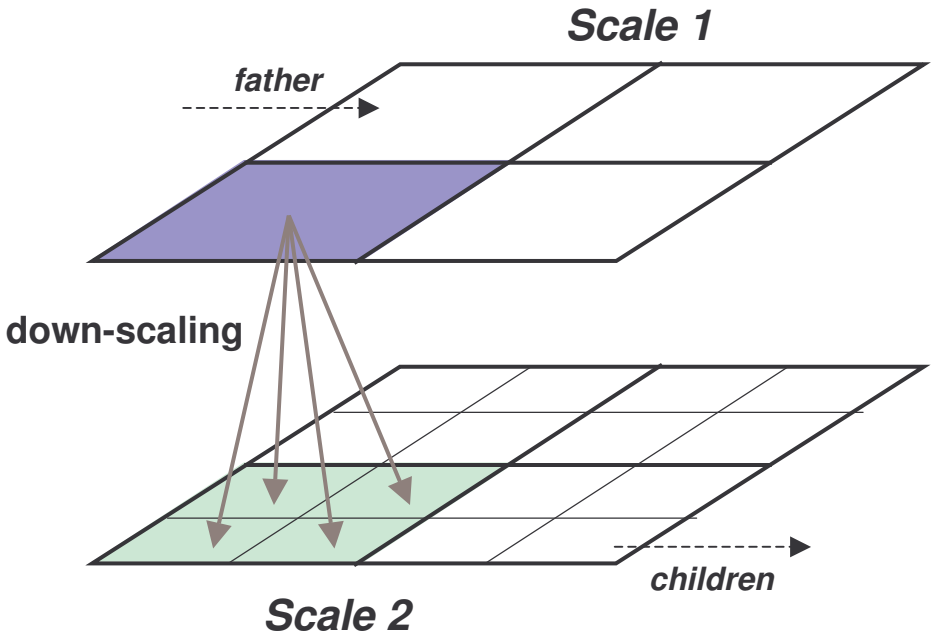
Hierarchical spatial relations

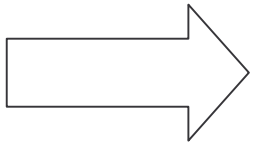


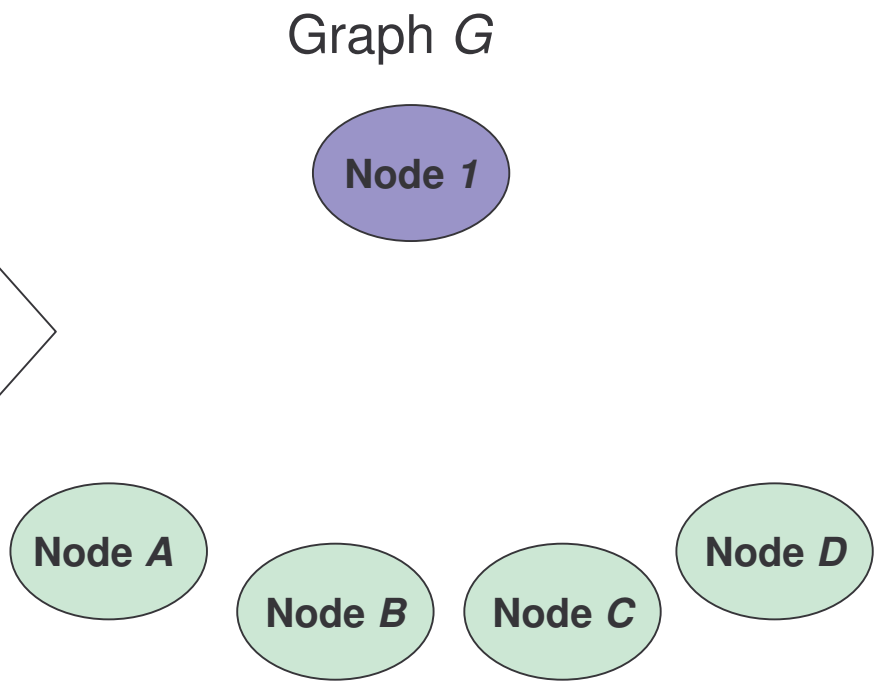
Graph *G*



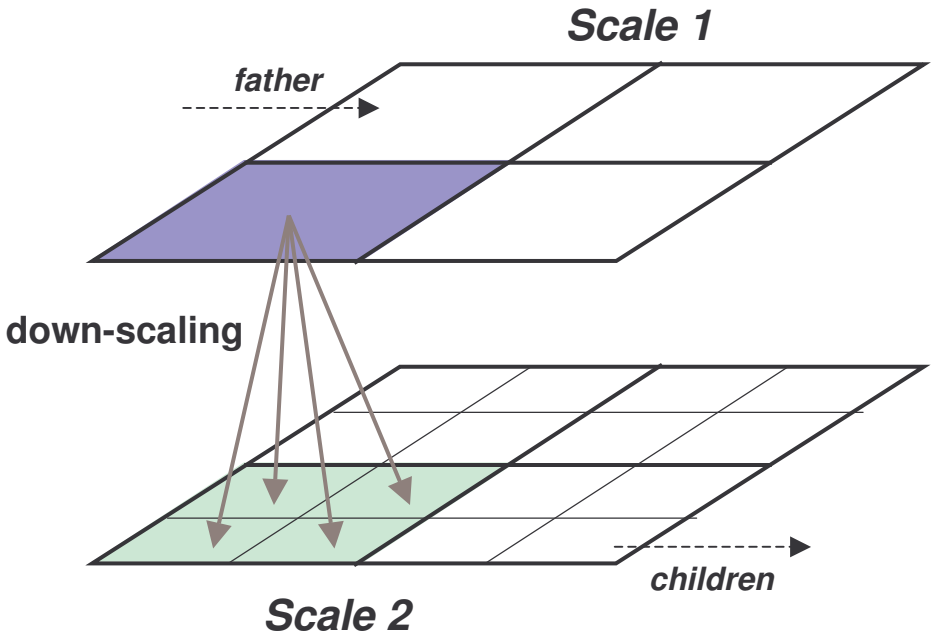
Hierarchical spatial relations

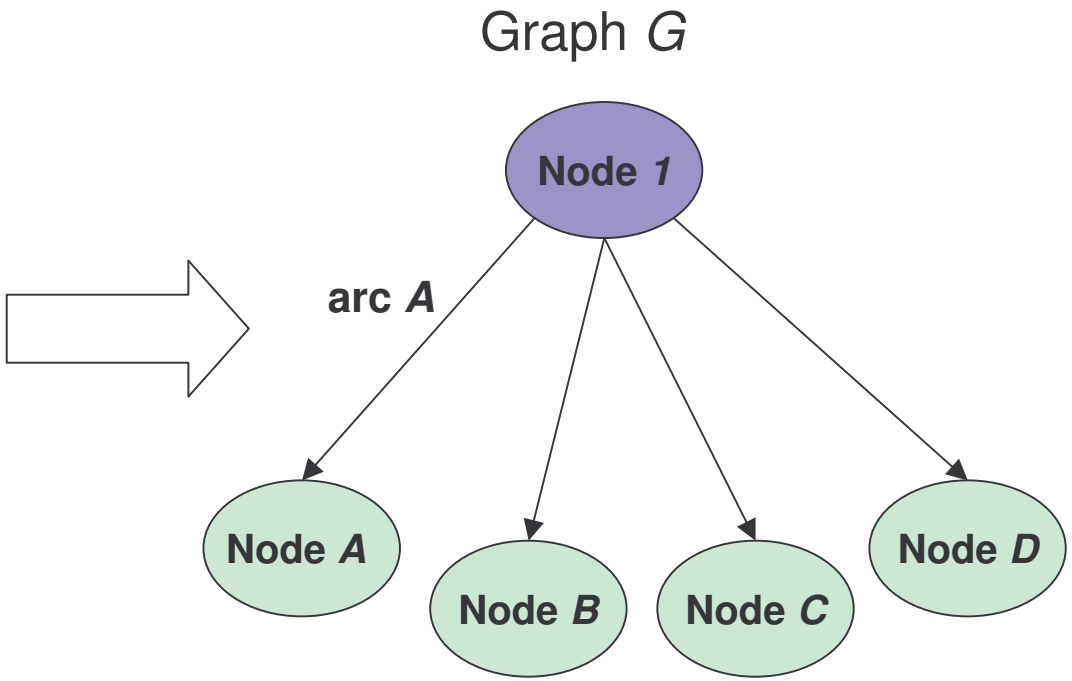




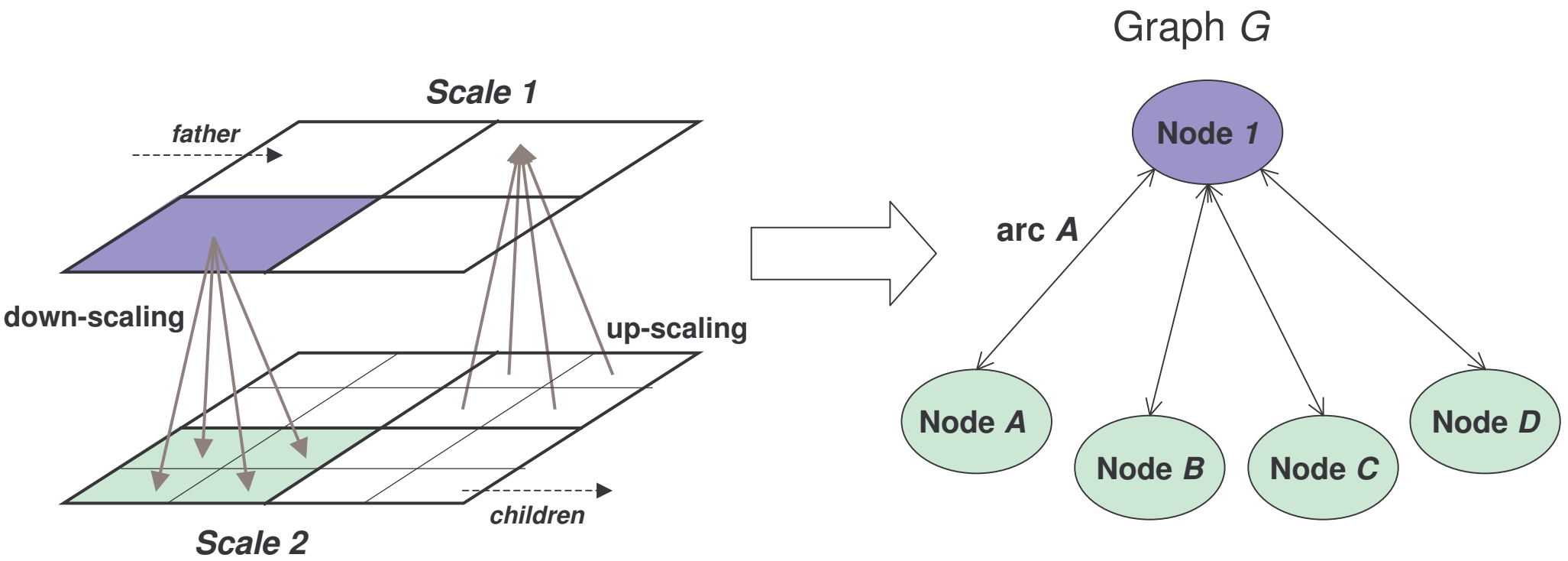


Hierarchical spatial relations

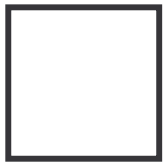


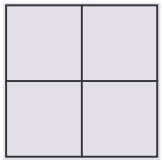


Hierarchical spatial relations

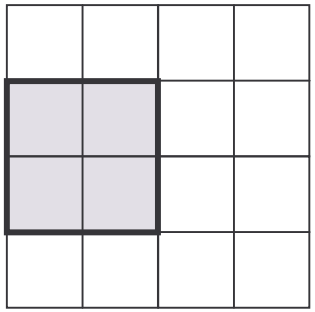


Hierarchical spatial relation strategies


upper *Entities*

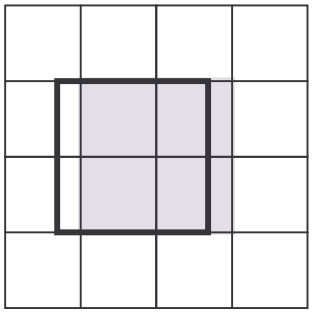

lower *Entities*

a) *Simple*

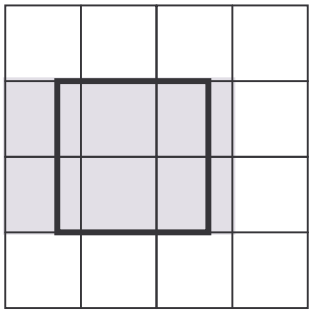


spatial operator:
"within" or
"coveredby" or
"equals"

b) *ChoseOne*



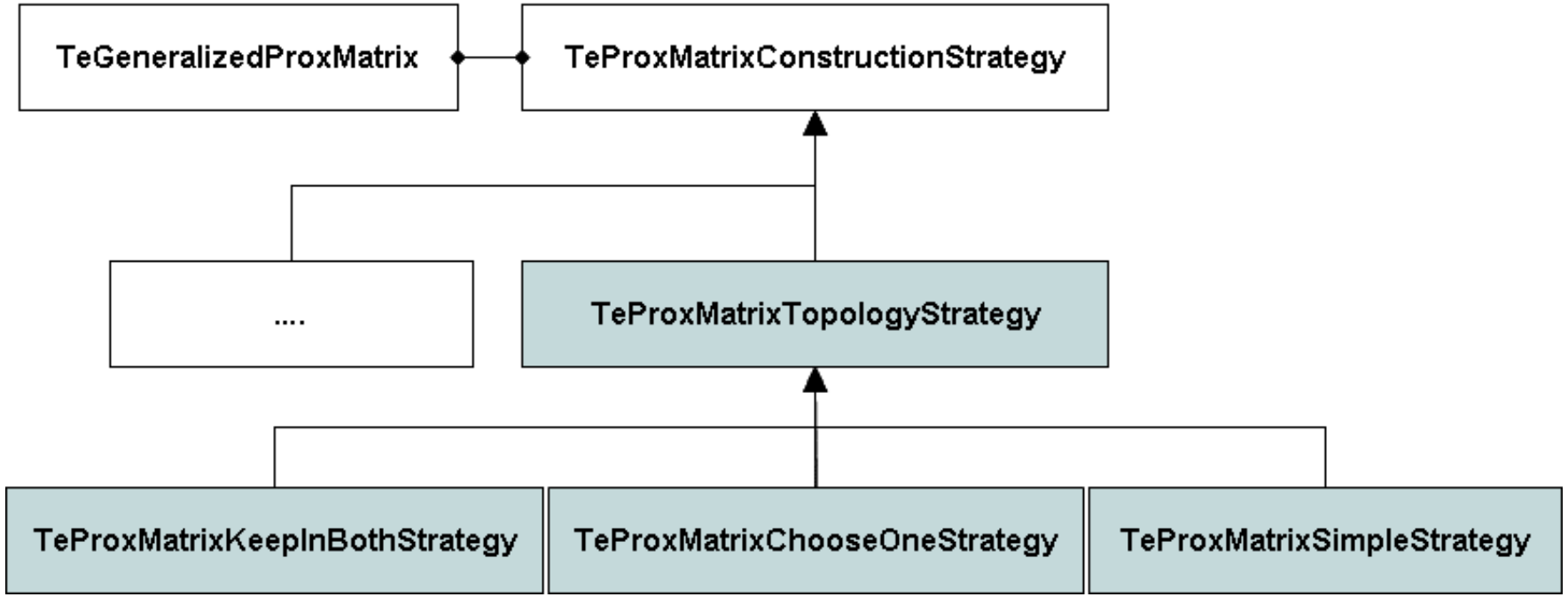
c) *KeepInBoth*



spatial operator:
"intersection"

Hierarchical spatial relations implementation

- **Terralib GIS library [Câmara et al, 2000]**
- **Added to the library as an extension of the GPM [Aguiar et al, 2003]**



Hierarchical spatial relation strategies

Hierarchical spatial relations implementation

TerraView Plugin

TerraME INTERPRETER

- model syntax semantic checking
- model execution

LUA interpreter

TerraME framework

Carneiro [2006]

MODEL DATA

GPM File

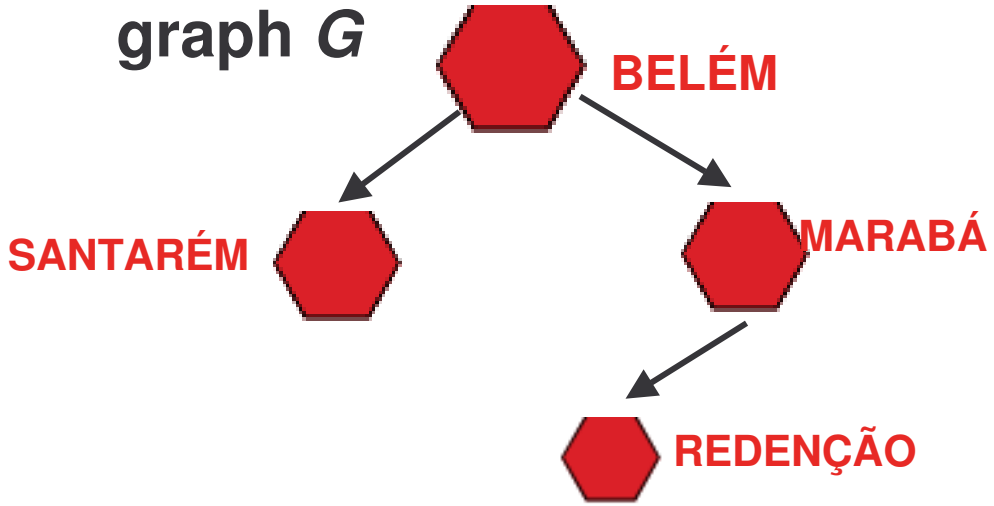
Model source code

TerraLib database

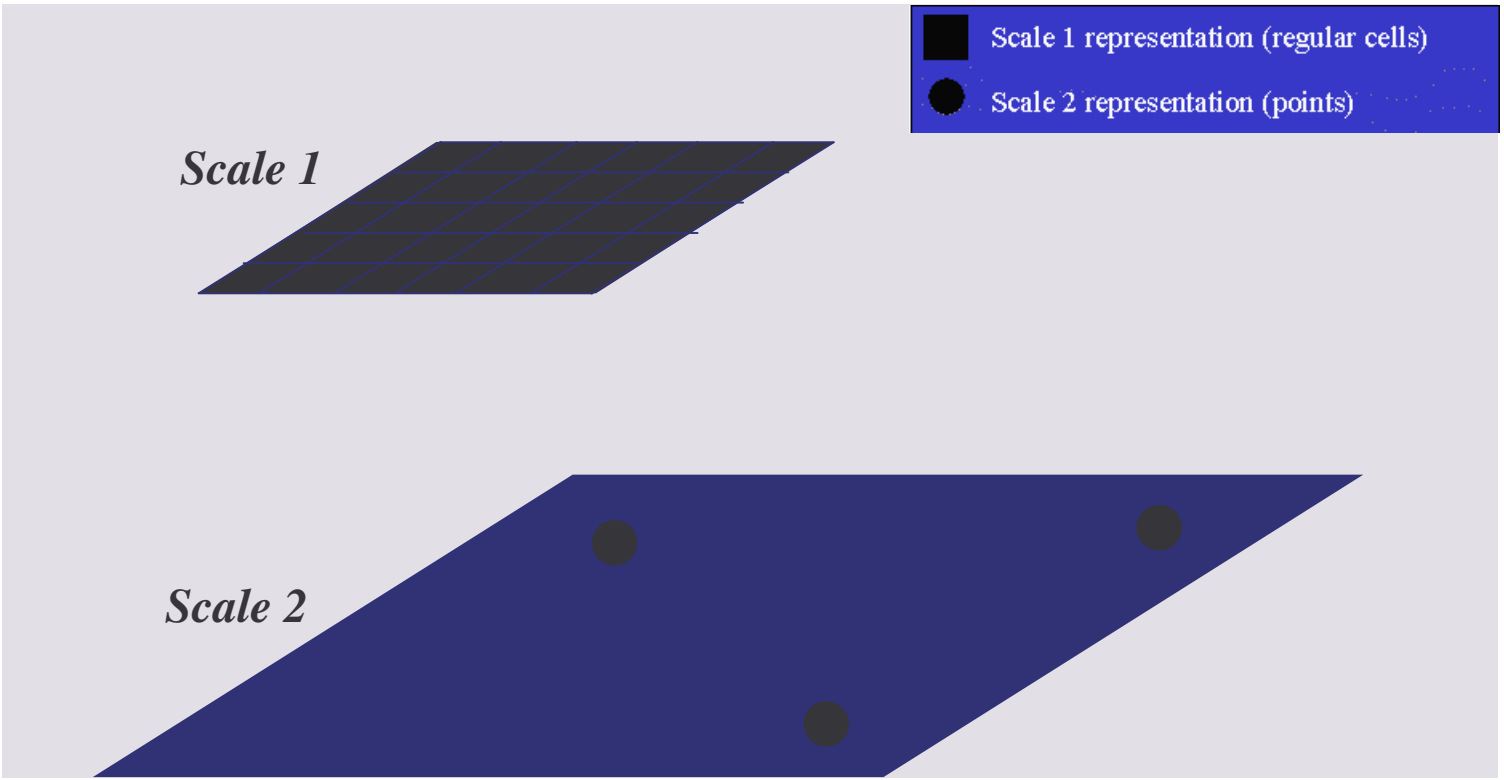
Hierarchical networks relations

Strategies: attribute based

COD_1B	MOME_1B	COD_1C	NOME_1C	COD_2C	NOME_2C	COD_3A	NOME_3A	COD_4A	NOME_4A	COD_4B	NOME_4B
150140	Belém	150420	Marabá	150613	Redenção	150270	Conceição do Araguaia			170600	Couto de Magalhães
150140	Belém	150420	Marabá	150613	Redenção			150808	Tucumã	150543	Ourilândia do Norte
150140	Belém	150420	Marabá	150613	Redenção			150808	Tucumã	150730	São Félix do Xingu
150140	Belém	150420	Marabá	150613	Redenção			150840	Xinguara	150034	Água Azul do Norte
150140	Belém	150420	Marabá	150613	Redenção			150840	Xinguara	150775	Sapucaia
150140	Belém	150420	Marabá	150613	Redenção					150125	Bannach
150140	Belém	150420	Marabá	150613	Redenção					150276	Cumaru do Norte
150140	Belém	150420	Marabá	150613	Redenção					150304	Floresta do Araguaia



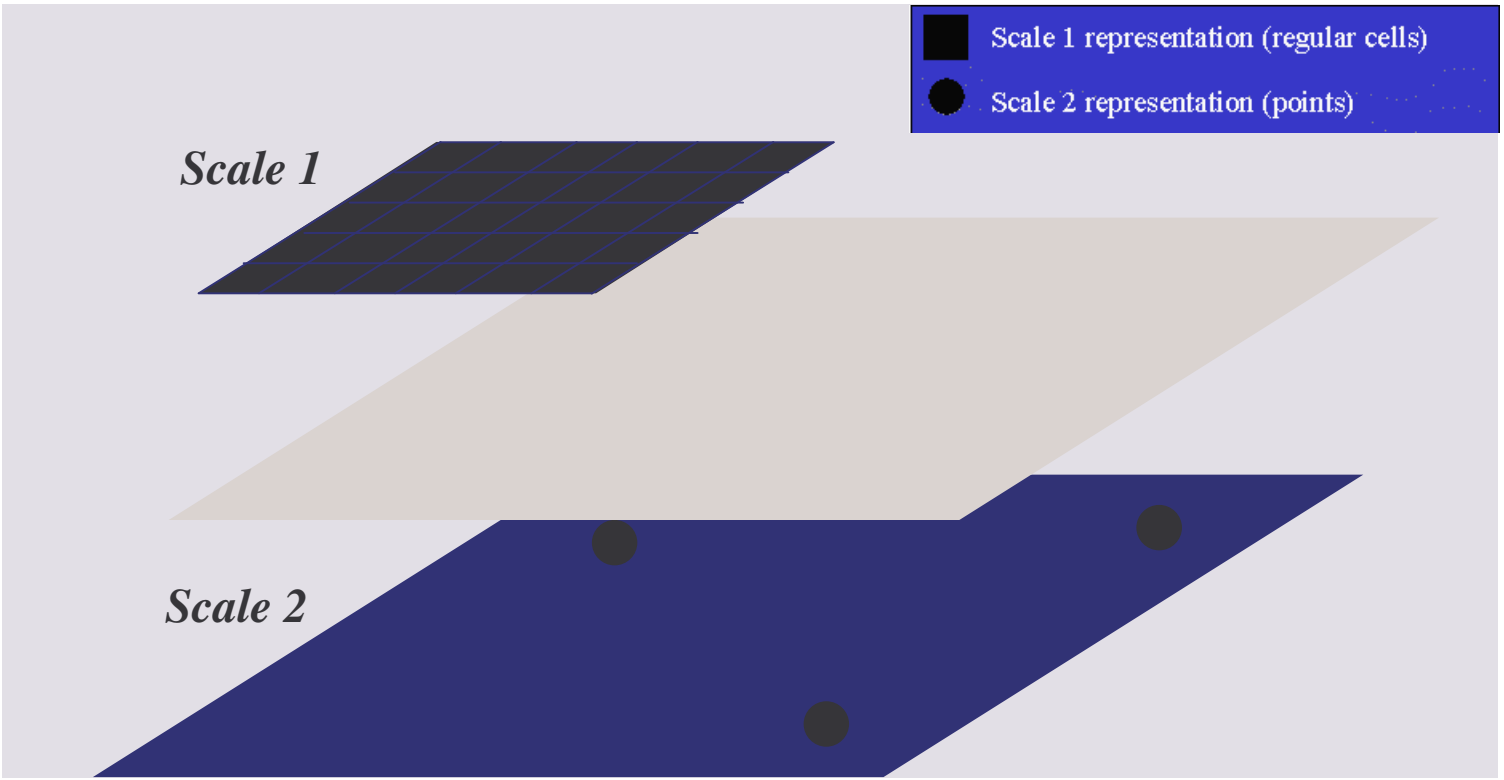
Networks-based relations



Network Physical - roads, rivers, energy

Network Logical - airline routes, market chains, migration fluxes

Networks-based relations



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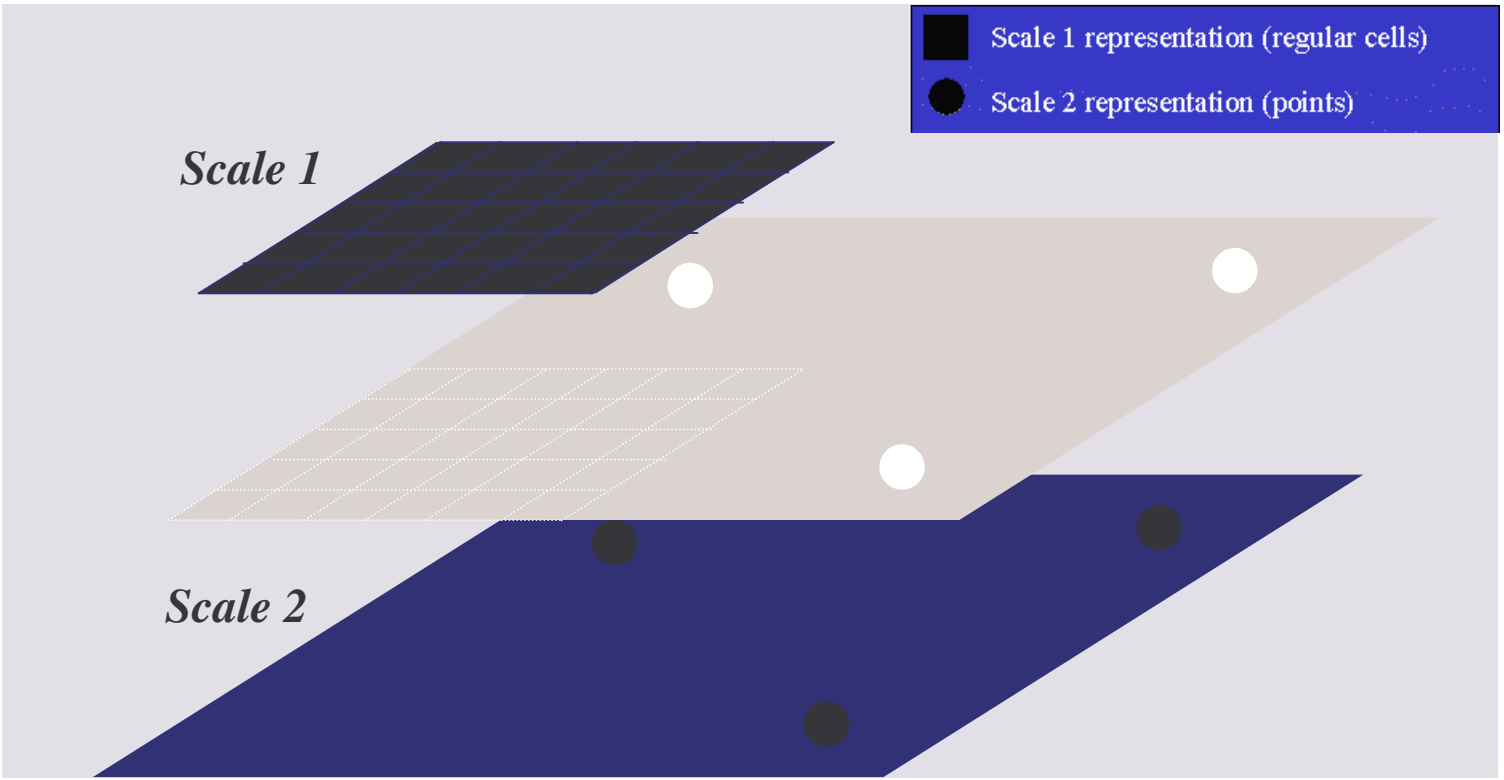

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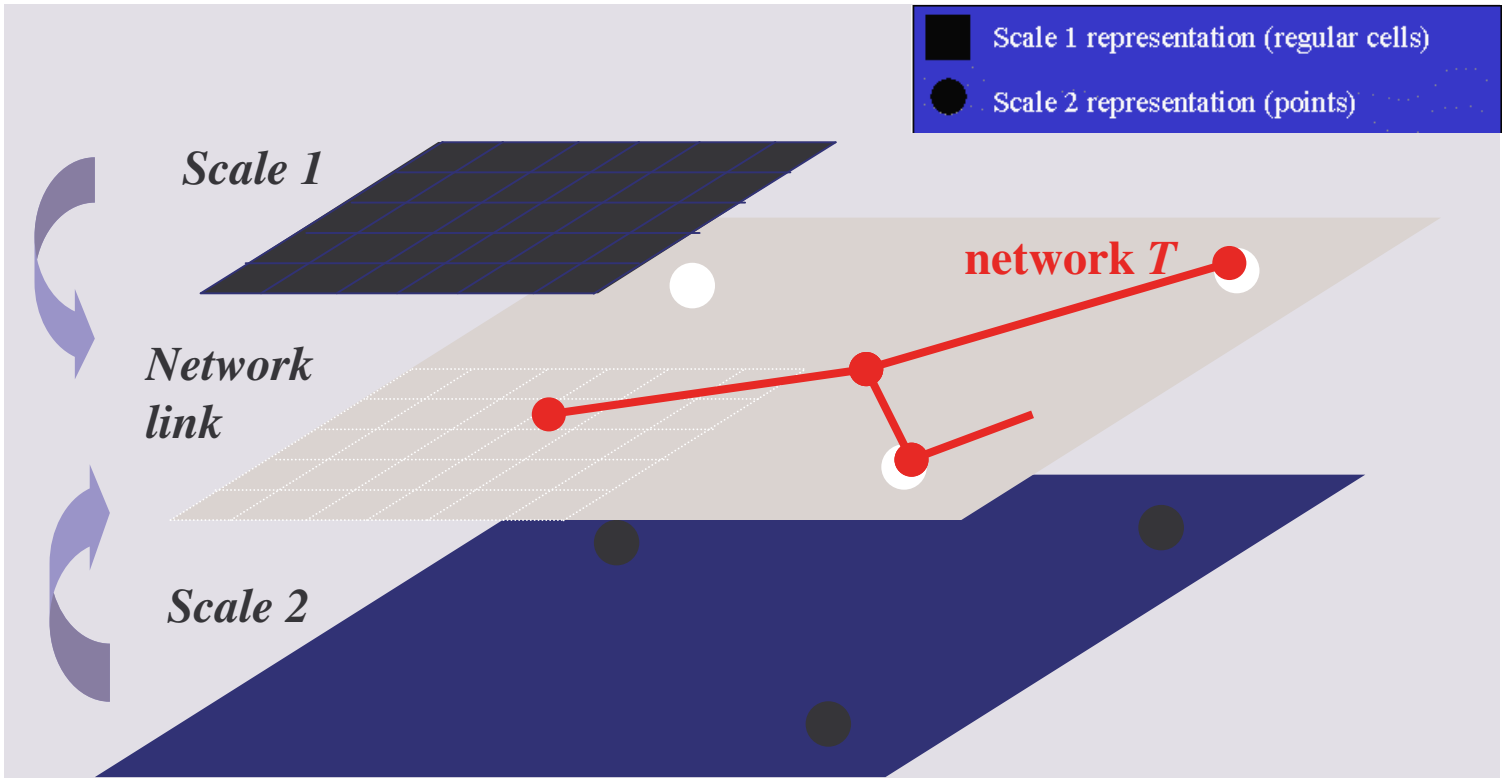
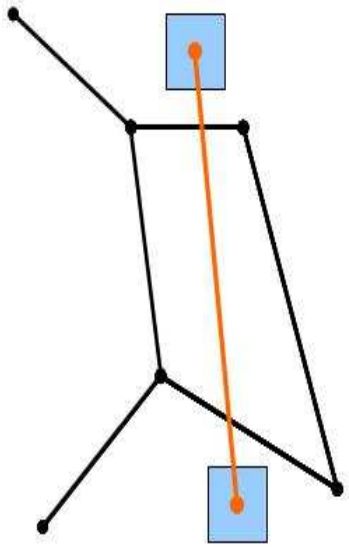


Network Physical - roads, rivers, energy

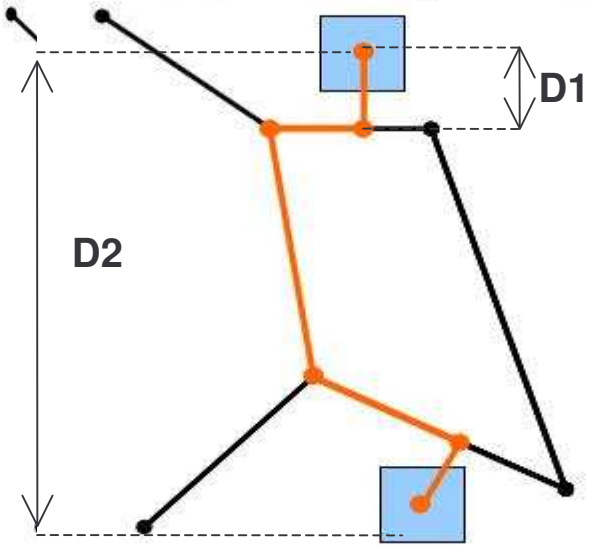
Network Logical - airline routes, market chains, migration fluxes

Construction strategies based on Generalized Proximity Matrices (GPM)

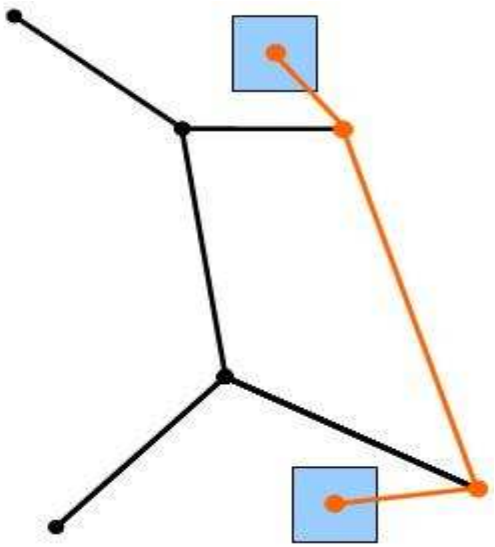
Euclidean space

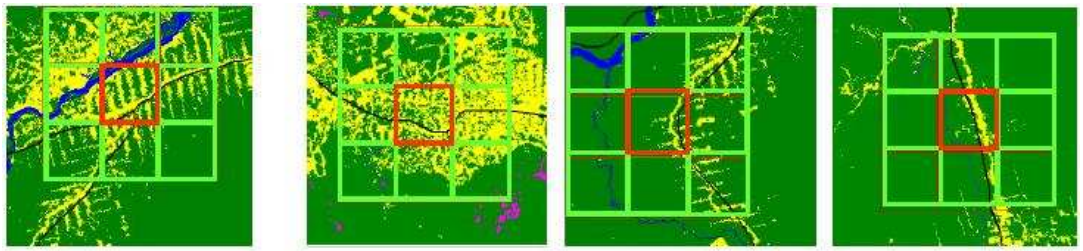


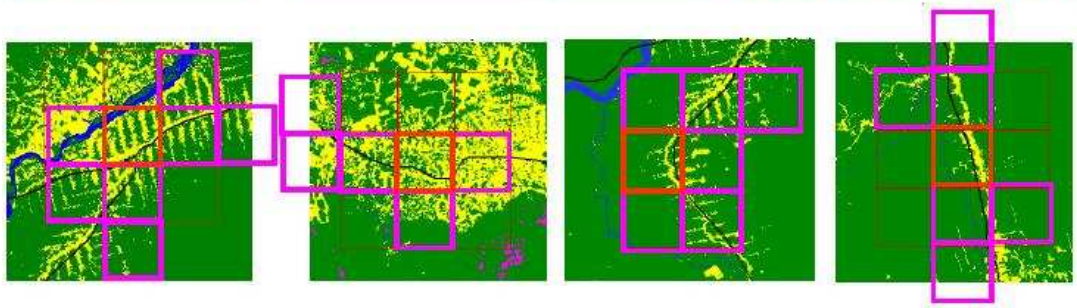
Open network



Close network





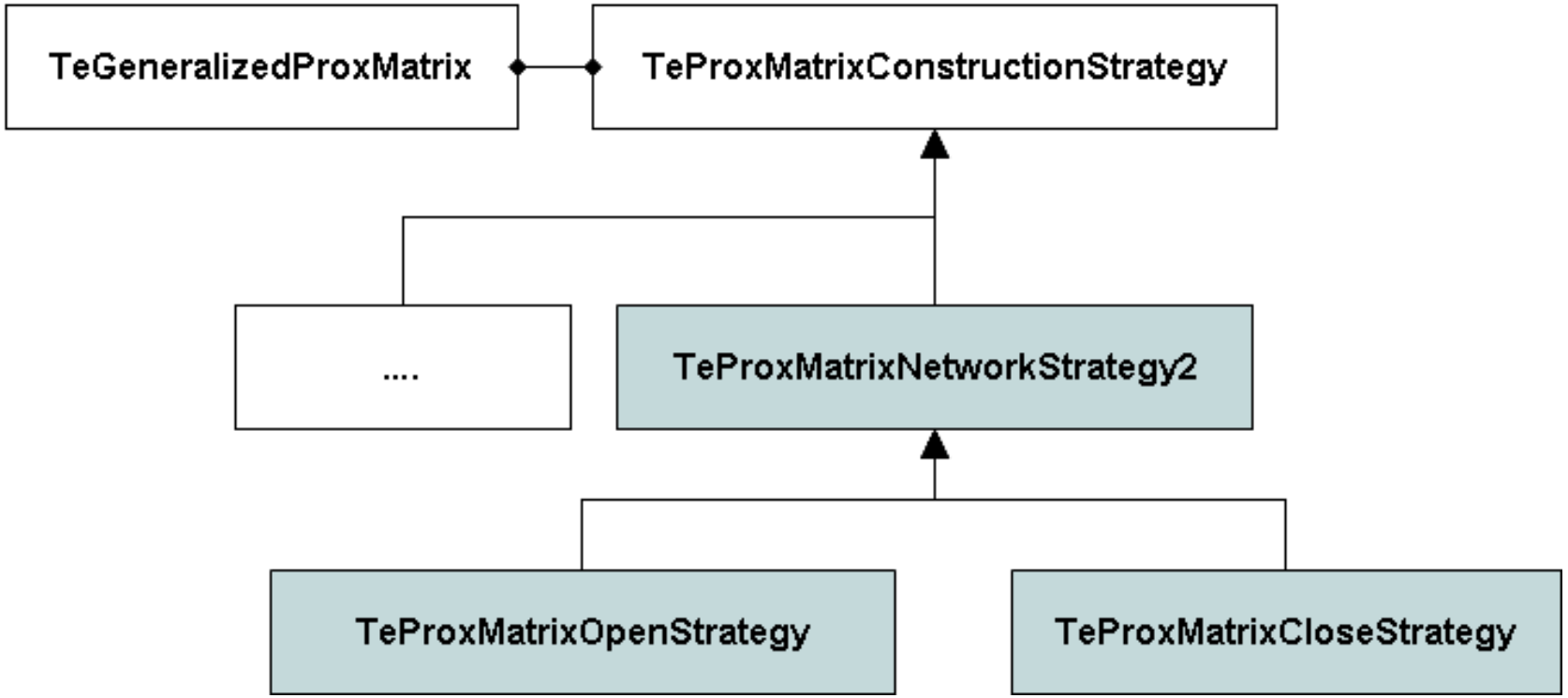


[Aguiar et al 2003]

Networks-based relations strategies

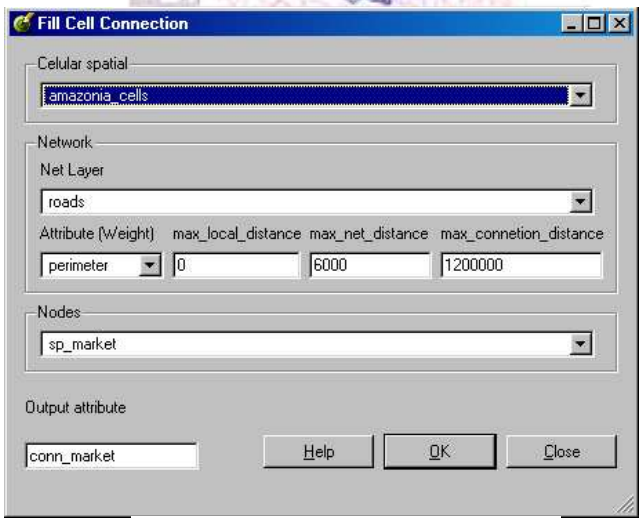
- *Multi-scale Closed-networks*
  - connect entities at different scales using networks in which the entrances and exits are restricted to its nodes
    - Encompass *logical* and some types of *physical networks*
- *Multi-scale Open-networks*
  - connect entities at different scales using networks in which any location is entrance or exit point
    - Always *physical networks*

Networks-based relations Implementation



Networks-based relations strategies

Networks-based relations implementation



TerraView Plugin

TerraMEINTERPRETER

- model syntax semantic checking
- model execution

LUA interpreter

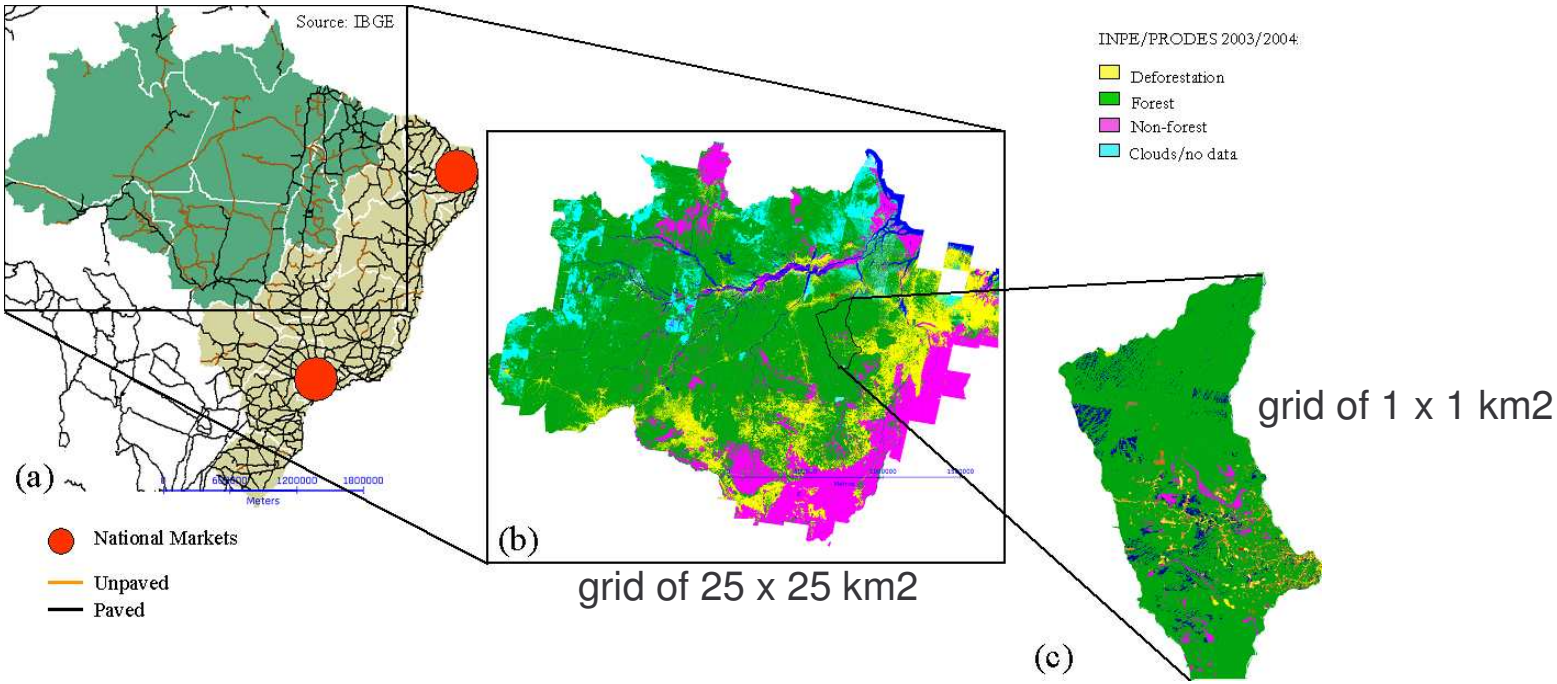
TerraMEframework

MODEL DATA

TerraLib database

Model source code

Study Case: Multiscale land change model for the Brazilian Amazonia



(a) National level - the main markets for Amazonia products (Northeast and São Paulo) and the roads infrastructure network;

(b) Regional level - for the whole Brazilian Amazonia, 4 million km2;

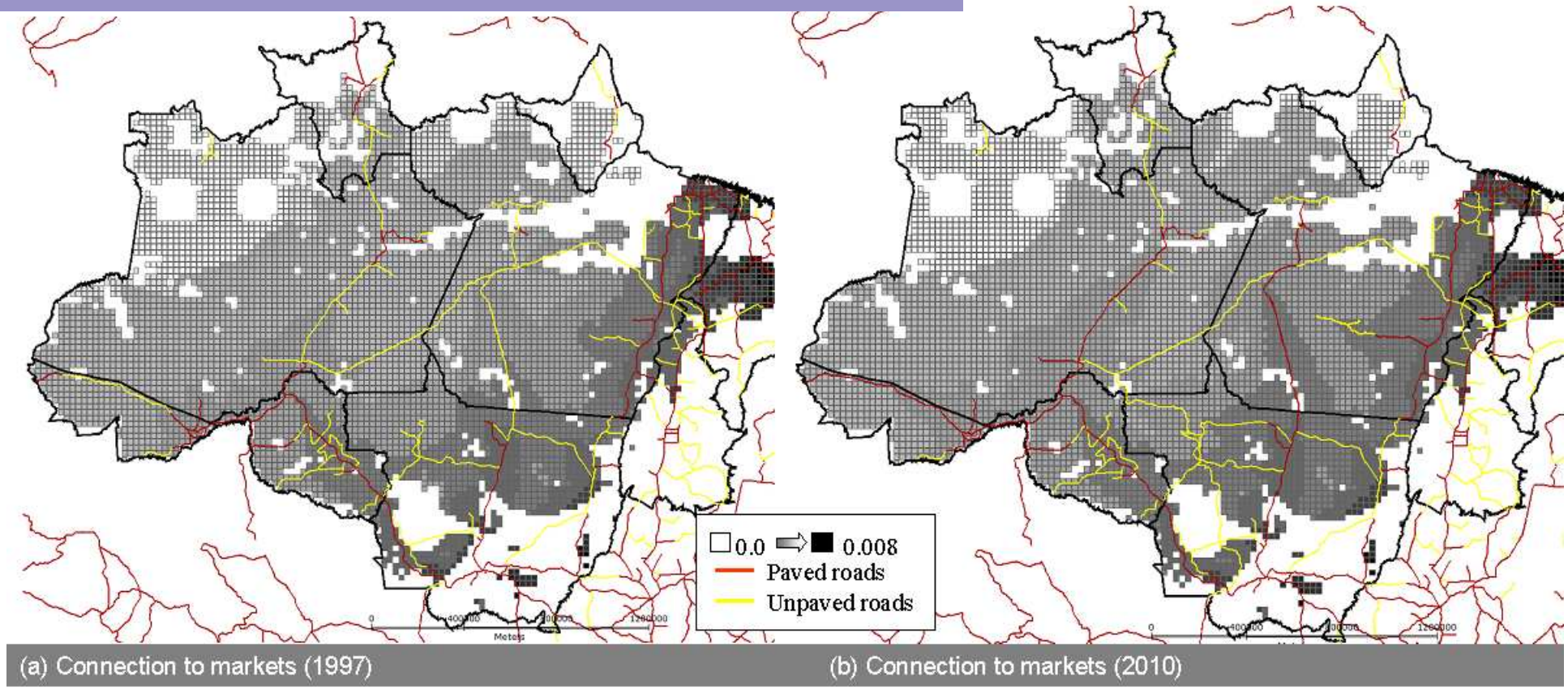
(c) Local level - for a hot-spot of deforestation in Central Amazonia, the Iriri region, in São Felix do Xingu, Pará State, 50 mil km2.

Aguiar [2006] and Moreira et al [2008]

Used strategies

- *KeepInBoth*
  - Used a hierarchical relation to provide the spatial support to dynamically link the two nested grids at 25 x 25 km^2 and 1 x 1 km^2 resolutions
- *Multi-scale Open-network*
  - Connect the regional scale 25 x 25 km^2 cells to the main places of consumption at the national scale (São Paulo and Northeast)

Used strategies

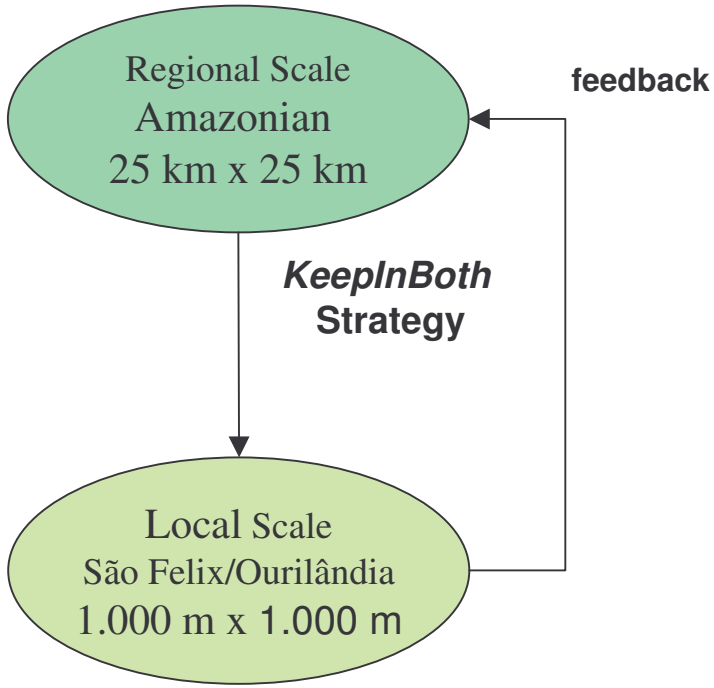


- Relationship (from cell to market) - *n:2*
- Each cell receives as attribute *conn_markets* the minimum *weight* value stored in G according to the roads network at that time
- Connection to markets variable: remote influence between São Paulo and their most connected cells

Land change models

- **Regional model**
  - Goals was to explore the hypothesis that connection to national markets through roads infrastructure is a key factor to explain the distribution of deforestation in the region.
  - Model projects the percentage of deforestation used a statistical allocation procedure based on regression models adapted from the CLUE model by Aguiar [2006]
- **Local model**
  - Given that a certain amount of pressure is projected for the Iriri by the regional model, how would local patterns of occupation evolve?

CLUE model
[Veldkamp and Fresco 1996]

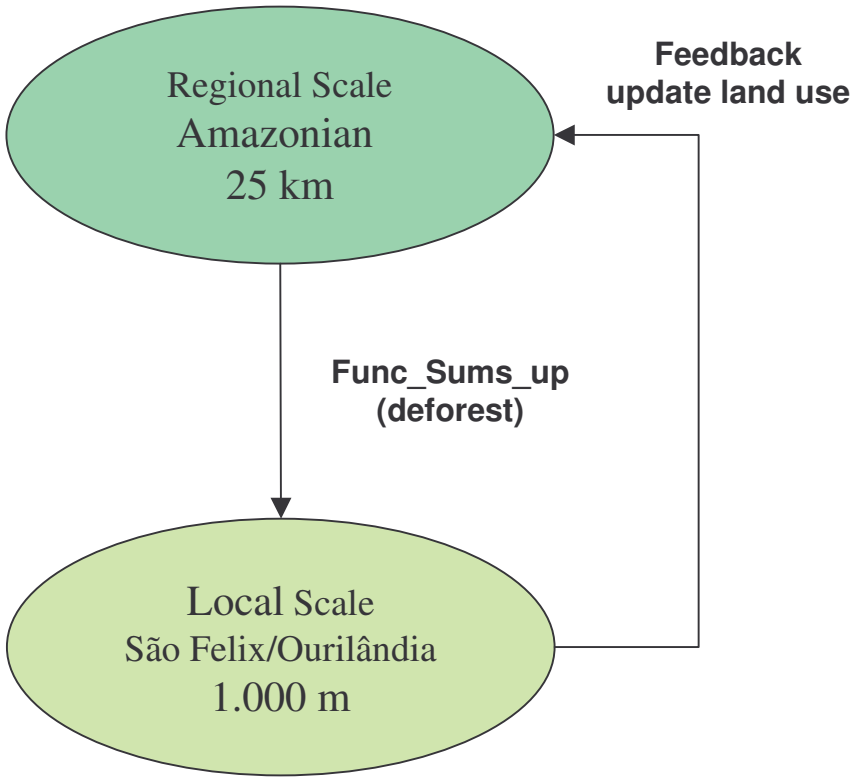


agent-based deforestation model
[Moreira, Costa, Aguiar et al. 2008]

Land change models

- **Interaction among models**
  - The *top-down* interaction: consists of the regional model signalling an expected demand for change at the Iriri.
    - Demand is calculated as a function that sums-up the deforested area (father-cells) at the regional scale and sends it to the local scale.
  - A *bottom-up feedback mechanism* sends this information back to the larger scale and thus modifies the macro scale model corresponding cells.

CLUE model
[Veldkamp and Fresco 1996]



agent-based deforestation model
[Moreira, Costa, Aguiar et al. 2008]

Final Remarks

- This paper discussed and conceptualized the use of multi-scale spatial relations in land change models
- Two types of relations were presented: hierarchical and network-based
- Multi-scale land-change models are often based on hierarchical relations, using nested objects at different scales
- We argue that combining hierarchical relations with network-based relations provide a comprehensive conceptual framework to include top-down and bottom-up interactions and feedbacks in multi-scale land-change models

Final Remarks

- Network-based relations can represent remote influences in the land use system. This has a growing importance in a globalized economy, in which places of consumption and production are increasingly separated
- Land systems cannot be adequately understood without knowing the linkages of different areas to decisions and structures made elsewhere
- We exemplified the use of such relations in a multi-scale land change model for the Brazilian Amazonia.

Acknowledgements