Exploration of patterns of land-use change in the Brazilian Amazon using the CLUE framework

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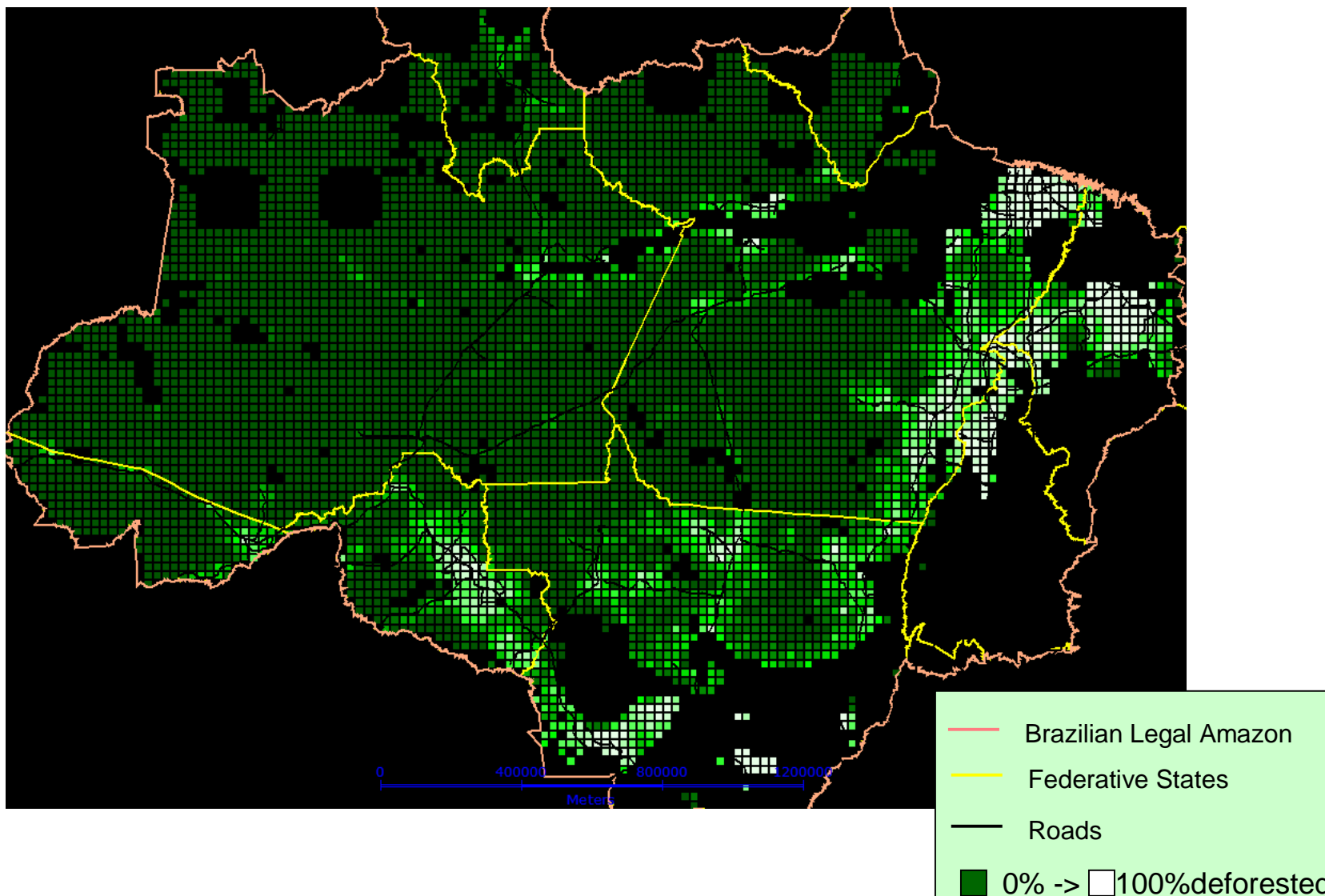# Land use change in the Amazon

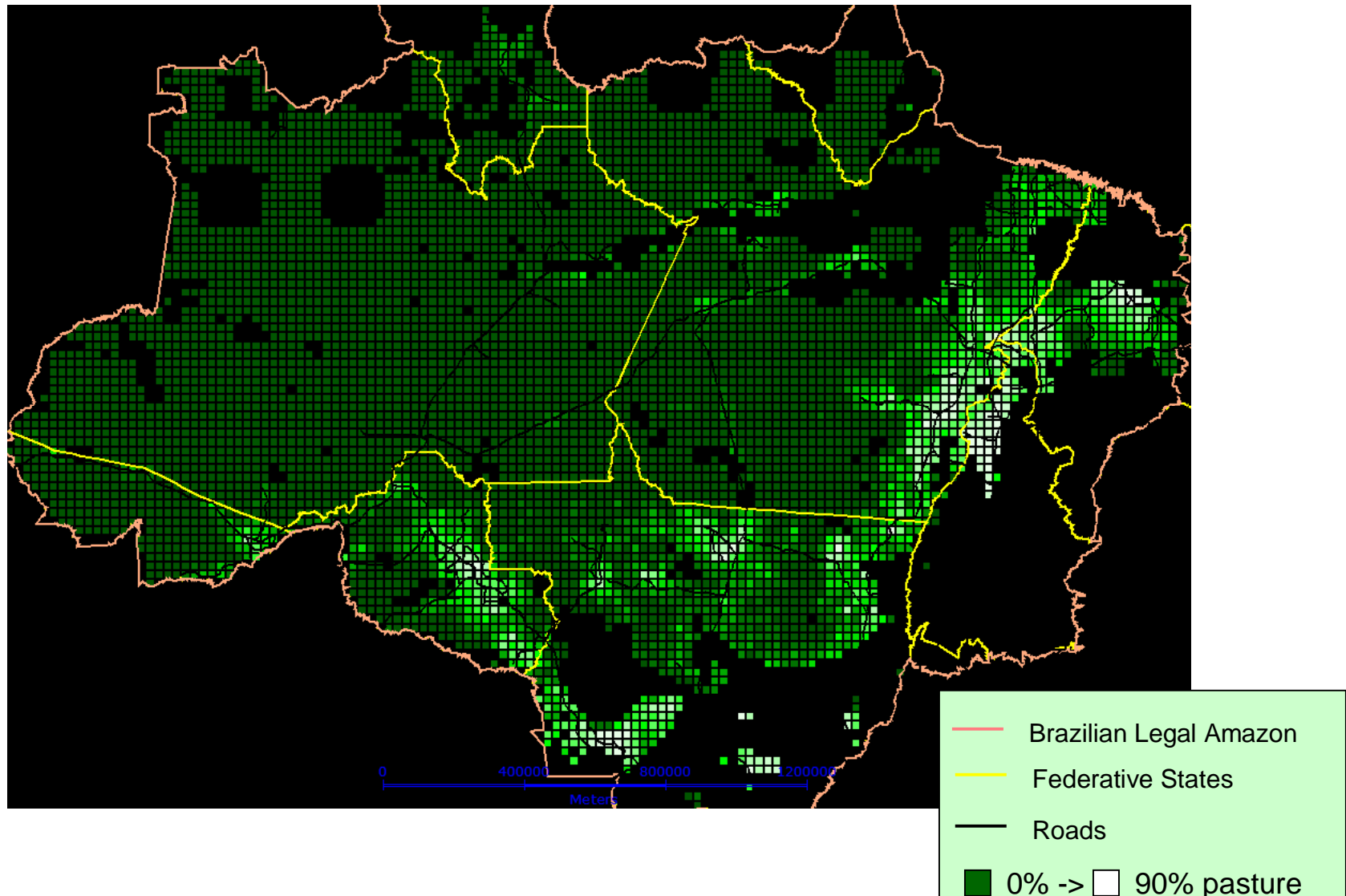Some photos from Diógenes Alves (www.dpi.inpe.br/dalves)

Deforestation pattern in 1997
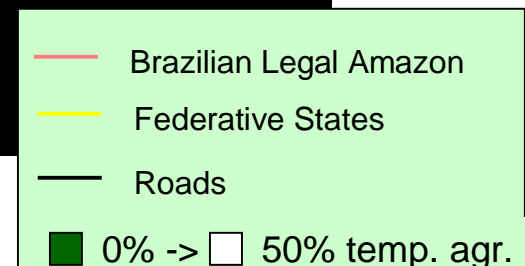**INPE/PRODES 1997 data combined with IBGE/Agricultural census 1996**

Brazilian Legal Amazon
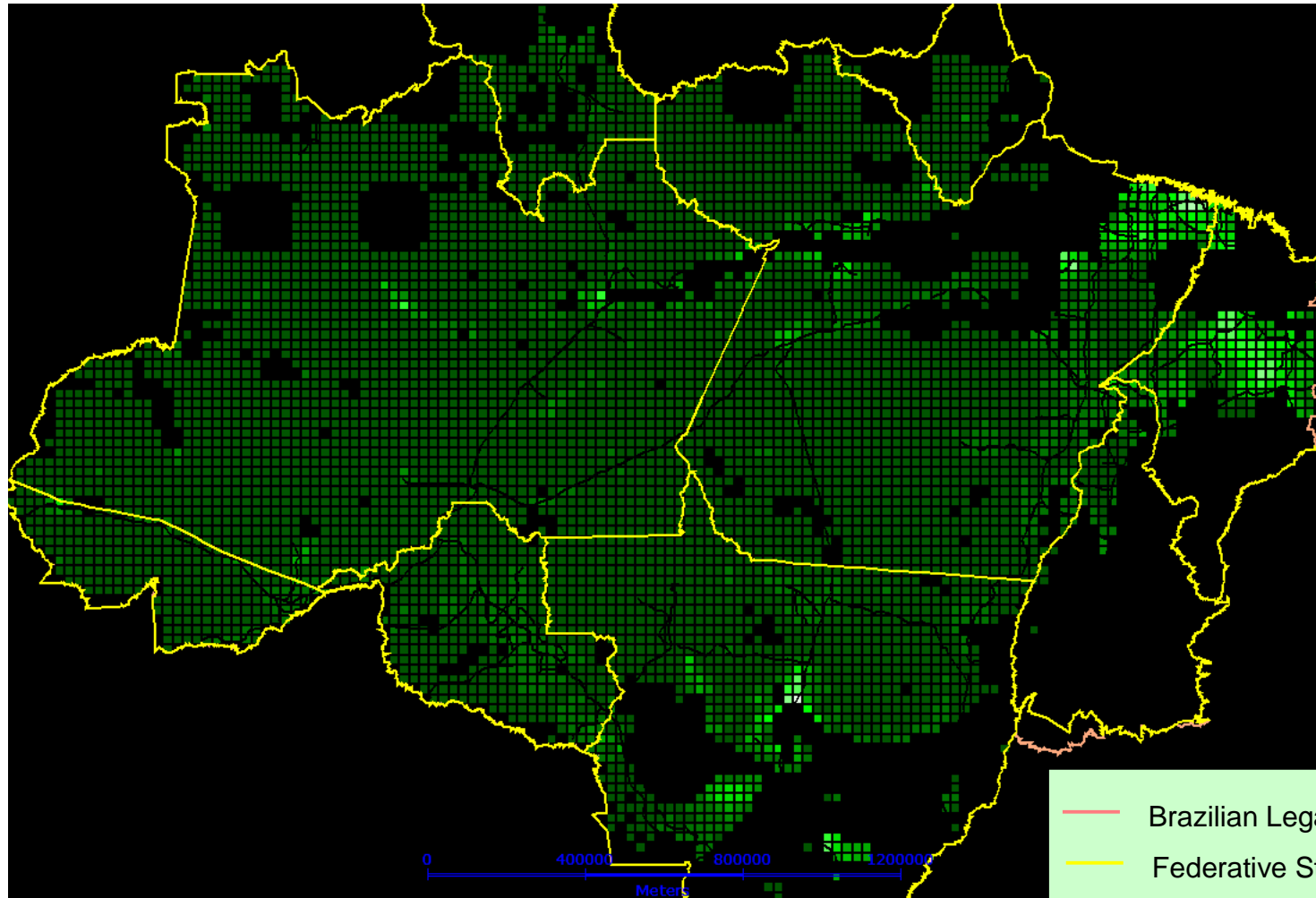
Federative States

Roads

0% -> ☐100%deforested

Pasture pattern in 1997

INPE/PRODES 1997 data combined with IBGE/Agricultural census 1996

Legend:
— Brazilian Legal Amazon
— Federative States
— Roads
0% -> 90% pasture

Temporary Agriculture pattern in 1997
INPE/PRODES 1997 data combined with IBGE/Agricultural census 1996

Brazilian Legal Amazon
Federative States
Roads
0% -> ☐ 50% temp. agr.

Goal of this work

- **n** Assess the use of the CLUE framework as a tool to explore alternative future patterns of deforestation and main land-uses in the Brazilian Amazon.

- **n** Explore model behavior in relation to the use of alternative environmental and socio-economic factors and space partitions.

- **n** Compare CLUE generated patterns to real data and knowledge about new Amazon frontiers in order to refine and select appropriated statistical models to perform policy scenario analysis.

CLUE modeling framework
Brazilian Amazon version

Legal Amazon level

demand module
scenarios of quantity of
changes in
land use types
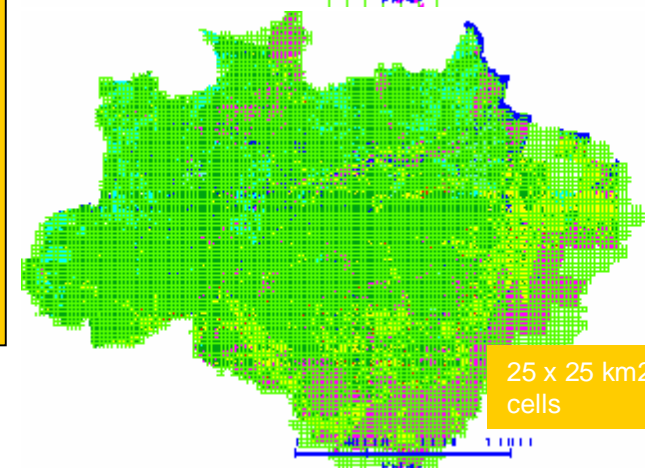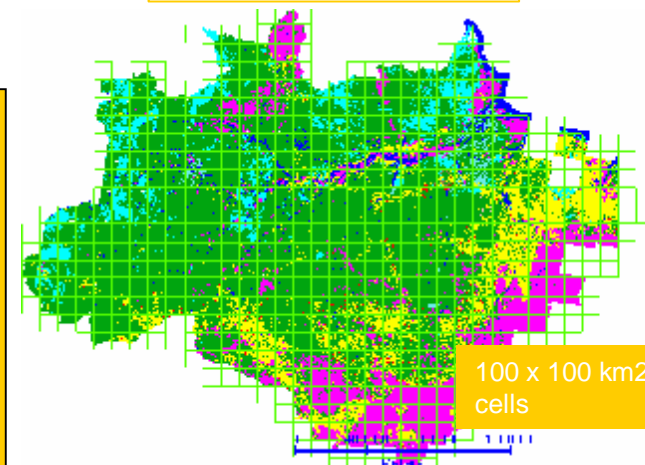
grid-based level

spatial analysis

'coarse scale'
multiple regression
models
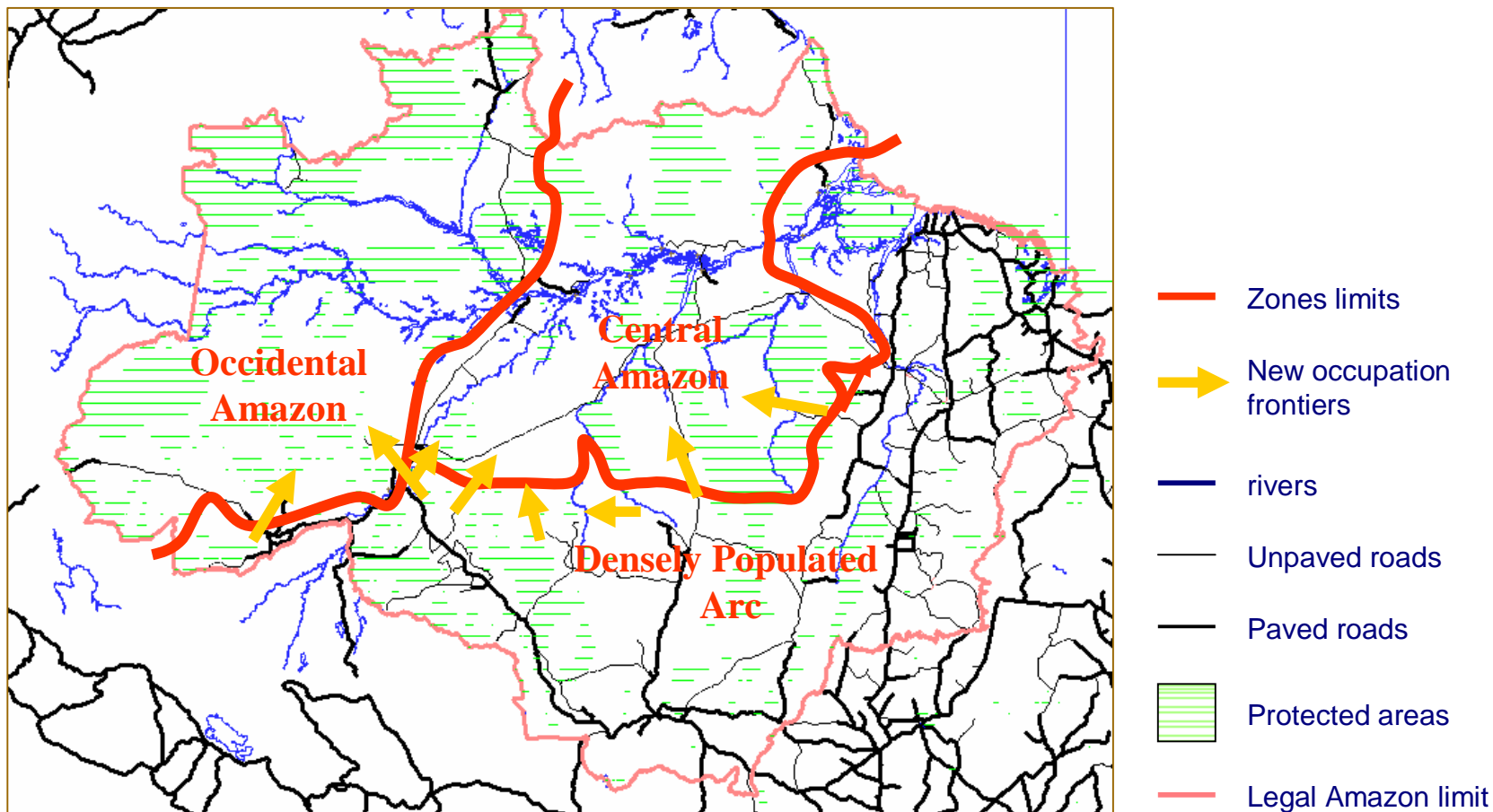
'fine scale'
multiple regression
models

allocation module
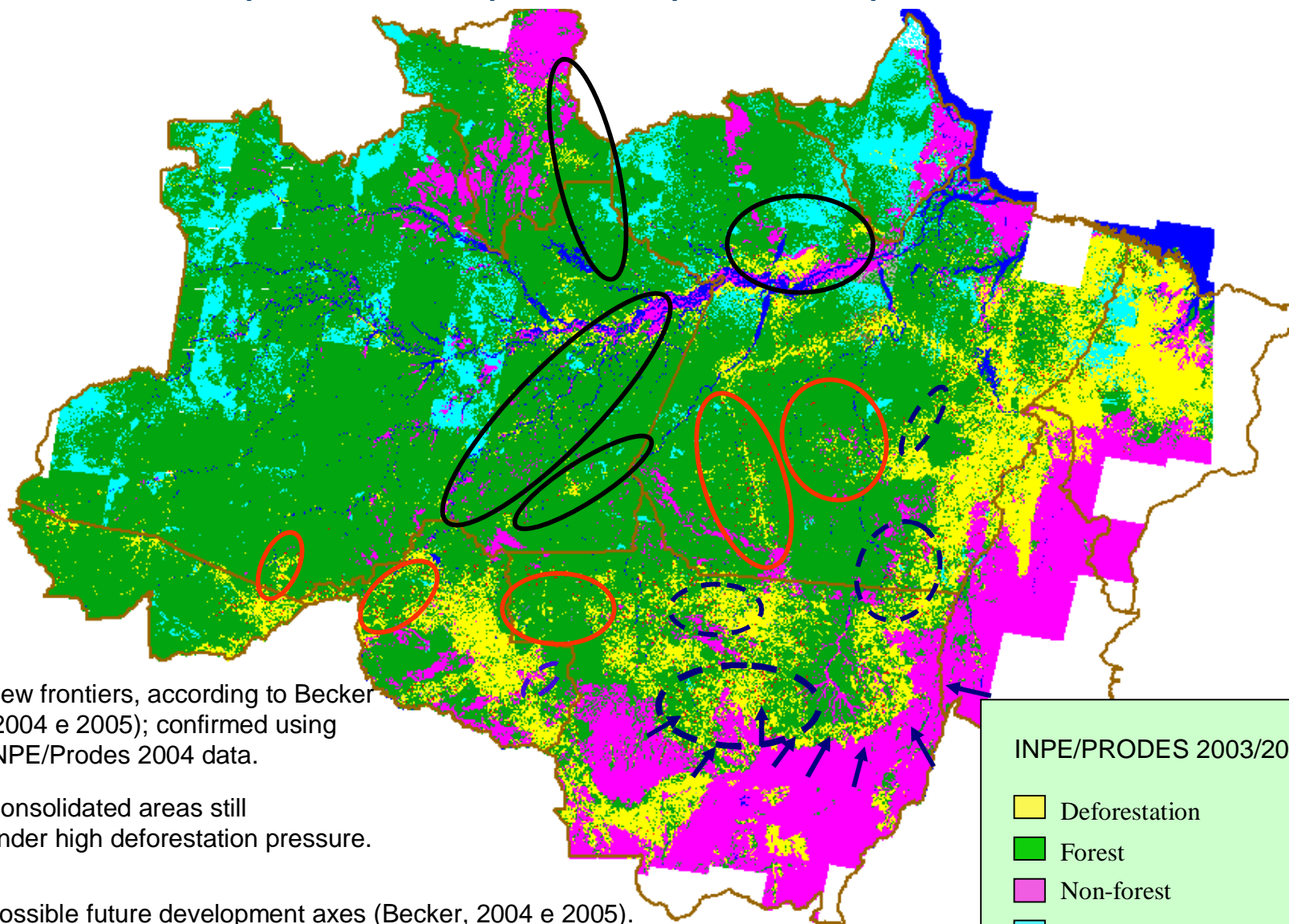
'coarse scale'
allocation

'fine scale'
allocation

100 x 100 km2
cells

25 x 25 km2
cells

Space partitions explored at the fine scale:
Macro zones (Becker 2004, 2005)

Legend:
- — Zones limits
- → New occupation frontiers
- — rivers
- — Unpaved roads
- — Paved roads
- Protected areas
- — Legal Amazon limit

Map labels: Occidental Amazon, Central Amazon, Densely Populated Arc

Dynamic areas (current and future)
Source: Escada (2005a, 2005b); Becker (2004, 2005)

New frontiers, according to Becker (2004 e 2005); confirmed using INPE/Prodes 2004 data.

Consolidated areas still under high deforestation pressure.

Possible future development axes (Becker, 2004 e 2005).

INPE/PRODES 2003/2004:

- Deforestation
- Forest
- Non-forest
- Clouds/no data

Exploring factors and patterns: linking to process knowledge

Compile spatially-explicit database (40 variables)

↓

Exploratory analysis: Selection of subset of variables and definition of non-correlated groups of variables in each space partition

↓

Regression Analysis: construction alternative candidate models for each group/partition/ land-use

→

Alternative CLUE runs 1997 to 2015

→

Comparison to real data and new frontiers process knowledge

Dynamic factors in each cell:
- n   Connection through roads network to national markets (SP and NE)
- n   Connection through roads network to main ports
- n   Euclidean distance to roads (log)

- n   Percentage of protected areas

Static factors in each cell:
- n   Euclidean distance to urban centers (log)
- n   Euclidean distance to wood extraction poles (log)
- n   Euclidean distance to mineral deposits (log)
- n   Euclidean distance to large rivers (log)

- n   Percentage of small properties (in area)
- n   Number of settled families (log)

- n   Percentage of high and medium fertility soils area
- n   Percentage of wetland soils area
- n   Average humidity in the three drier subsequent months of the year

GROUPS….

Summary of CLUE runs

n <u>20 tests</u> (iteratively defined) to explore the effects of:

- Alternative space partitions for demand and regression models;
- Alternative groups of factors in regression models;
- Combination of different groups of factors at different scales;
- Removal of certain factors from the regression models;
- Allocation parameters values.

Sample of results

- **Test 2:** Without demand or regression regionalization;

- **Test 8:** With demand and regression regionalization (one model for fine scale partition – Arco, Central and Occidental);

- **Test 13:** With demand and regression regionalization (Arco regression model used at Central partition).

Test 2: regressions of group "roads+clima"
without demand or regression regionalization

Factors - fine scale regressions:

Connection to national markets

Connection to ports

Distance to roads

Percentage of protected areas

Distance to urban centers

Distance to wood extraction poles

Euclidean distance to mineral deposits

Distance to large rivers
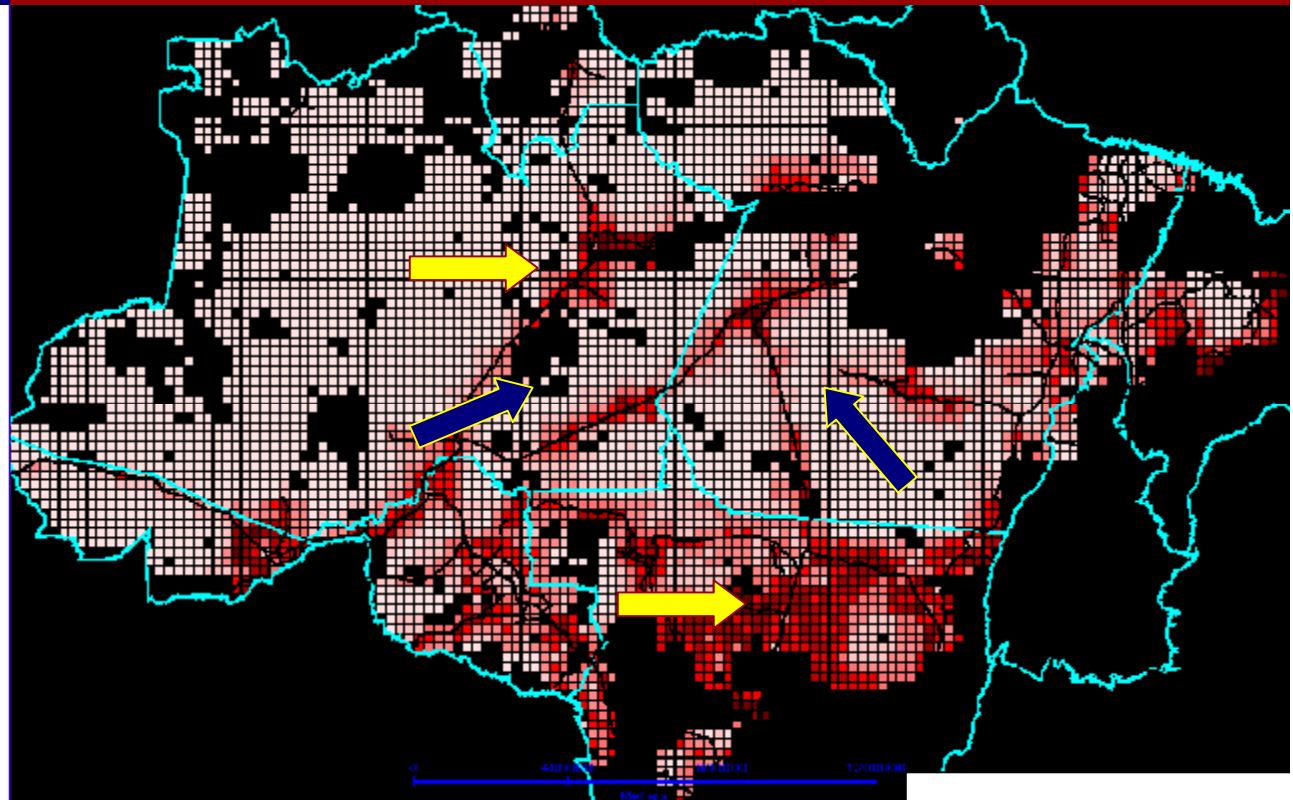
Percentage of area o small properties

Number of settled families
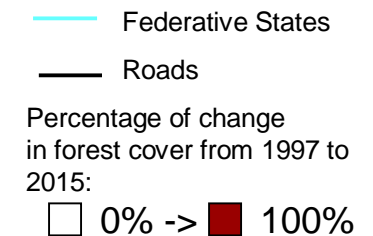
Percentage of high/medium fertility soils

Percentage of wetland soils

Average humidity in the three drier months

Projected hot spots of deforestation from 1997 to 2015:

Changes too concentrated on Arc, and little pressure on Central area

— Federative States

— Roads

Percentage of change in forest cover from 1997 to 2015:

☐ 0% -> ■ 100%

Test 8: Different groups at different scales
with demand and regression regionalization

Factors:

Coarse scale:
• urban+conn

Fine scale:
• Arc – roads+conn
• Central – roads+conn+clima
• Occidental – roads+conn+urban

Projected hot spots of deforestation from 1997 to 2015:

— Federative States

— Roads

Percentage of change
in forest cover from 1997 to
2015:

☐ 0% -> ■ 100%

Regionalizing the demand improves pressure on Central area, but Central area regressions emphasizes proximity to ports and rivers, due to historical process in the area, and not connectivity to the rest of the country.

Test 13: Arc model applied to Central area
with demand regionalization, and different groups at different scales
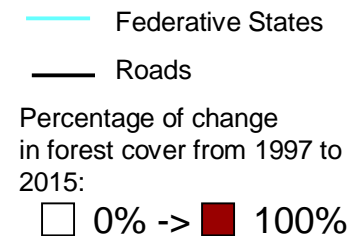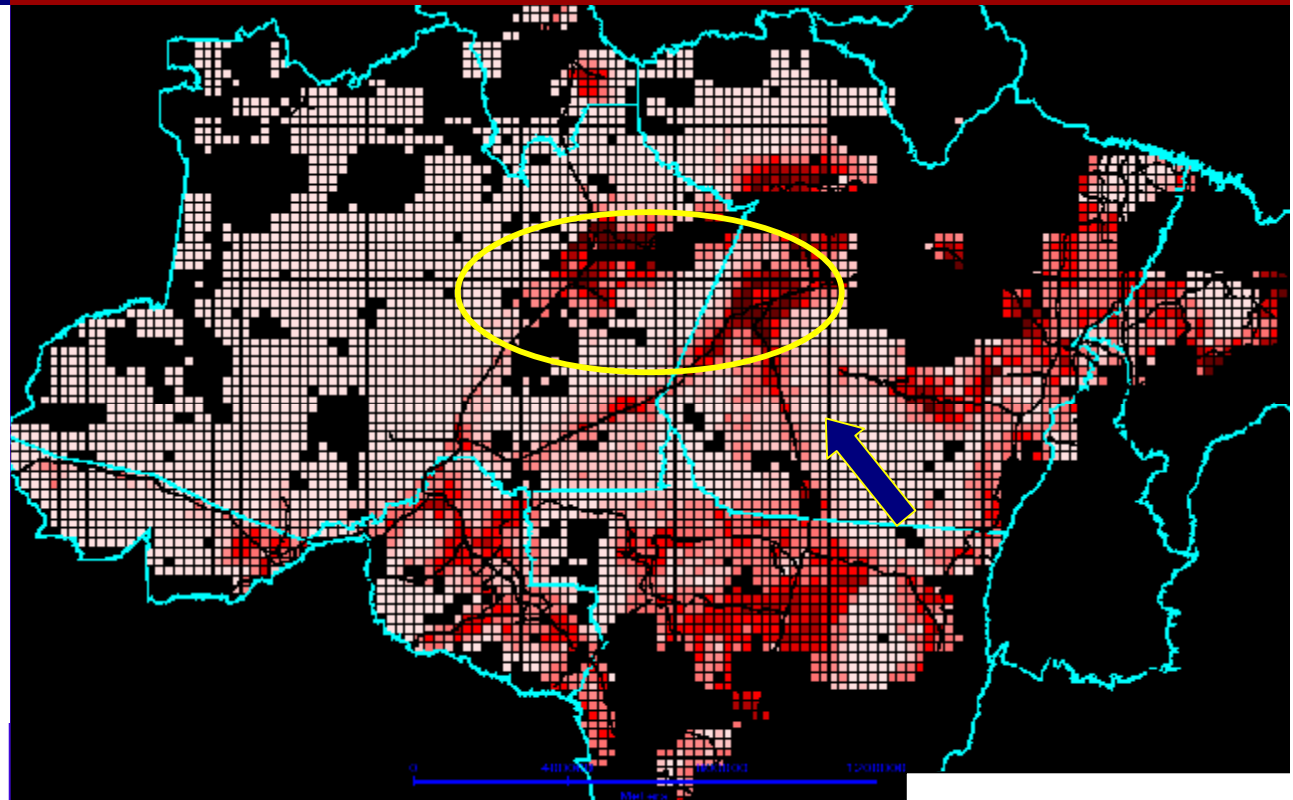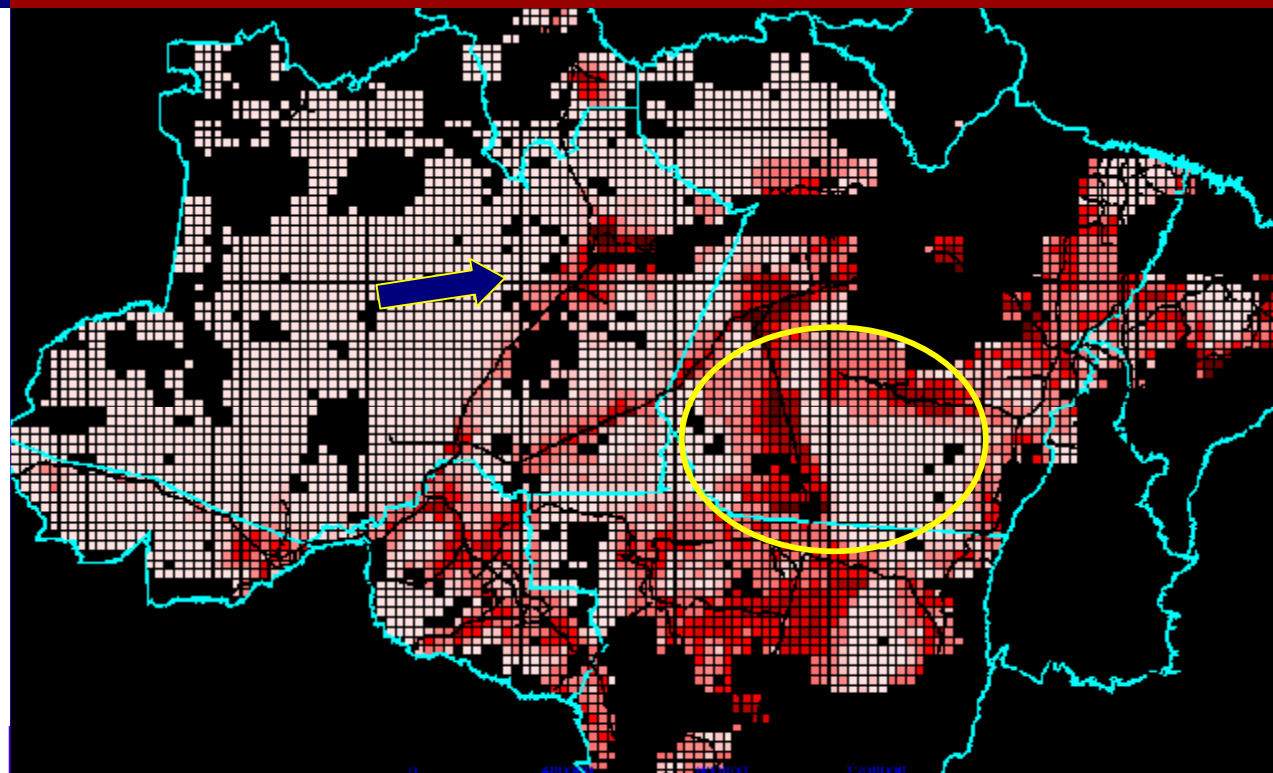
Factors:

Coarse scale:
• urban+conn

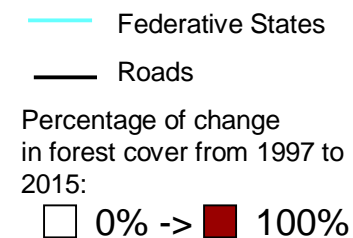**Fine scale:**
• Arc – roads+conn
• Central (Arc model)
• Occidental – roads+conn+urban

Projected hot spots of deforestation from 1997 to 2015:

Federative States

Roads

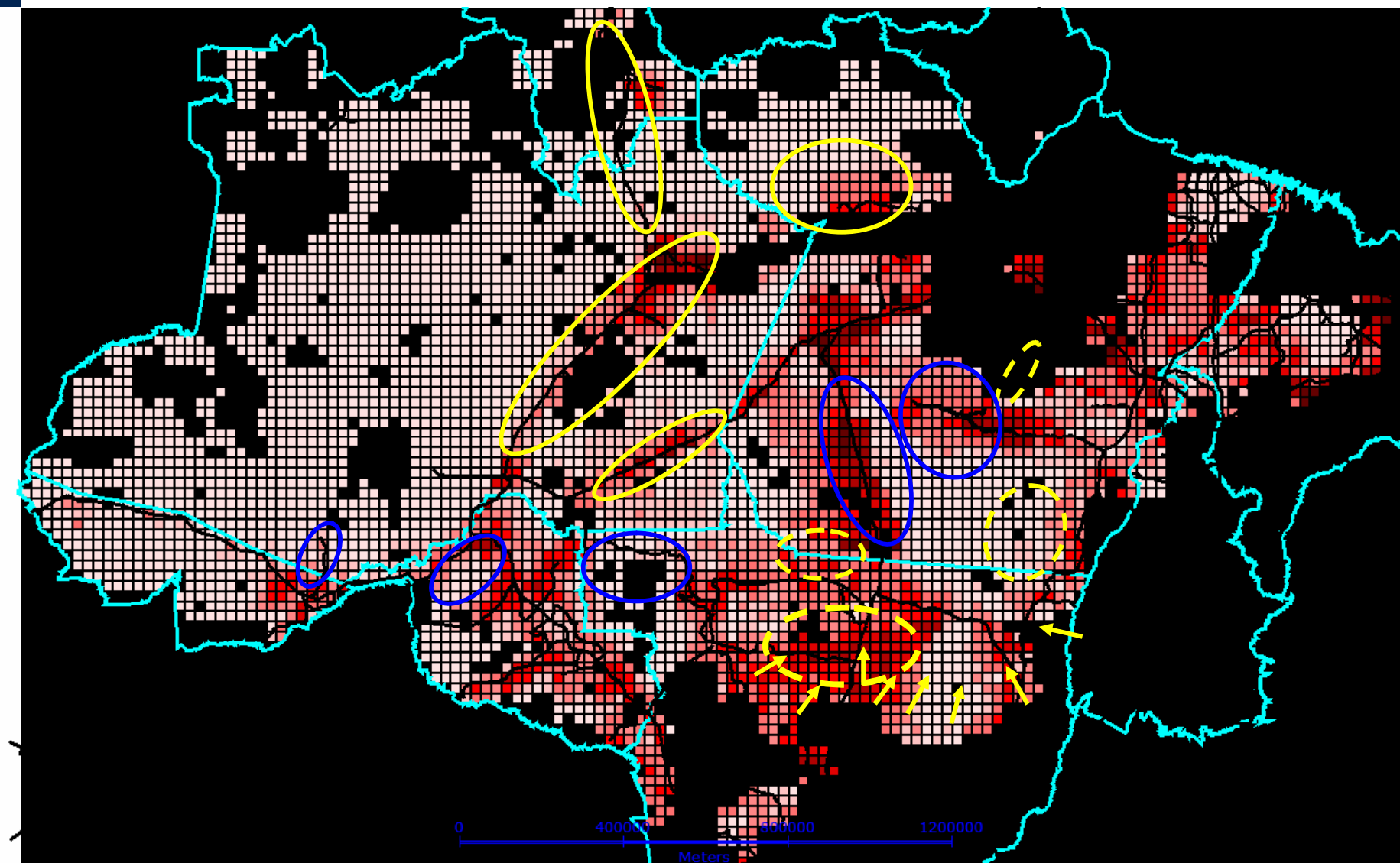Percentage of change in forest cover from 1997 to 2015:

0% -> 100%

Using Arc model increases importance of connection to markets and roads, and lowers the emphasis on ports and rivers. It also increases protected areas restriction.

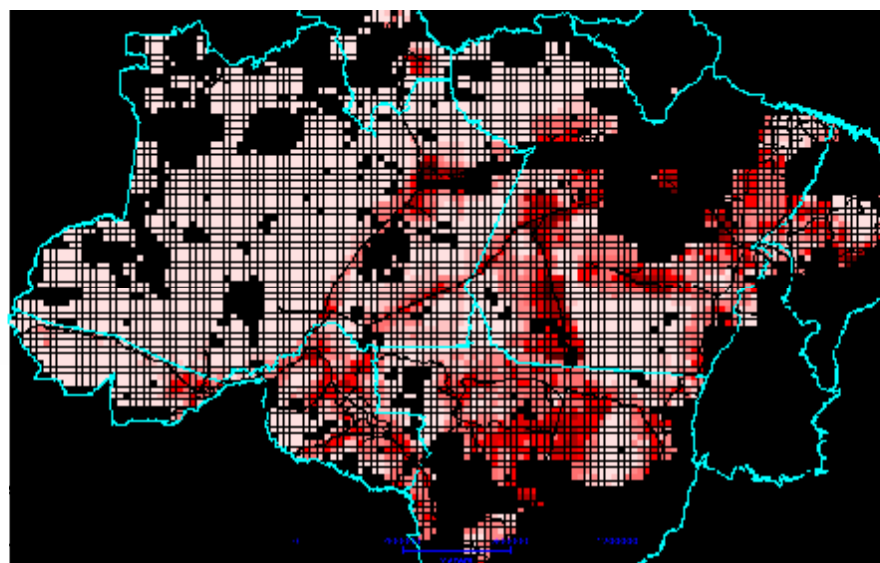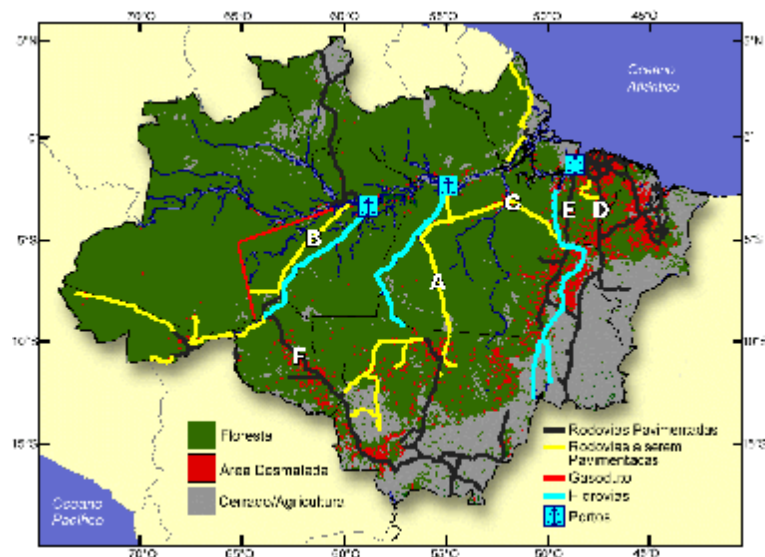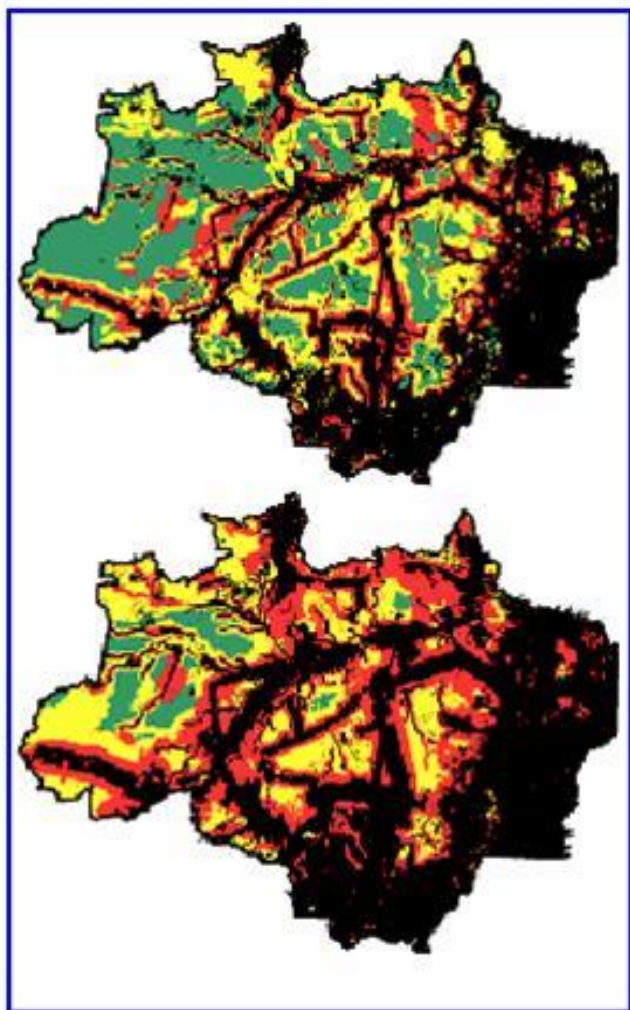# Results and dynamic areas (test 13)

Conclusions

n   Results presented are for "Base scenario" (current deforestation rates until 2015; no new roads, or paving or protected areas created after 2000). Next step is scenario analysis for alternative public policies.

n   Combination of statistical analysis and CLUE framework proved a valuable tool in generating patterns that match current deforestation process and expert understanding of what may happen in the region.

n   Complexity and heterogeneity of the Amazon calls for non-single factor and adoption of spatial partitions that account for intra-regional differences.

n   Intra-regional differences depend on variables such as connection to markets and ports, climatic conditions and agrarian structure. Distance to roads and to urban areas are the most important variables over the whole region, but capturing heterogeneity depends on combining them to the other variables.

Future work: GEOMA scenario analysis taking into account region heterogeneity, multiple factors and different land-uses

Fonte: Laurence et al., 2001

Links and references

GEOMA – Network for Environmental Modeling Research in the Amazon
http://www.geoma.lncc.br

Brazilian Science and Technology Ministry institutions:

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

INPE – Instituto Nacional de Pesquisas Espaciais: http://www.inpe.br
DPI – Divisão de Processamento de Imagens: http://www.dpi.inpe.br

Links and references (cont.)

- n IBGE (Instituto Brasileiro de Geografia e Estatística): http://www.ibge.gov.br
- n CLUE framework: http://www.dow.wau.nl/clue/

References:
- n Becker, B. Amazônia: Geopolitica na virada do III Milenio. Ed. Garamond. São Paulo. 2004.168 p. (in Portuguese)
- n Becker, B. Geopolítica da Amazônia. Revista Estudos Avançados. USP, São Paulo. vol.19 (53). 2005. p 71-86. (in Portuguese)
- n Escada,M.I.S. et al. Processo de Ocupação nas novas fronteiras da Amazônia: O interflúvio di Xingu/Iriri. Revista Estudos Avançados. USP, São Paulo. vol.19 (54). 2005. p 09-23. (in Portuguese)
- n Escada, M.I.S.; Aguiar. A.P.D.; Monteiro, A. M. V. O Avanço do Desmatamento na Amazônia no Contexto das Novas Fronteiras. Acessado em 25/09/2005. On line: http://www.obt.inpe.br/prodes/seminario2005/ (in Portuguese)
- n Laurance, W.F., Cochrane, M.A., Bergen, S., Fearbside, P.M., Delamônica, P., Barber, C., Dangelo, S., Fernandes, T. The future of Brazilian Amazon. Science, vol. 291, January 2001.

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