

LUCC Patterns and Process in Amazonia



Maria Isabel Sobral Escada

isabel@dpi.inpe.br



The INPE team

Antonio Miguel Monteiro

Erika Sato

Gilberto Camara

Joyce da Mota

Leila Fonseca

Marcelino Silva (UFRN)

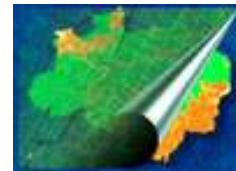
Marcio Azeredo

Silvana Amaral

Thales Korting

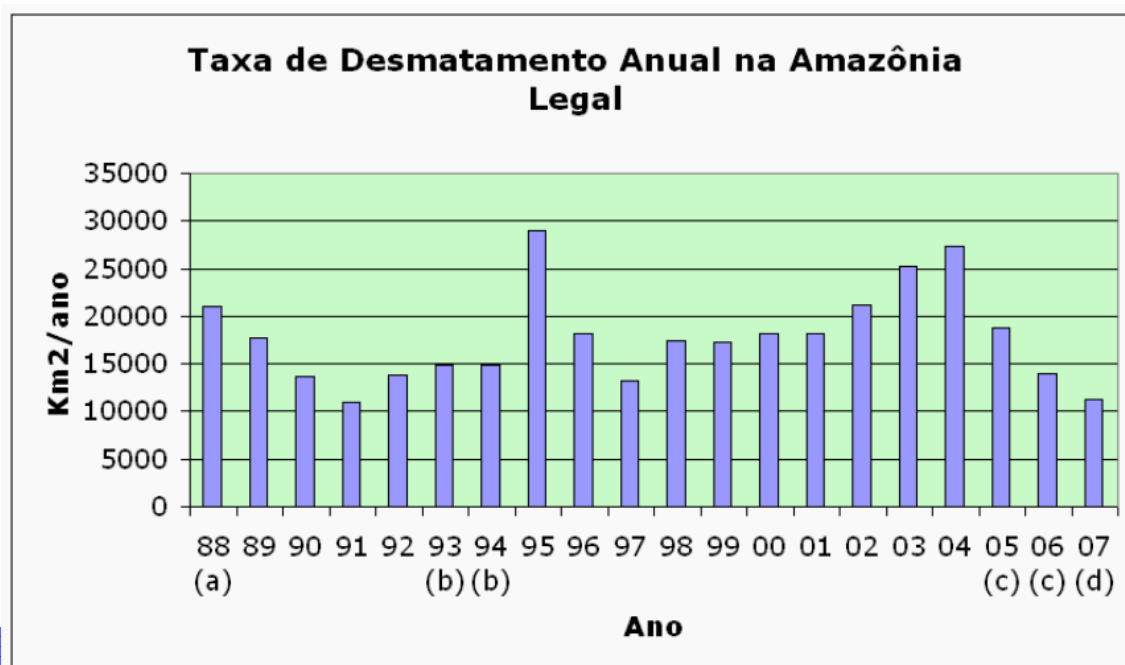
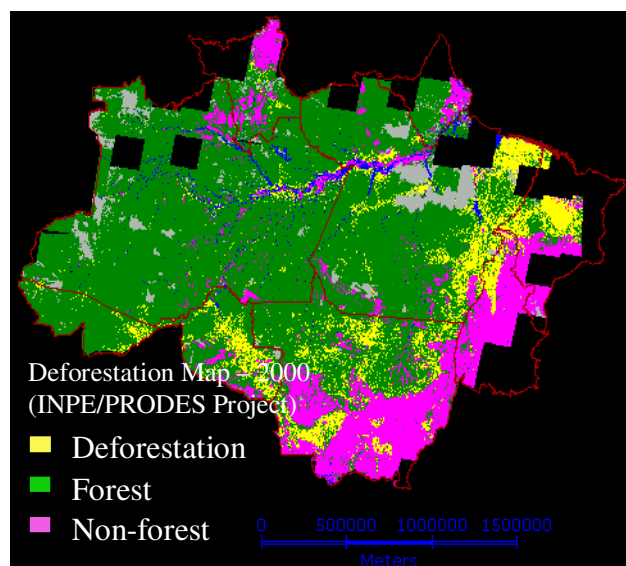
About this lecture

- **To explore deforestation data to identify LUCC patterns in Amazonia.**
- **To discuss LUCC patterns and processes in Amazonia pointing out economic, political and social drivers.**
 1. Regional level
 2. Local level: Sao Felix do Xingu (PA) Case study

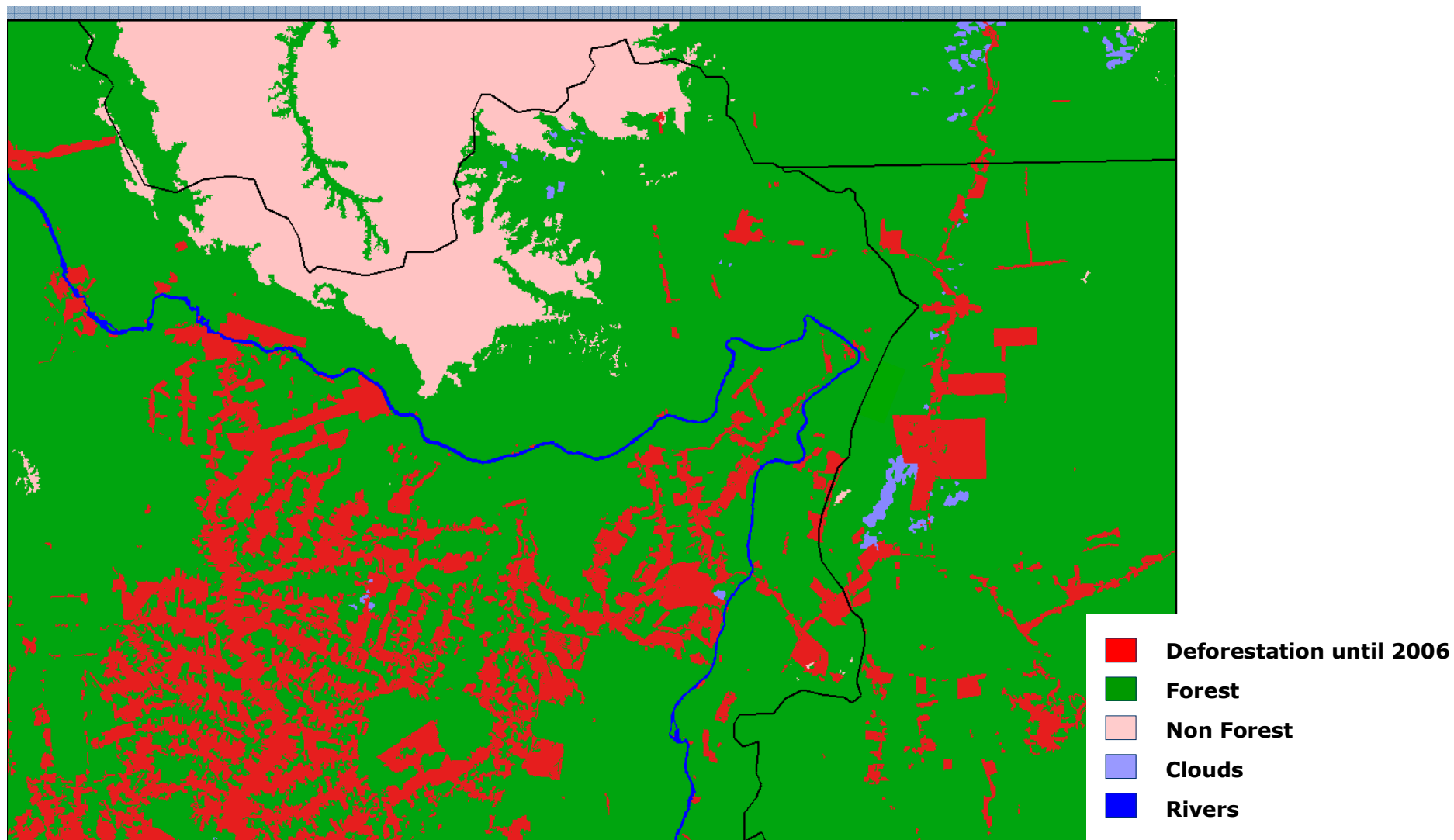


Satellite data to detect land cover dynamics

- Monitoring Amazon Forest data - PRODES started in 1988. Using TM/Landsat and Cbers. Products:
 - Annual deforestation rate estimative per Landsat scene or State;
 - Digital geographic database 1997 – 2008.

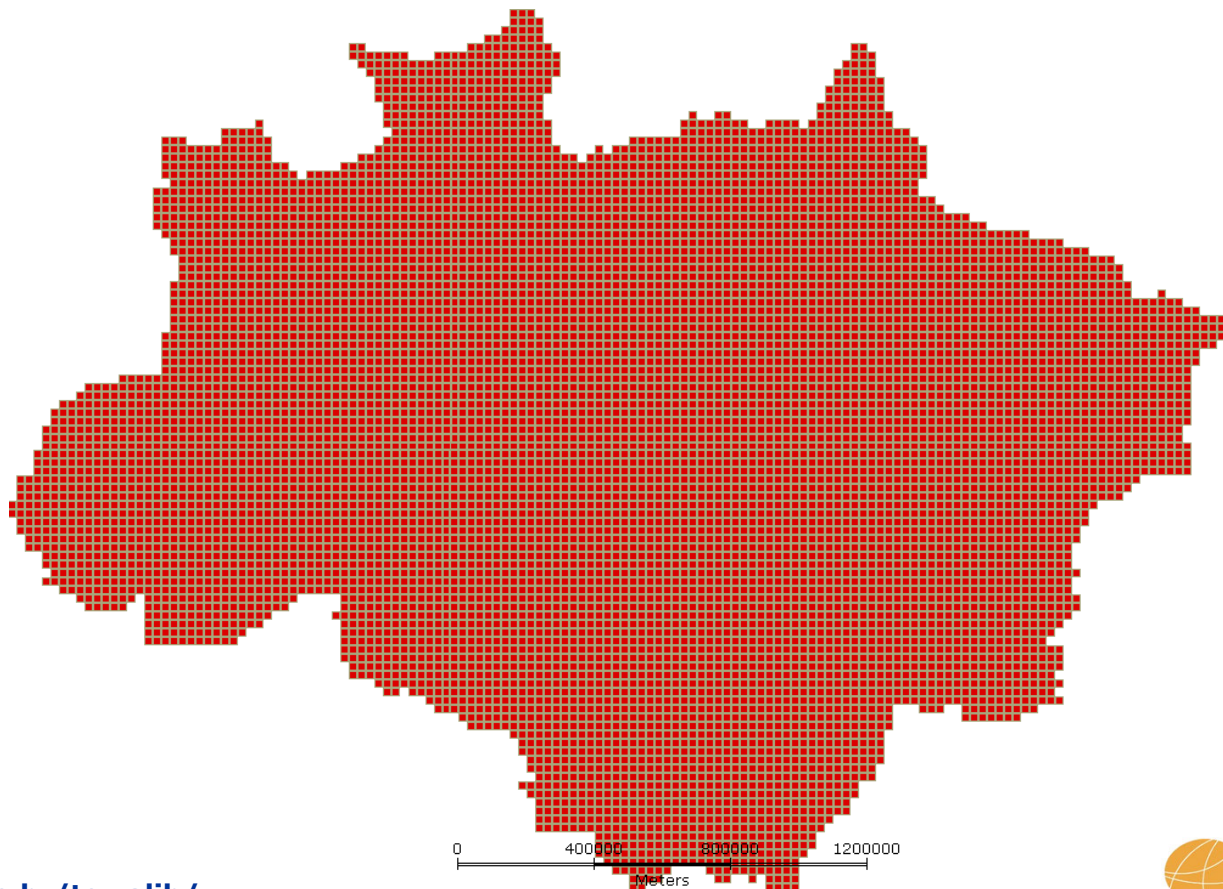


Deforestation until 1997, 2000, 2003, 2006



Cell Data Base Construction

Deforestation map with resolution 25 X 25 km.



<http://www.dpi.inpe.br/terralib/>

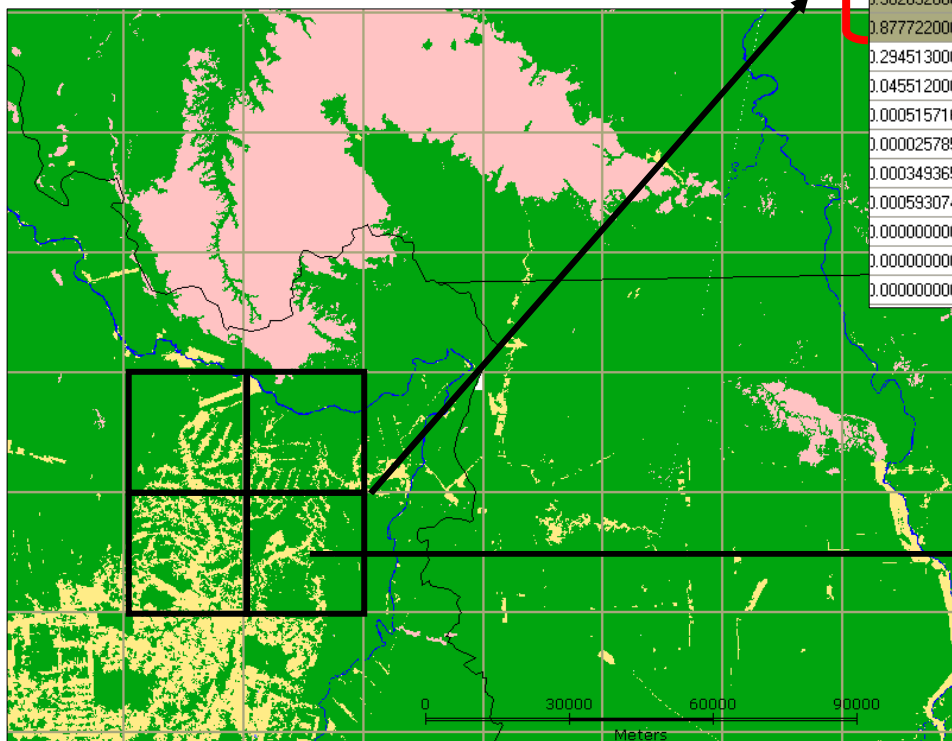


Filling Cells in TerraView

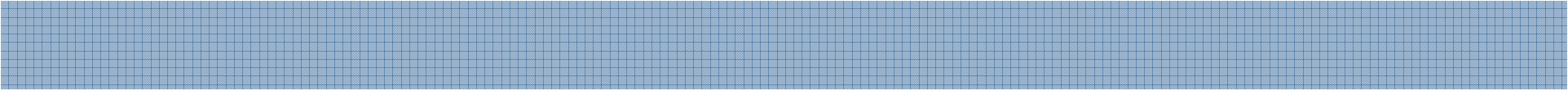
■ Operator

- Percent of each class

acum2003_0	acum2003_3	acum2003_6	acum2003_4	acum2003_8	acum2003_5	acum2003_7
0.000425466000000	0.855715000000000	0.019313600000000	0.004589880000000	0.119956000000000	0.000000000000000	0.000000000000000
0.000038678700000	0.975387000000000	0.000000000000000	0.003313480000000	0.021260400000000	0.000000000000000	0.000000000000000
0.000747789000000	0.975774000000000	0.000000000000000	0.003339260000000	0.020138700000000	0.000000000000000	0.000000000000000
0.000142334000000	0.997179000000000	0.000000000000000	0.000000000000000	0.002678470000000	0.000000000000000	0.000000000000000
0.000077357500000	0.981383000000000	0.000000000000000	0.000090250400000	0.018449800000000	0.000000000000000	0.000000000000000
0.000000000000000	0.999446000000000	0.000000000000000	0.000000000000000	0.000554395000000	0.000000000000000	0.000000000000000
0.402375000000000	0.597548000000000	0.000000000000000	0.000000000000000	0.000077357500000	0.000000000000000	0.000000000000000
0.994514000000000	0.005486330000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
0.902852000000000	0.097148100000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
0.877722000000000	0.115912000000000	0.000000000000000	0.000116455000000	0.001449220000000	0.004800540000000	0.000000000000000
0.294513000000000	0.695727000000000	0.000000000000000	0.000000000000000	0.002797760000000	0.006962170000000	0.000000000000000
0.045512000000000	0.946365000000000	0.004499630000000	0.000000000000000	0.000000000000000	0.003622910000000	0.000000000000000
0.000515716000000	0.977296000000000	0.002501220000000	0.000012892900000	0.018913900000000	0.000760682000000	0.000000000000000
0.000025785800000	0.999923000000000	0.000000000000000	0.000000000000000	0.000051571600000	0.000000000000000	0.000000000000000
0.000349365000000	0.999651000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
0.000593074000000	0.999407000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
0.000000000000000	0.998981000000000	0.000000000000000	0.000000000000000	0.001018540000000	0.000000000000000	0.000000000000000
0.000000000000000	0.990140000000000	0.009859870000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000



625 km²

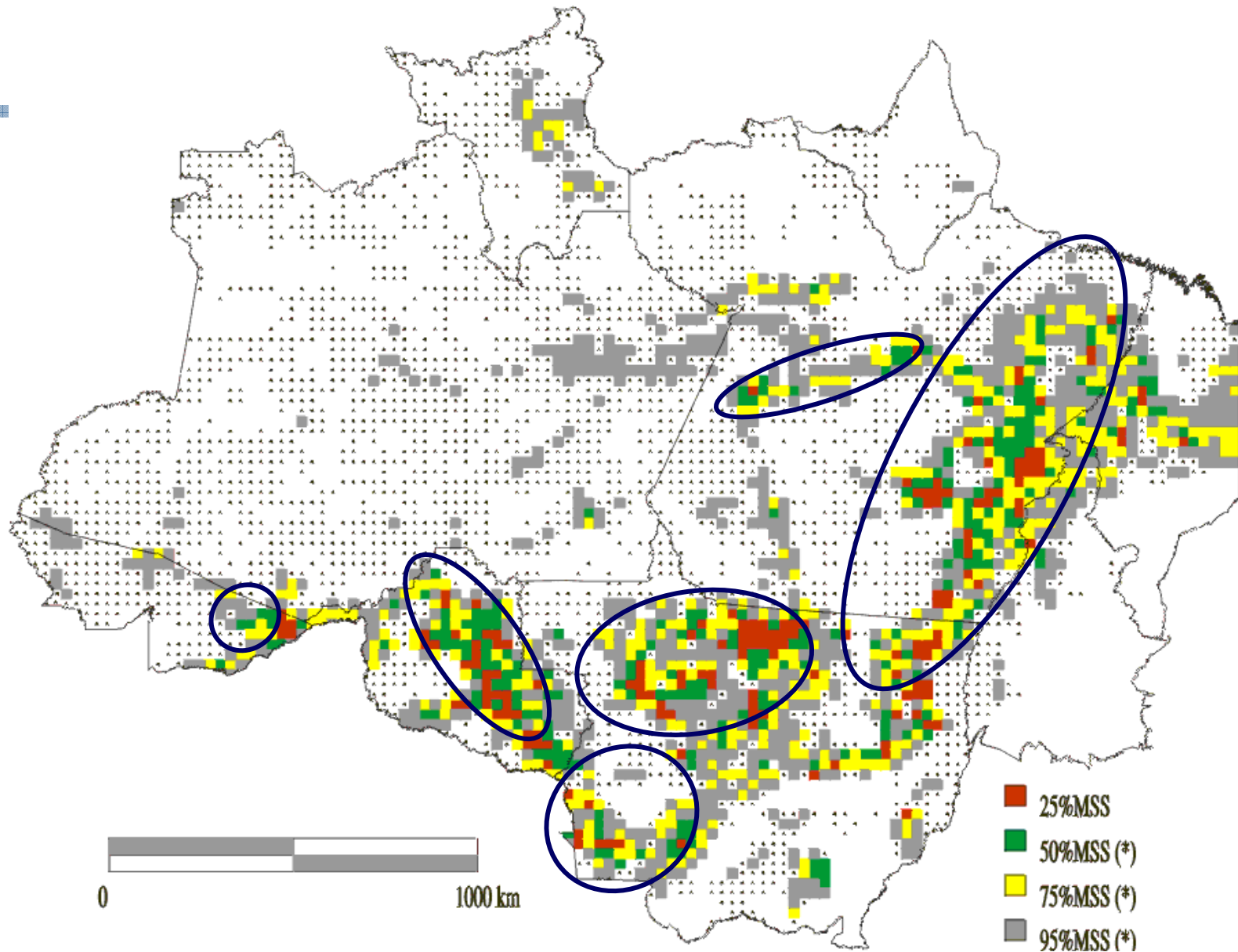


1. Amazonian Occupation Frontier Expansion

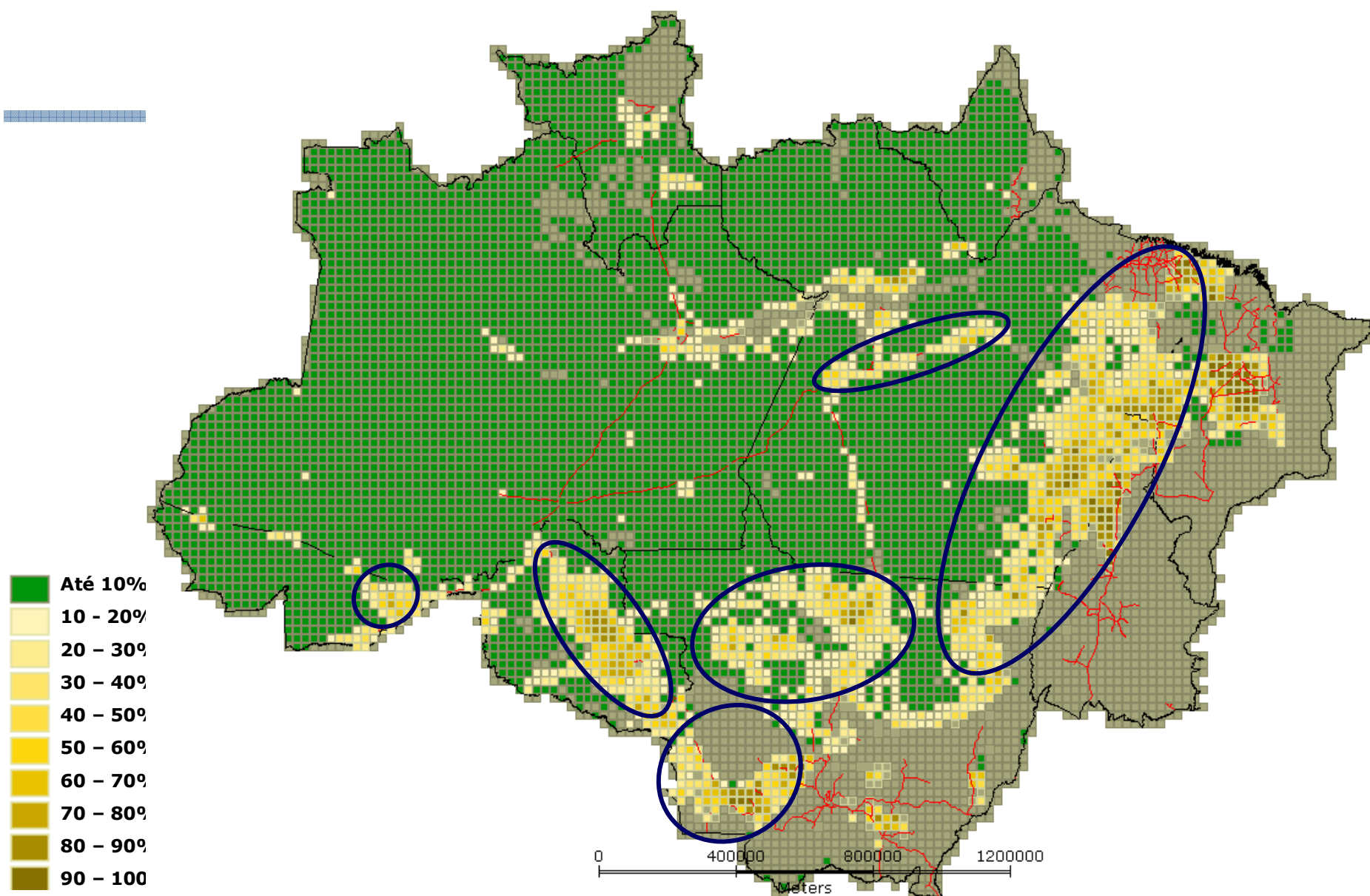
From the 50's to the 80's: Amazonian occupation strategy

- **Geopolitical strategies to occupy Amazonian territory based on:**
 - Implantation of infrastructure networks to integrate the territory: telecommunication, hydroelectric, urban and roads network (*Cuiabá-Santarém (Br-163), Transamazônica (Br 230), Belém-Brasília, Cuiabá-Pvelho (Br-364)*);
 - Implantation of public (INCRA) and private colonization projects;
 - Inducing migration from other regions;
 - Providing fiscal incentives (BASA and SUDAM);
 - Establishment of axes and poles of development.

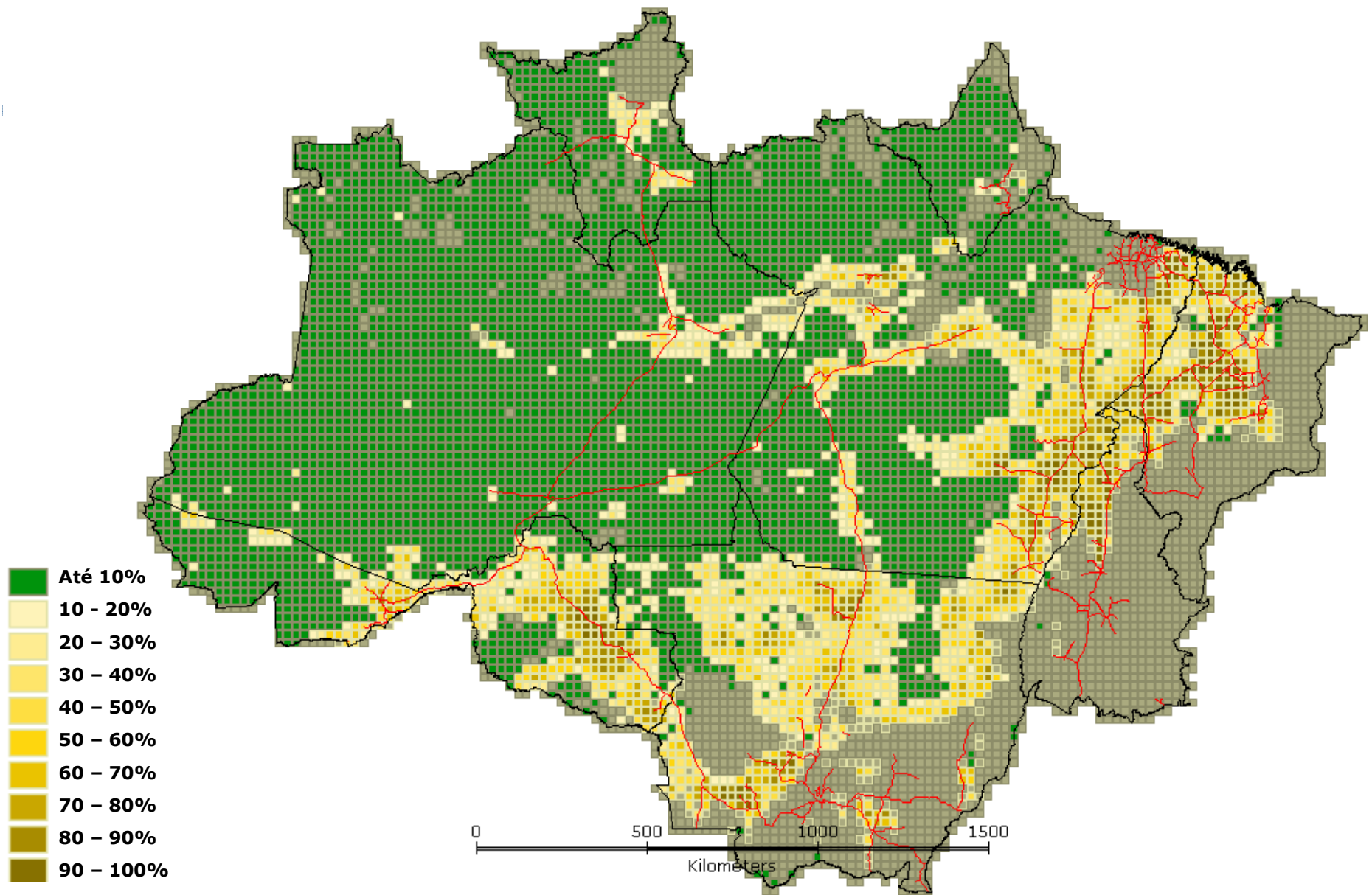
Alves. D. S., 2000
Legal Amazônia 1991-1996 Deforestation



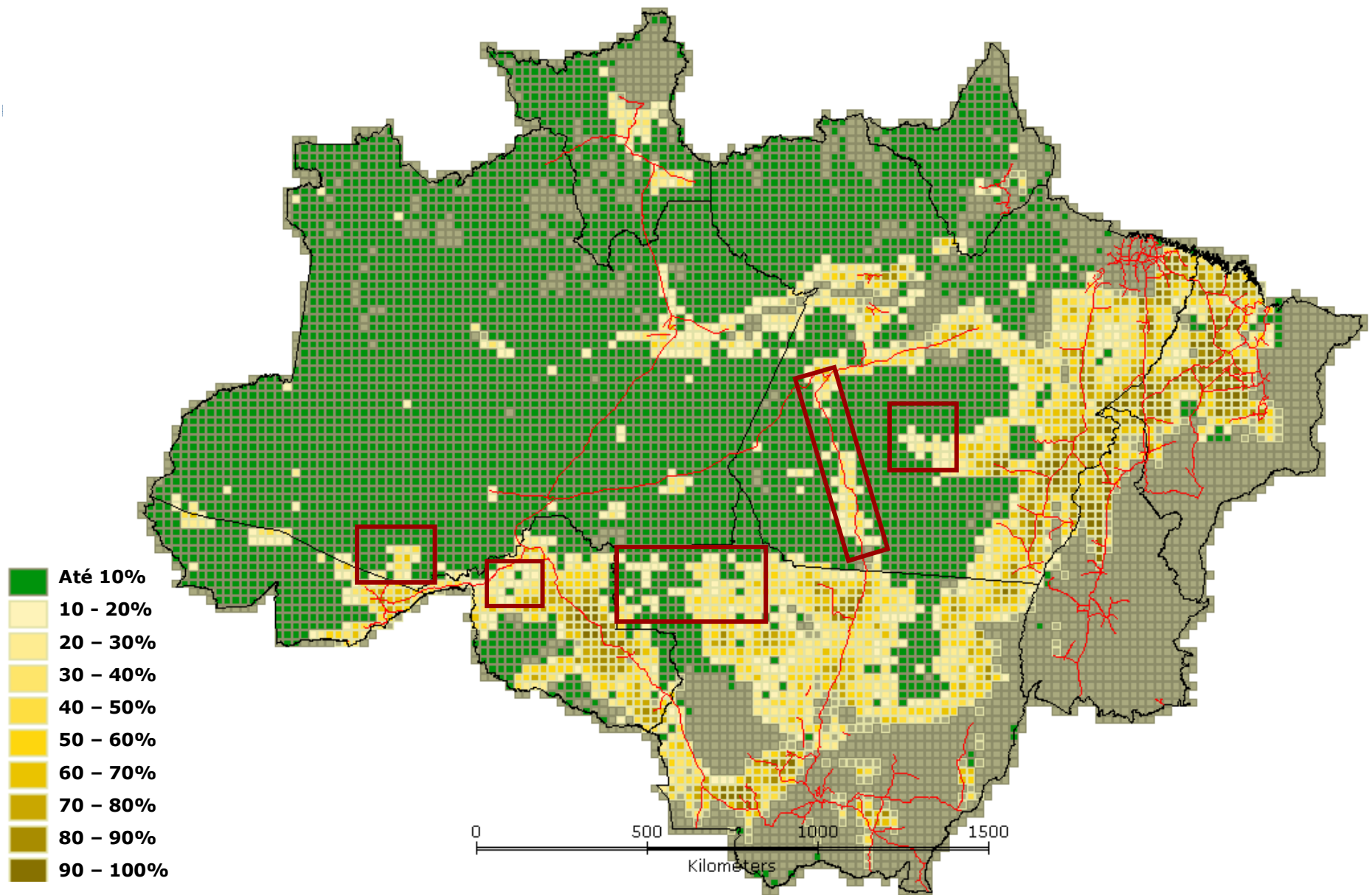
Deforestation 1997



Deforestation 2006 - New deforestation fronts



Deforestation 2006 - New deforestation fronts



Amazonian new frontier

(Becker, 2004;2005)

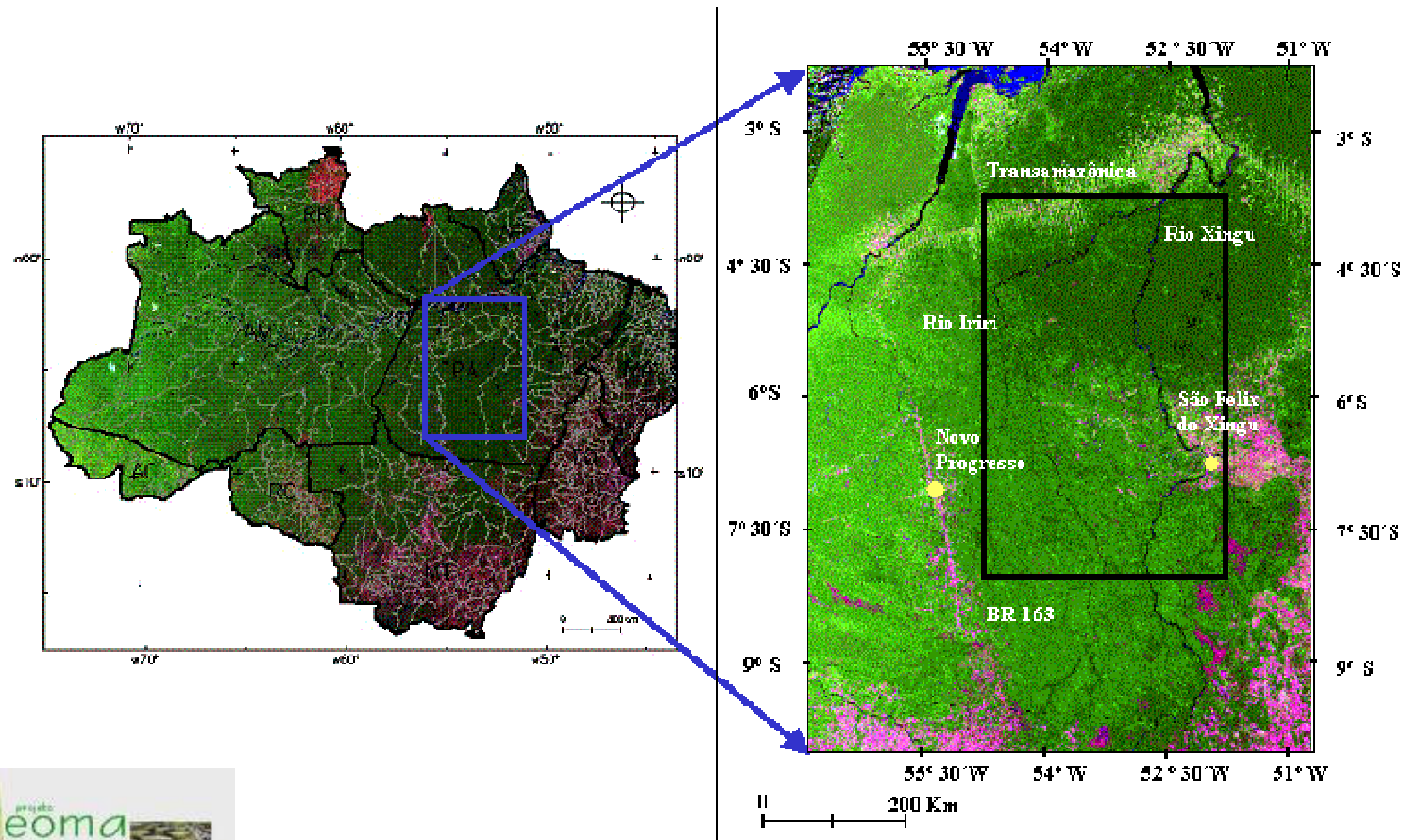
■ "The actual frontiers are different from the 60's and the 70's"

- Today it's induced mostly by private economic interests and it's concentrated on focus areas in different regions.
- Different patterns of migration (intra-regional and rural-urban);
- Activated by new actors with their own capital and land use strategies
- Motivation
 - Agroindustry : Soybean, Logging, Cattle Ranching;
 - Land market;
 - Expectation of new transportation network establishment



**Santarém, PA – Cargill grain port
2005. Foto: Carlos Stefen**

2. Case study: Land use and Land Cover Dynamic in São Félix do Xingu-Iriri (PA)

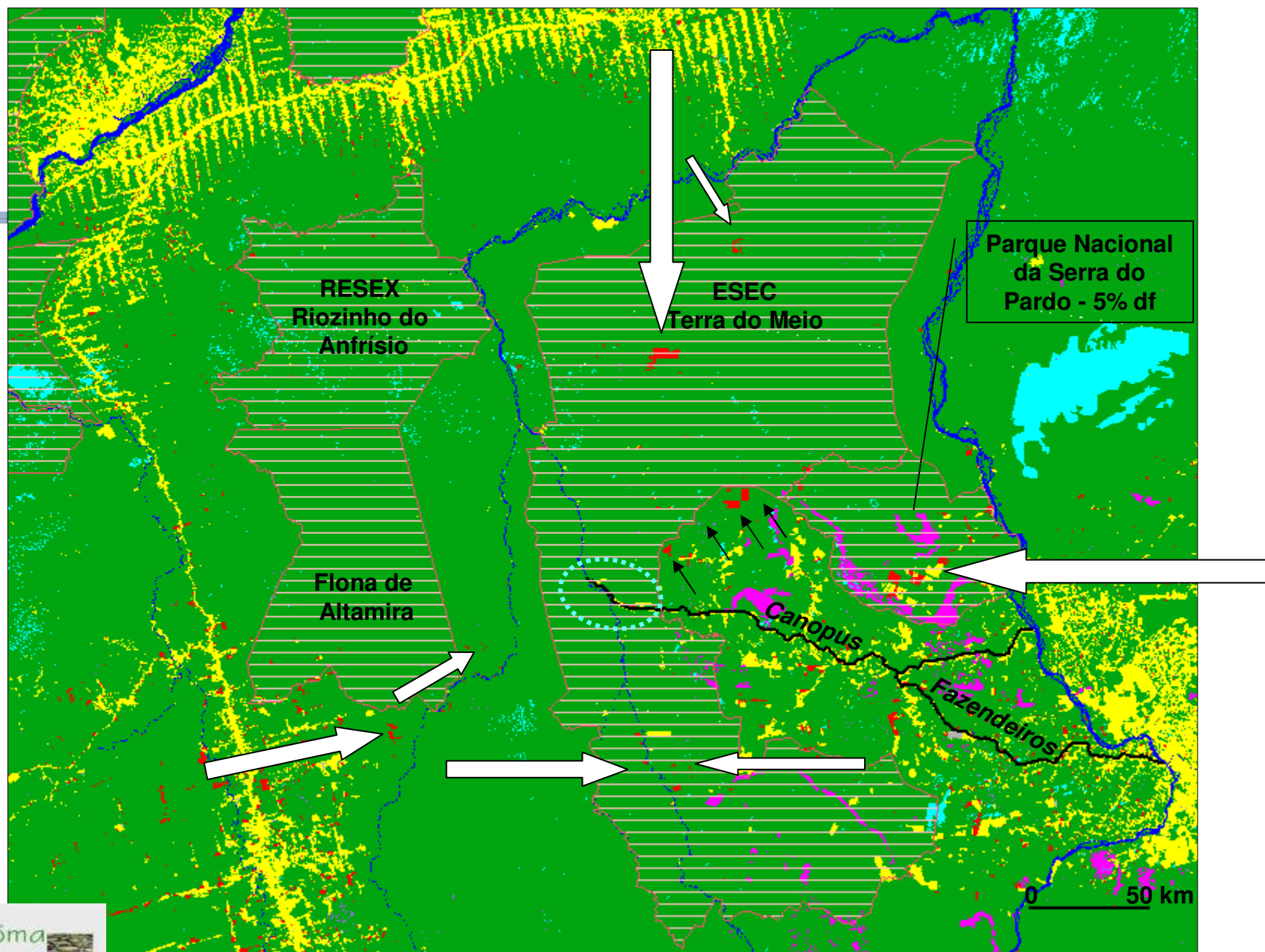


Main Goals

- **To produce diagnosis of land cover change and the drivers behind changes:**
 - **Analyzing actors, socio-economics strategies, land appropriation system and the Institutional role;**
 - **Characterizing population and human settlement patterns;**
 - **Analyzing social, transport and telecommunication network**
- **To build and explore computational model of land use change for São Félix/Iriri region to construct scenarios for public policies and territorial planning.**

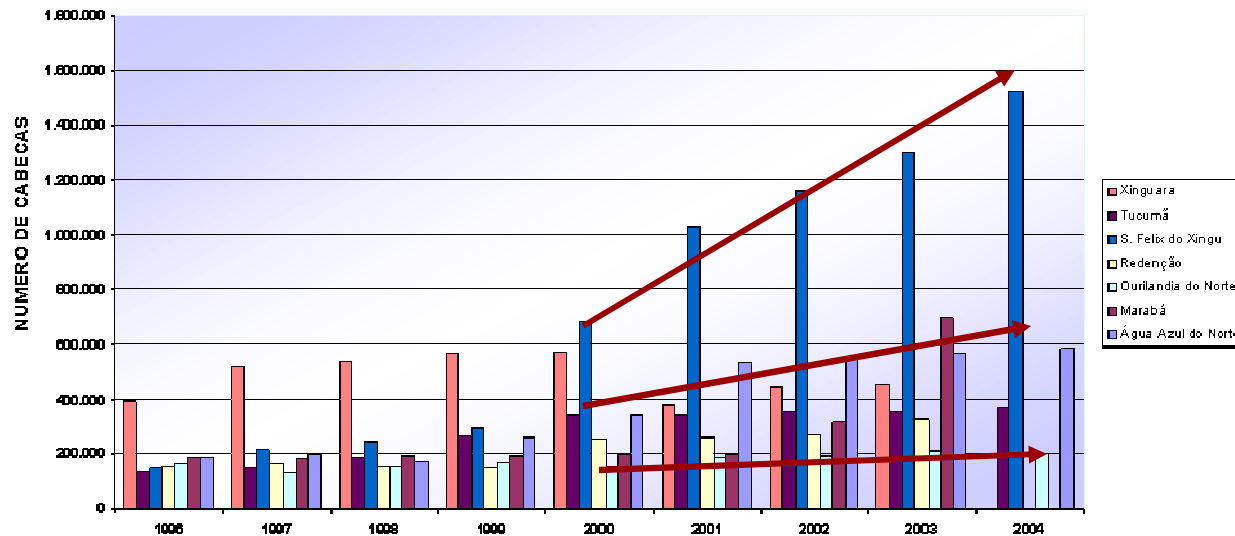


“Terra do Meio” - Connectivity



Cattle ranching and deforestation

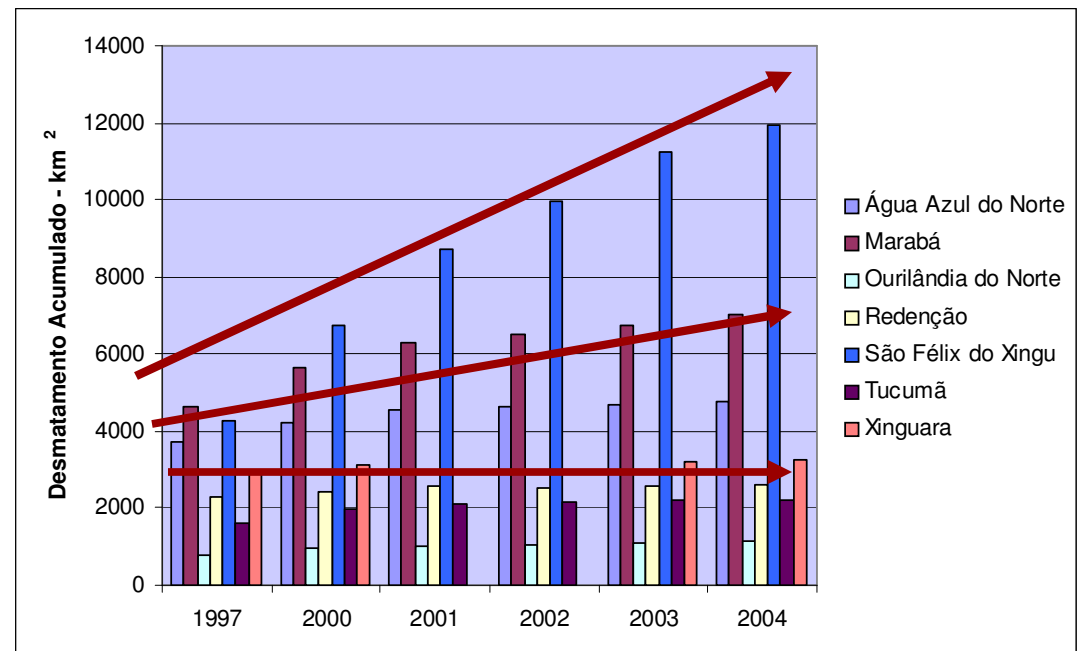
Amount of cattle head



Source: DePará, 2005



Accumulated Deforestation

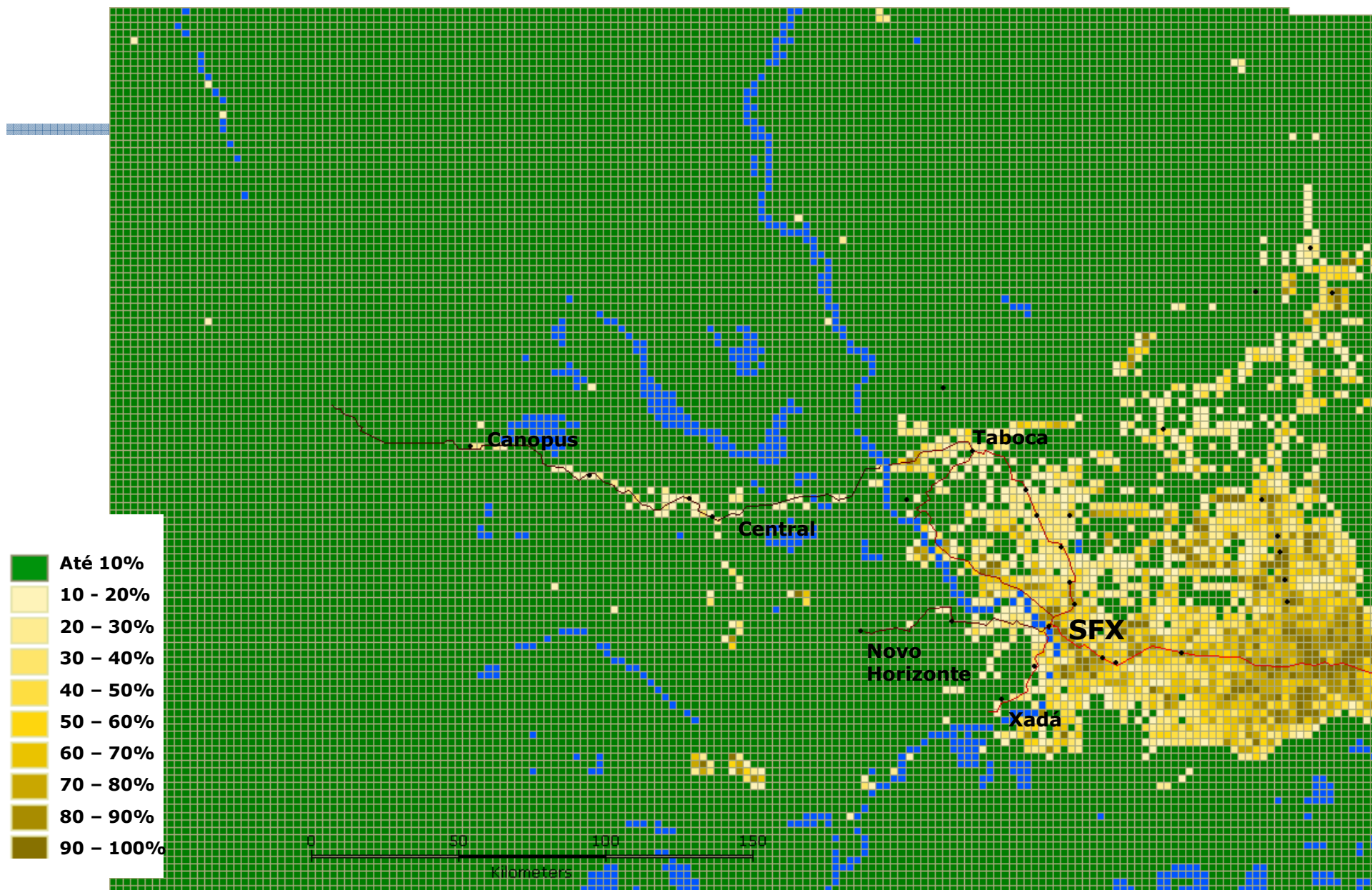


Escada et al, 2005 – Estudos Avançados , N° 54

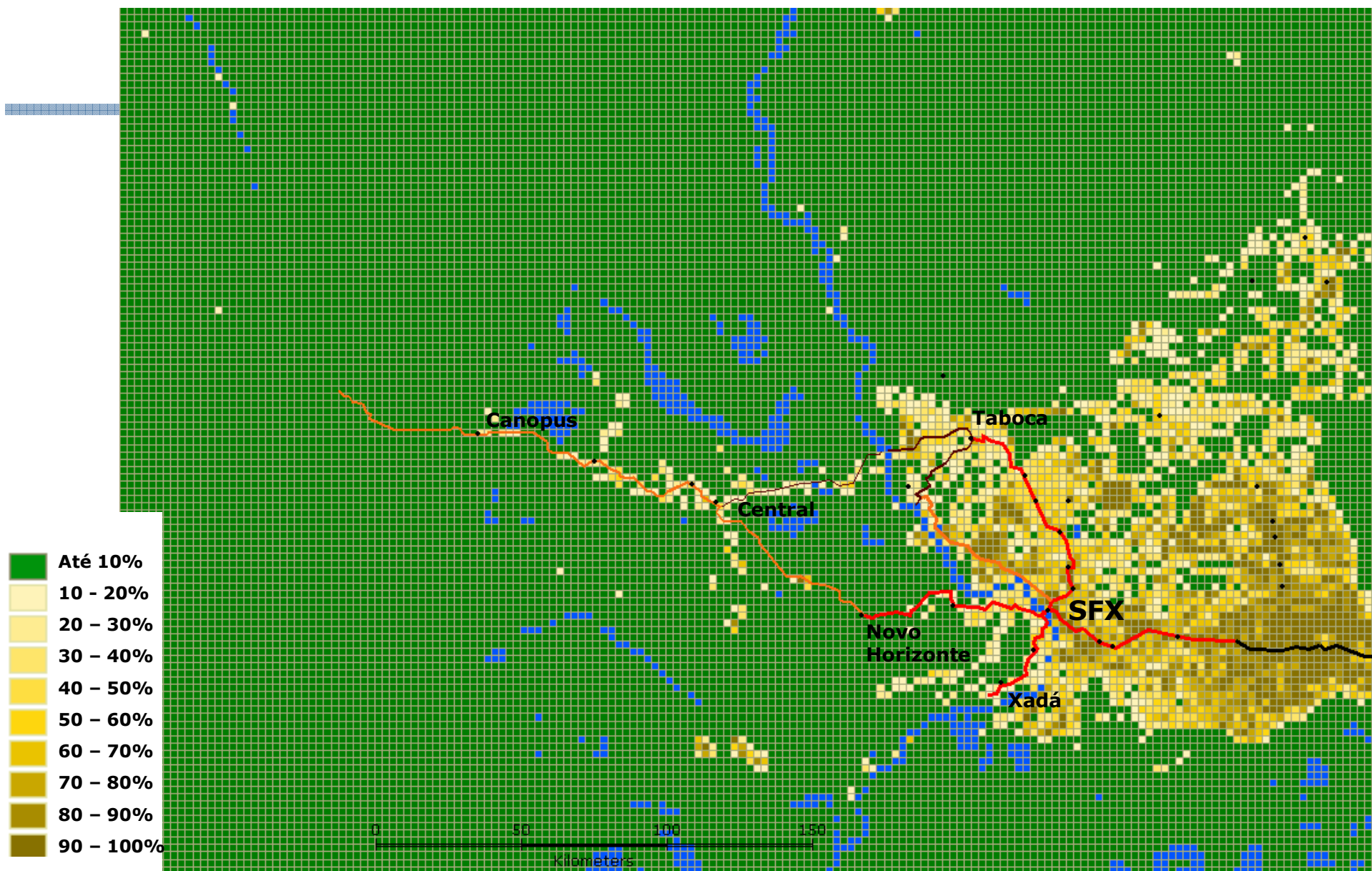


Museu Paraense Emílio
Goeldi e Embrapa Oriental

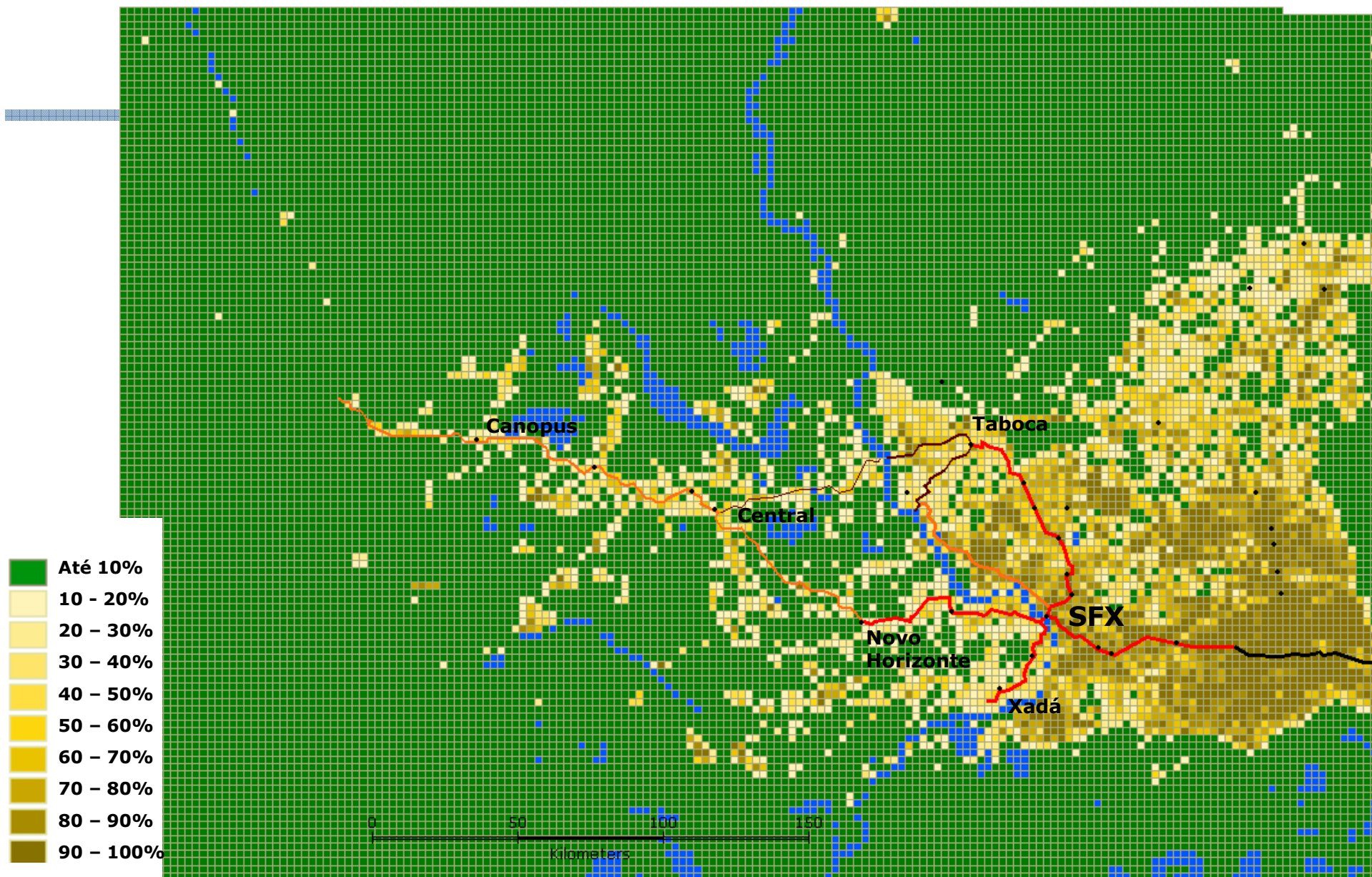
Deforestation 1997



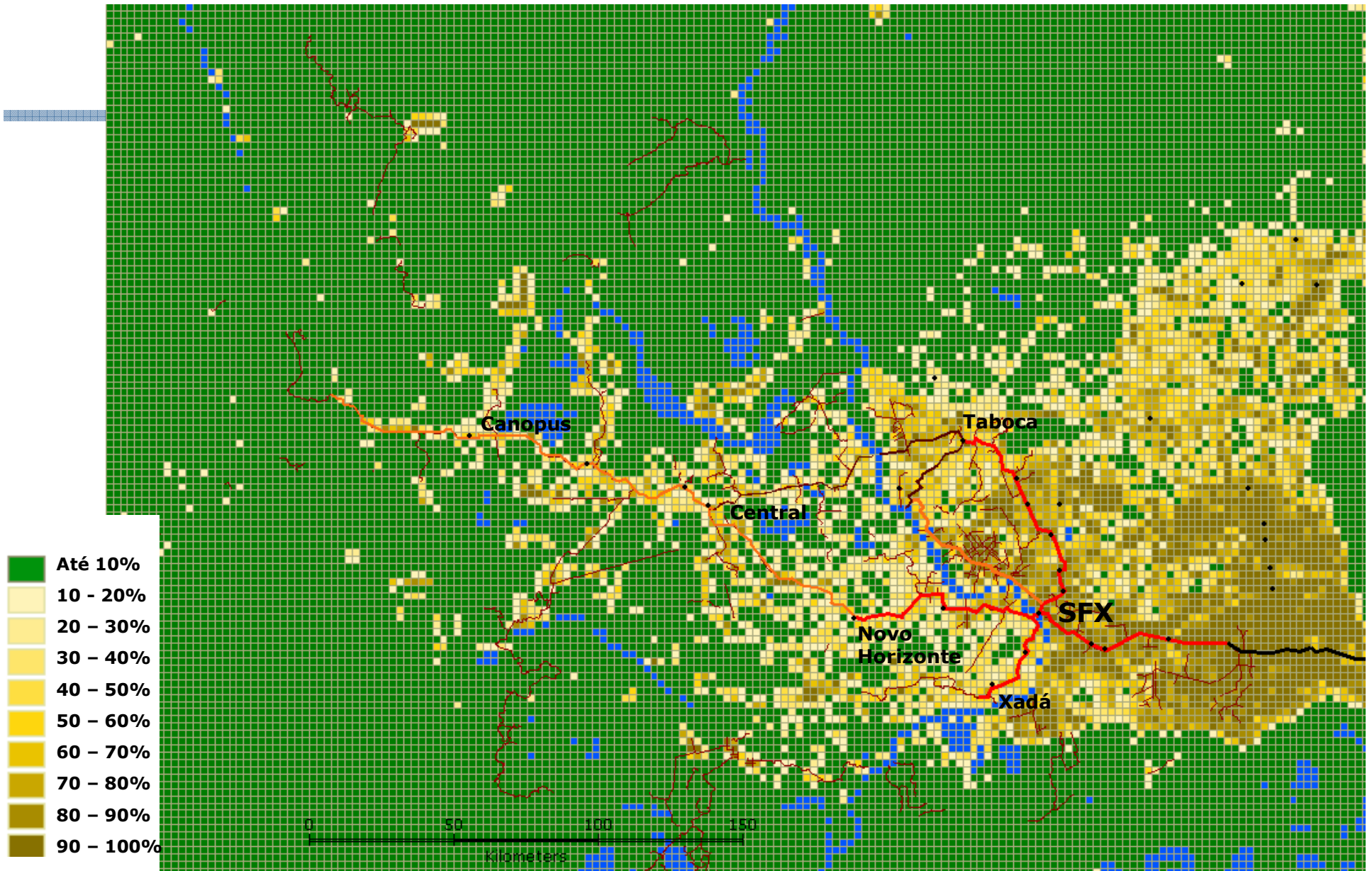
Deforestation 2000



Deforestation 2003



Deforestation 2006



The results show:

- Different spatial and temporal patterns
- Different stages of occupation
 - Initial
 - Expansion
 - Consolidation

Mining Deforestation Patterns in Remote Sensing Image Databases

- **What are the different land use patterns present in the database?**
- **When did a certain land use pattern emerge?**
- **What are the dominant land use patterns for each region?**
- **How do patterns emerge and change over time?**

Image Data Mining

- **Using data mining concepts, digital image processing and landscape ecology theory, it's possible to develop a methodology for LUCC semantic information recognition from remote sensing image databases**

Two approaches

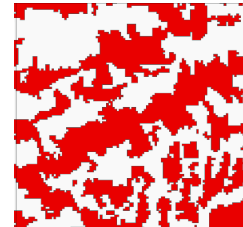
■ Landscape objects (Silva et al, 2008).

- A landscape object is a structure detected in a remote sensing image by an image segmentation algorithm or visual interpretation.

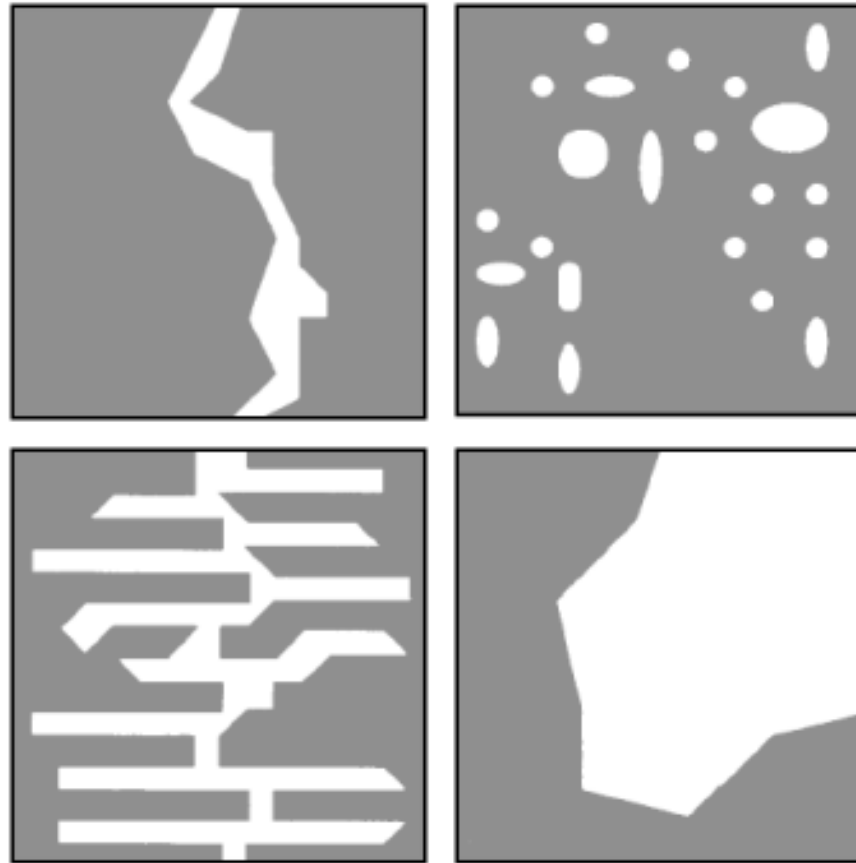


■ Cells (Azeredo et al. , in press)

- Cells aggregate a set of landscape objects representing a distinct occupation pattern.



Spatial Pattern Typology

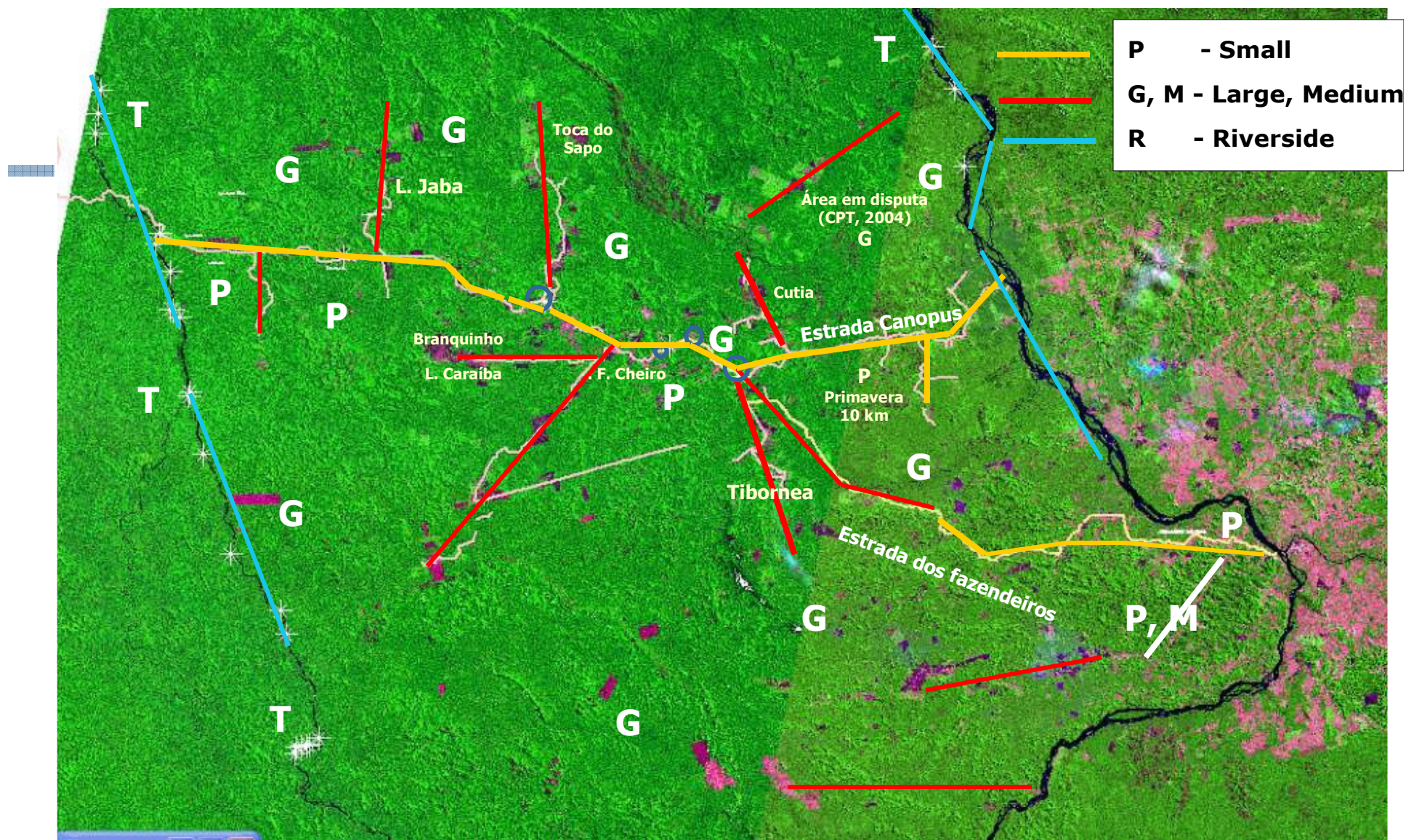


Tropical Deforestation Spatial Patterns: Corridor,
Diffuse, Fishbone, Geometric (*Lambin, 1997*)

Extraction of Attributes

1. Establishment of land cover typology
2. Classification - Geographic Data Mining Analyst (GeoDMA)
 - Extraction of the attributes
 - Training
 - Classification
3. Validation/Evaluation

The actors (rural pruducers) spatial distribution based on fieldwork – 2004 and 2007



TM Landsat7, 543 (2003)

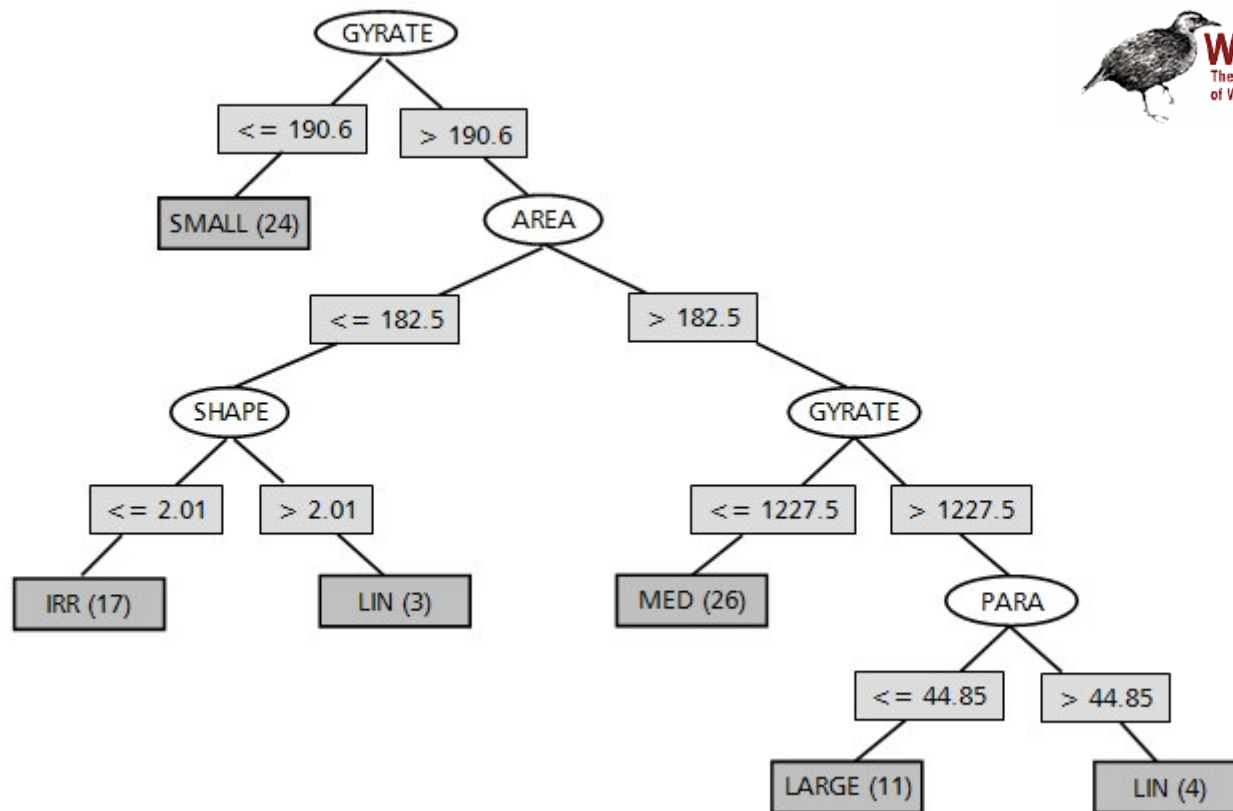
Source: CPT(2004) , Taravello, R. (2004), Isa (2001) , Geoma(2004), Escada et al (2005)

Image Data Mining – Patterns and Typology

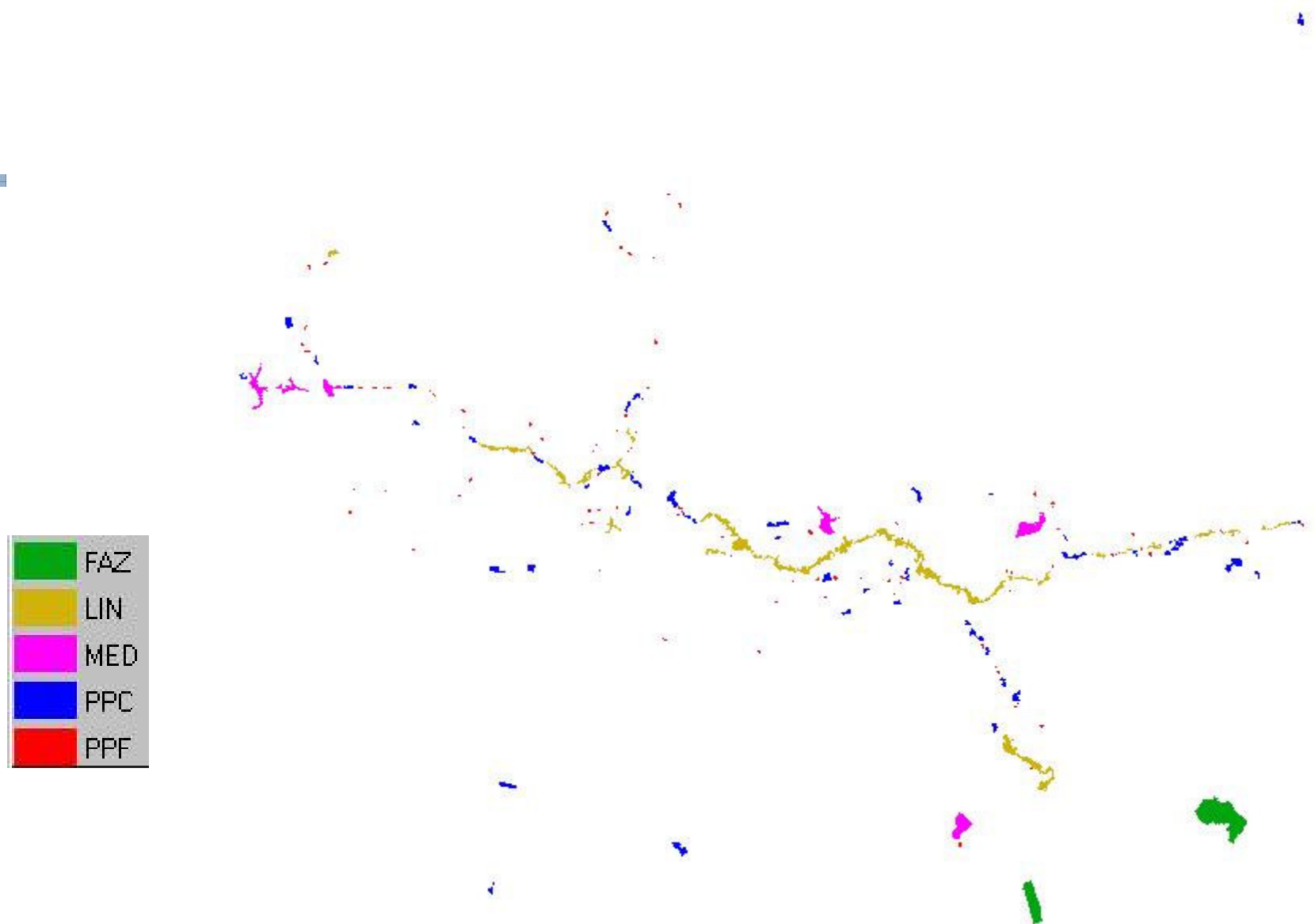
Clearing Patterns	Spatial Distribution	Clearing size	Actors	Main land use	Description
1. Linear 	Roadside	Variable	Small household	Family labor, subsistence crop and/or cattle ranching	Roadsided clearings, with linear pattern following main roads corresponding to the earlier stages of colonization.
2. Small Irregular 	Near main roads and populational nucleus	Small (< 35 ha)	Small farmers and/or family household	Family labor, subsistence crops and/or cattle ranching	Located near main roads (Canopus and Fazendeiros Road), up to the distance of 10 km
3. Irregular 	Near roads and populational nucleus	Small (35-190 ha)	Small farmers	Cattle ranching mainly	Located near roads, associated to small family household. These actors often have another incoming source from salary, commercial activities, etc. They use family and external labor
4. Medium Geometric 	Isolated or near secondary roads	190 - 900 ha	Medium farmers	Cattle ranching	Located near secondary roads, associated to large farms.
5. Large Geometric 	Isolated or the end of secondary roads	large (> 900 ha)	Large farmers	Cattle ranching	Located in isolated region, sometimes near rivers. Almost of them have airstrip.

Model – 94% - cross validation (GYRATE, AREA, SHAPE, PARA)

Decision Tree (J48)

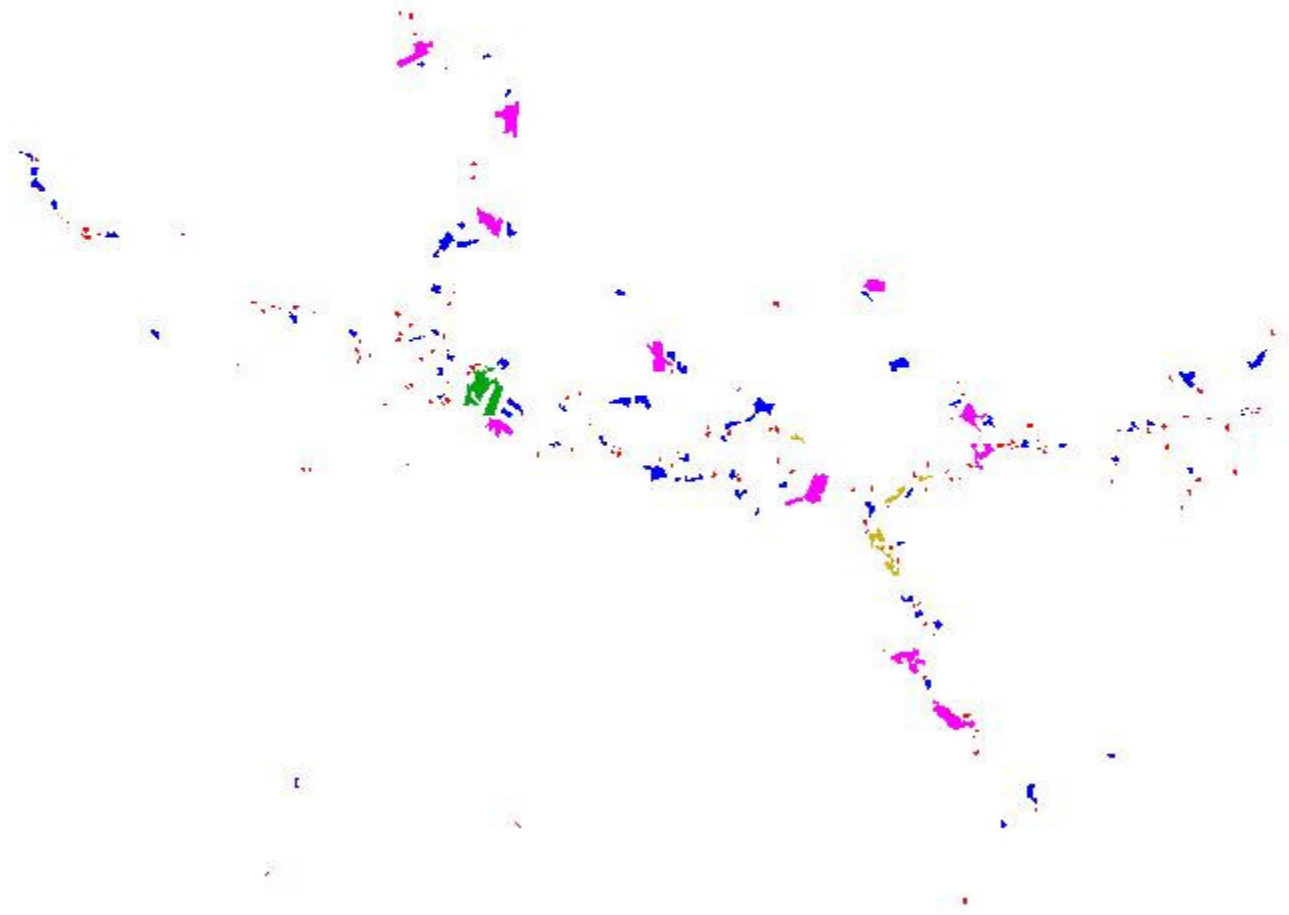


Terra do Meio - até 1997

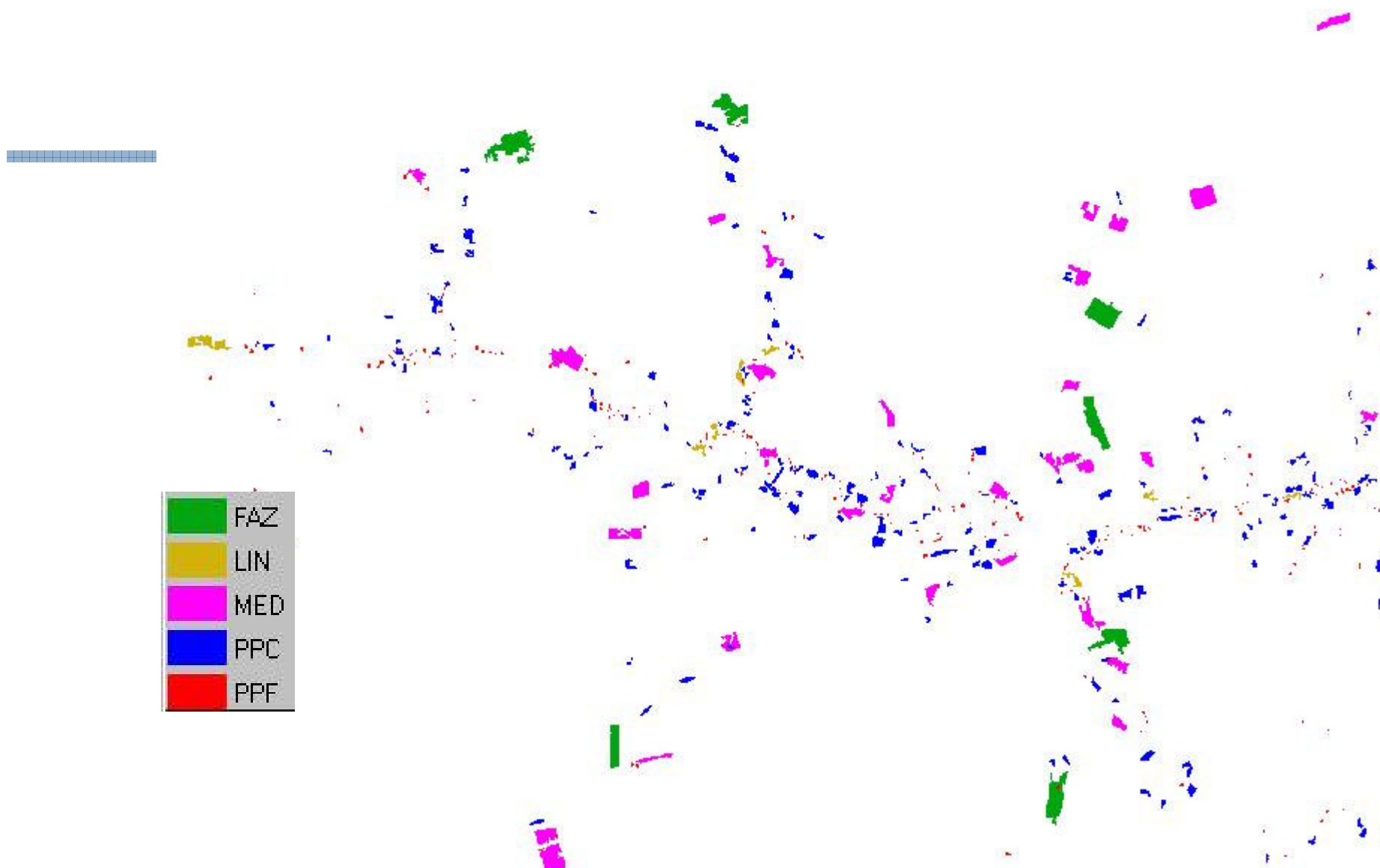


Silva, M.P. S. S. et al, 2008. International Journal of Remote Sensing

Terra do Meio 1997 - 2000



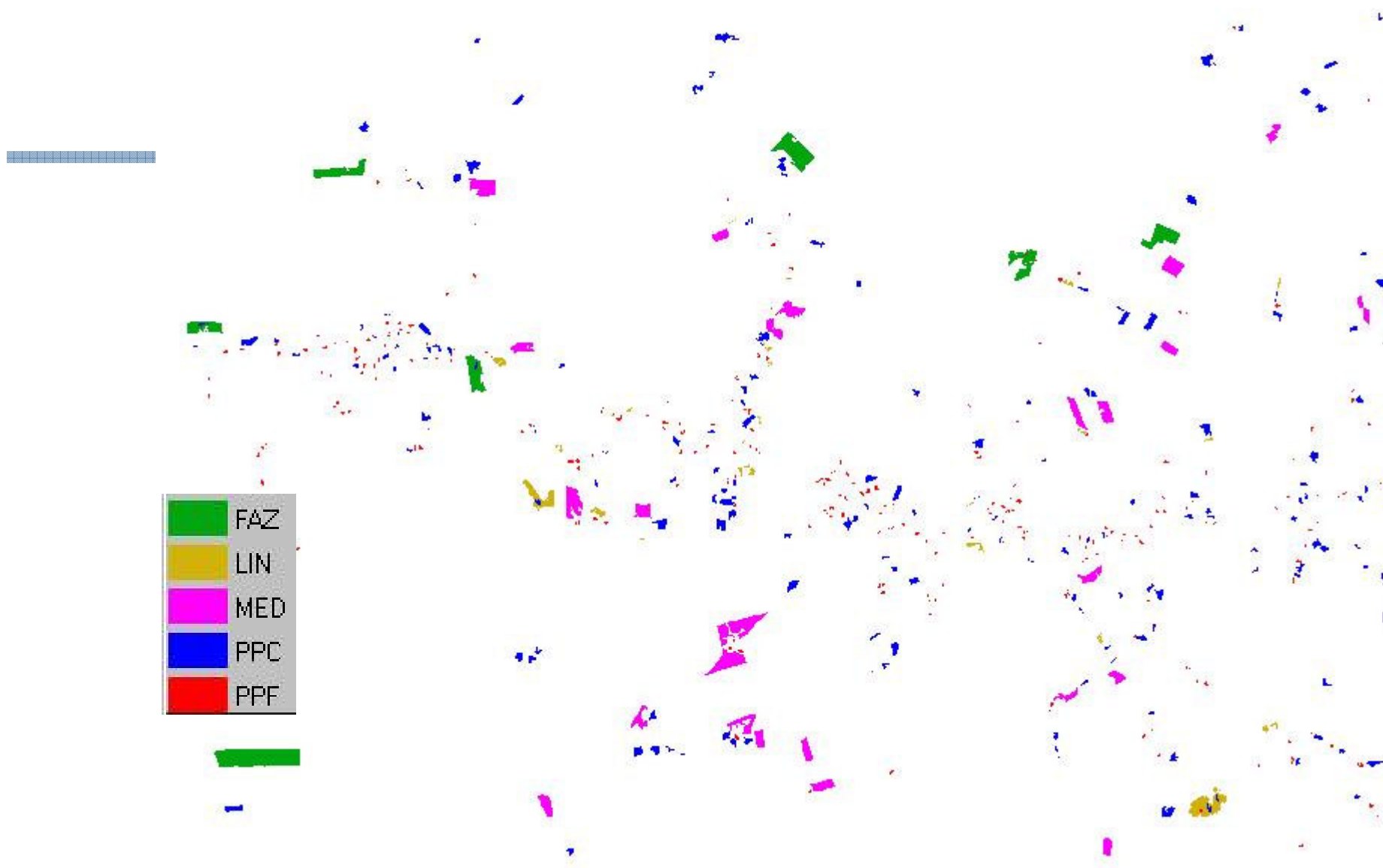
Terra do Meio 2000 - 2001



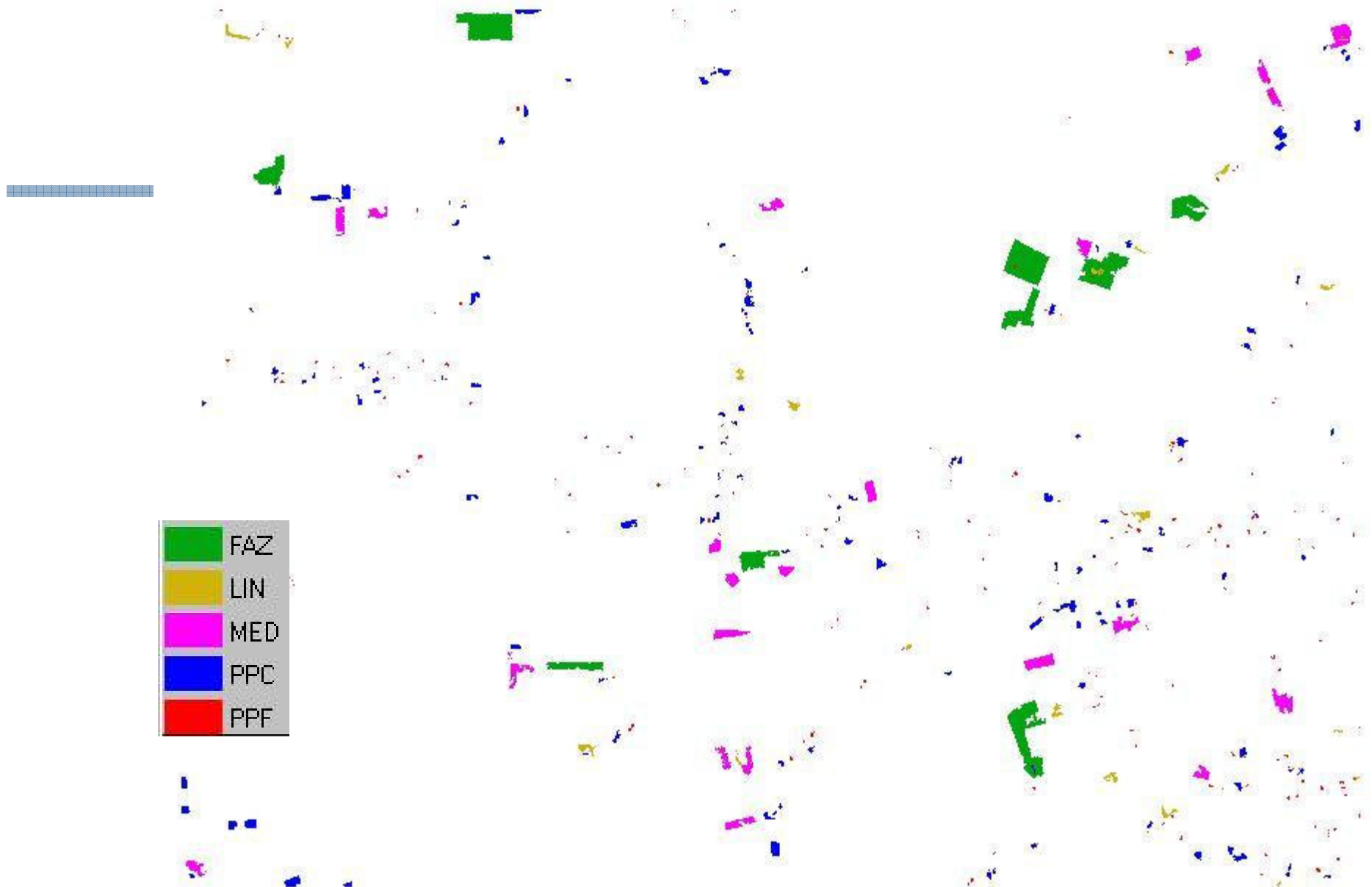
Terra do Meio 2001 - 2002



Terra do Meio 2002 - 2003



Terra do Meio 2003 - 2004

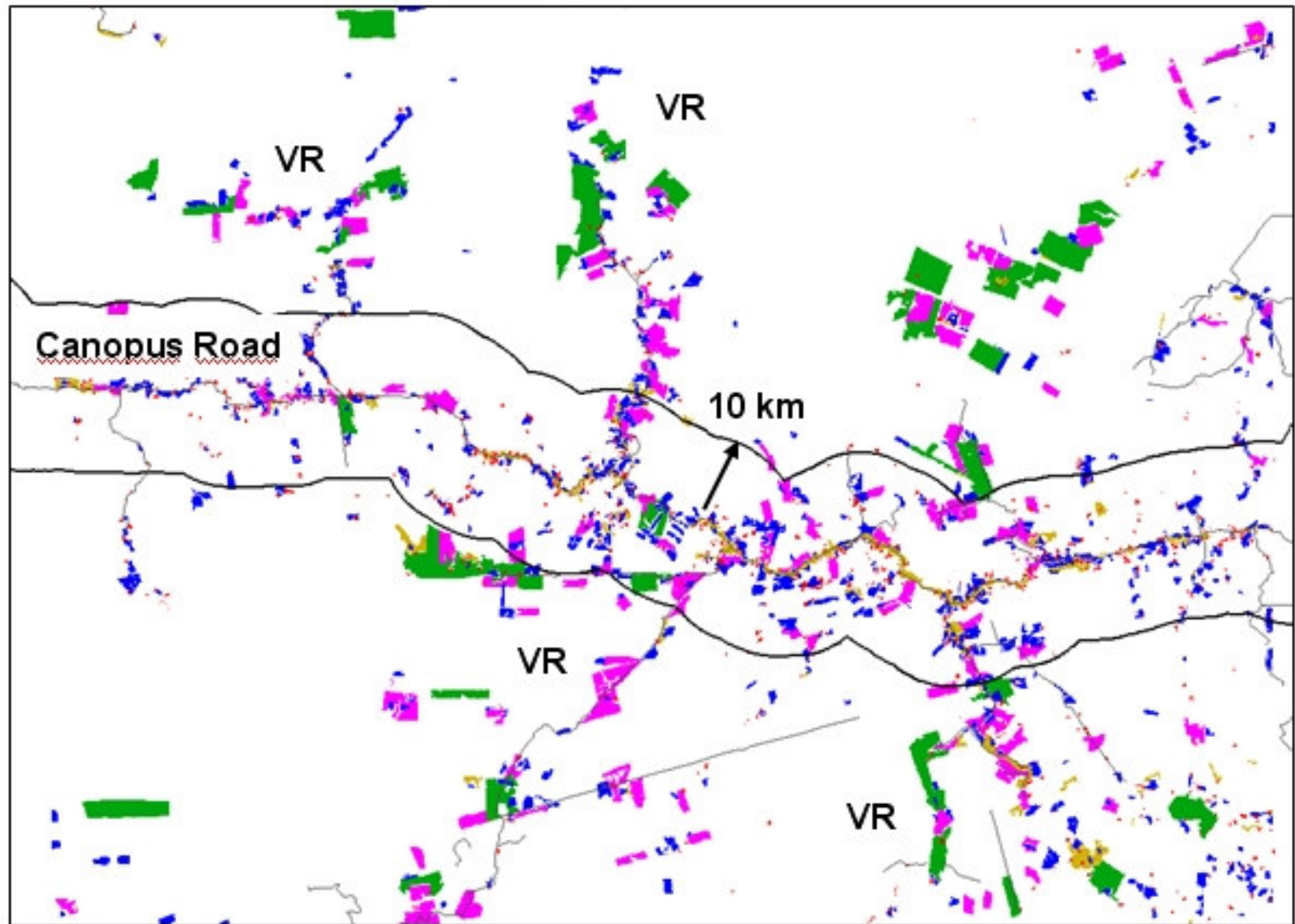


Terra do Meio 1997 - 2004

How the farms are spatially organized in the region?

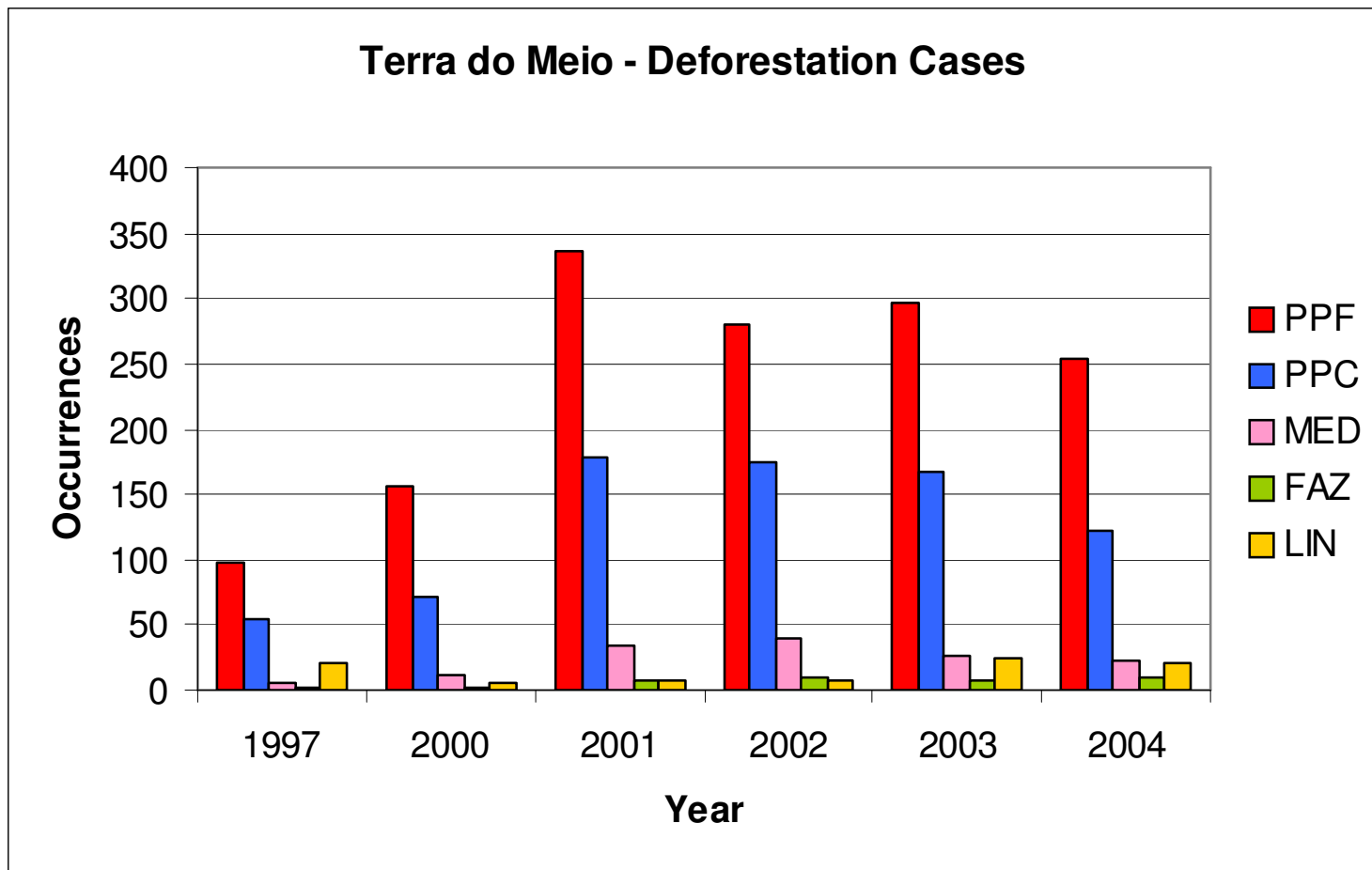


Small lots – ITERPA rural settlement – Lots
in a distance of 10 km from Canopus Road



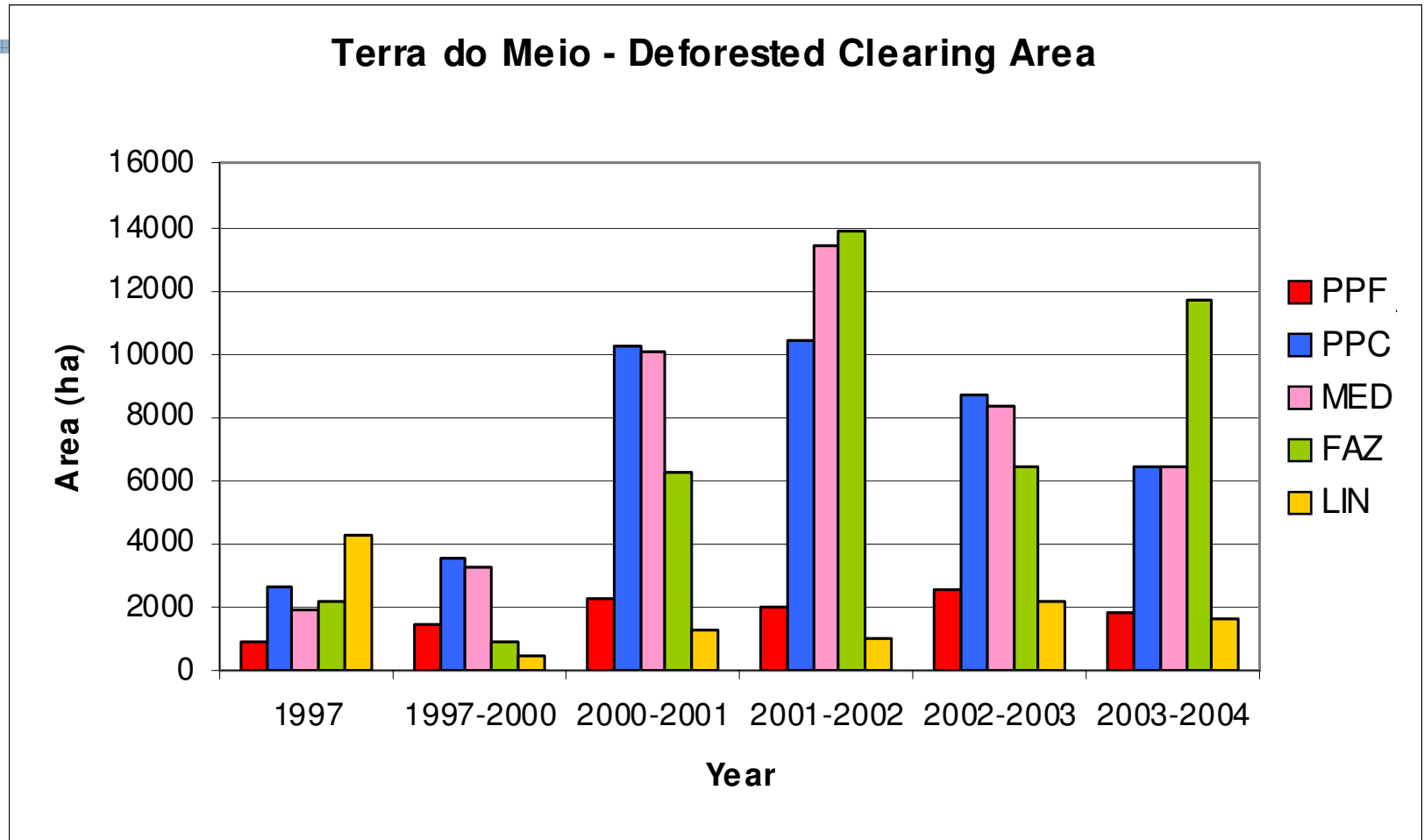
Source: CPT(2004) , Taravello, R. (2004), Geoma(2004), Escada et al (2005)`, Amaral et al (2007)

Land Cover Patterns: 1997 - 2004



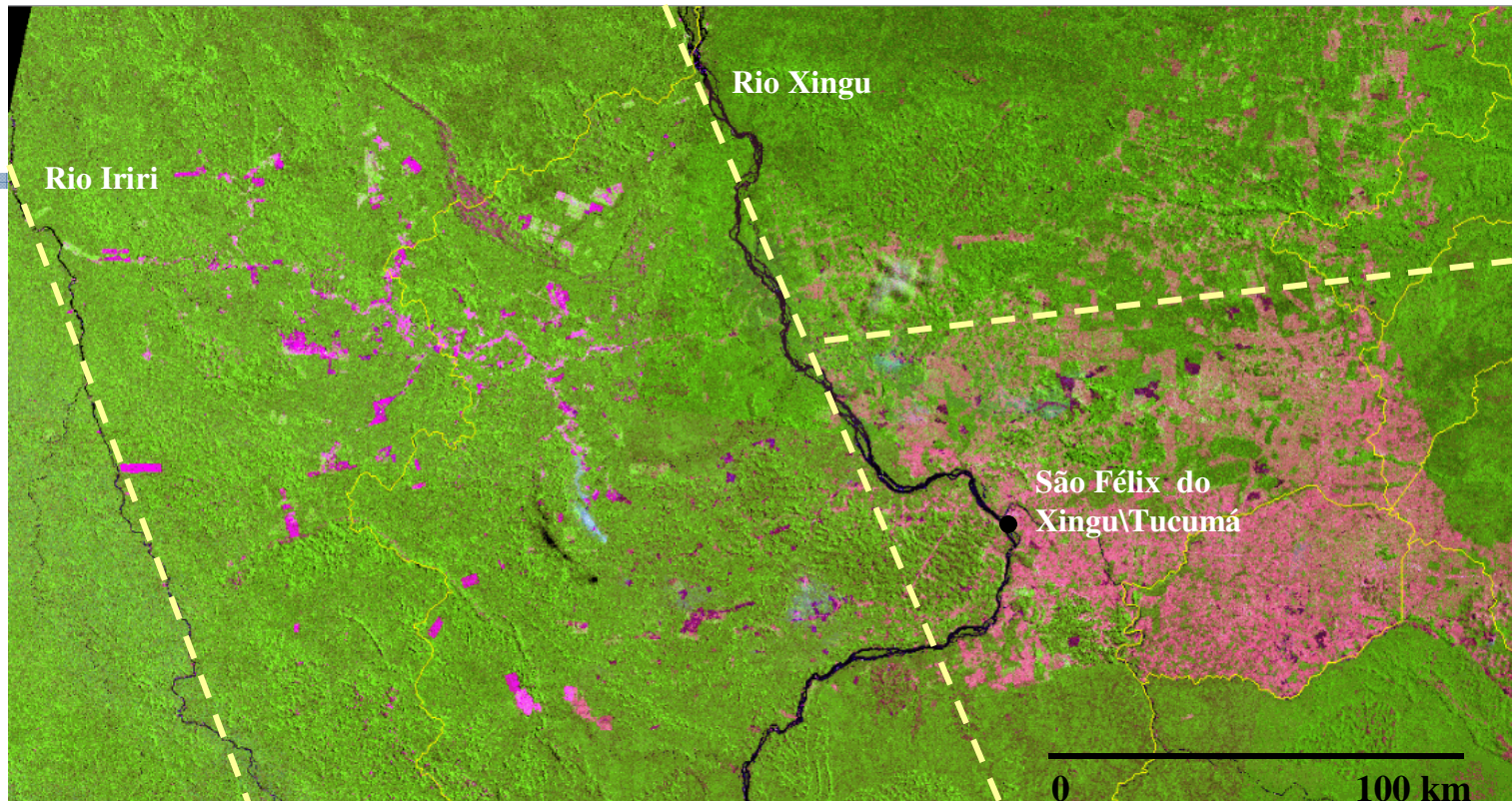
- What are the dominant patterns?

Land Cover Patterns: 1997 - 2004



- What are the dominant patterns in terms of area?

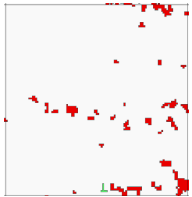
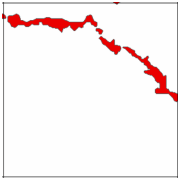
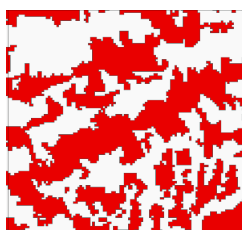
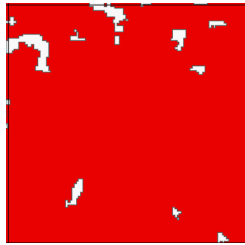
Different histories and occupation process and stages



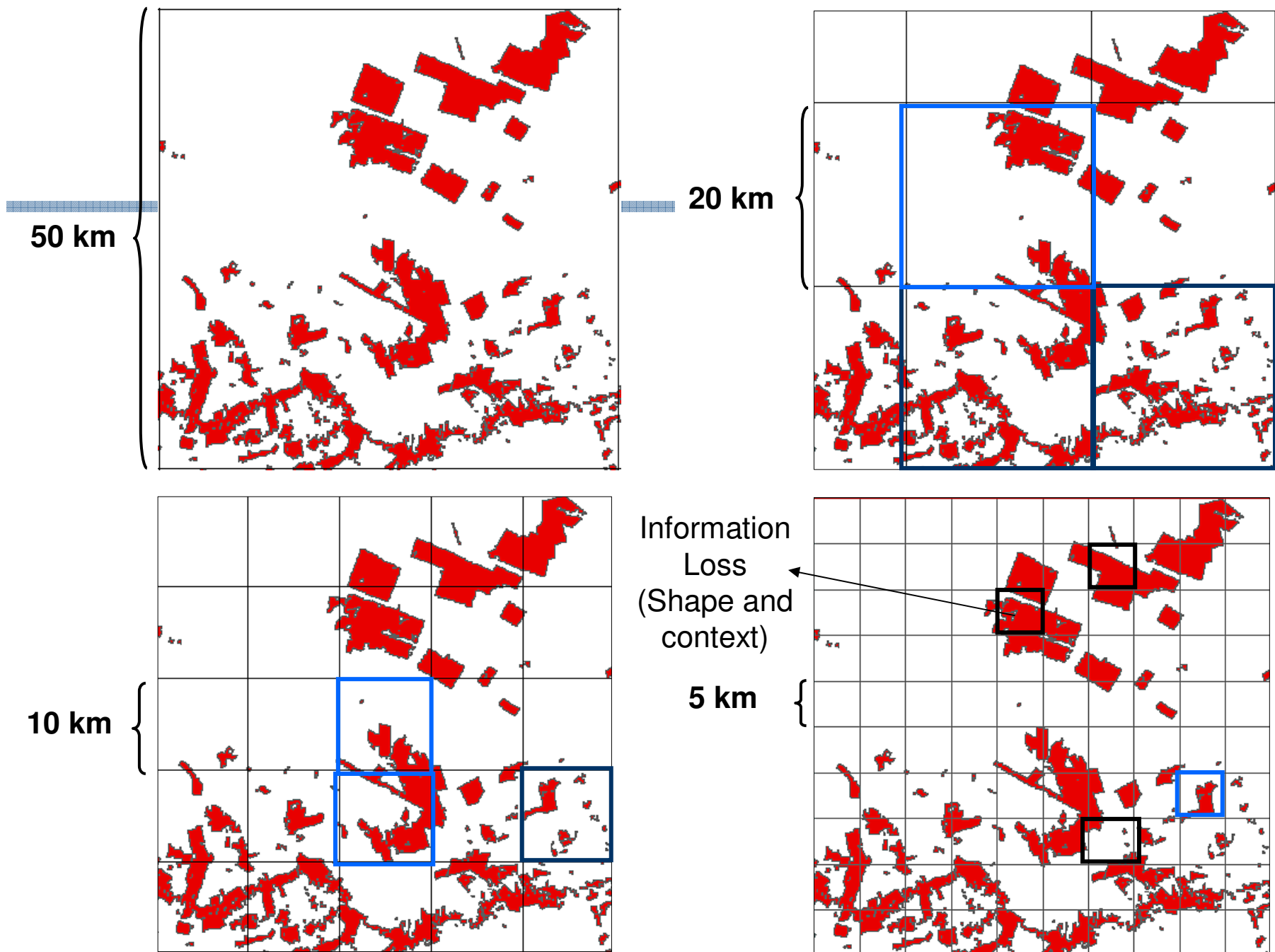
- 1) Tucumã (1984/85) – Mining, Private Colonization, small to medium farms; Consolidated occupation.
- 2) São Félix (beginning of XX century– The 80) Extractives, mining, cattle ranching, large and small farms, spontaneous occupation. North of Tucumã and São Félix (90) – logging, cattle ranching, large farms – planned rural settlement (INCRA 95) , Indian Land invasion
- 3) Terra do Meio (1998/2000) – Mining, logging, illegal land market, cattle ranching small and large farms.

Human Occupation Patterns Typology

Analysis Elements: Deforestation Patches

	Pattern	Pattern Description (1:100.000)	Semantic
	Diffuse	▪ Small and isolated patches ▪ Low to medium density ▪ Uniform distribution	▪ Beginning or non intensive occupation process ▪ Non planned occupation ▪ Small farms or household family ▪ Occupations along rivers
	Linear	▪ Linear patches like corridors ▪ Low density ▪ Unidirectional	▪ Beginning of the occupation process ▪ Non planned occupation ▪ Occupation along roads ▪ Small farmers
	Large Geometric	▪ Large and medium isolated patches ▪ Geometric patches ▪ Low to medium density	▪ Beginning or intermediary stage of the occupation process ▪ Medium and large farms
	Multidirectional	▪ Medium and Small patches ▪ Several shapes (irregular, geometric and linear) ▪ Medium to high density patches ▪ Multidirectional	▪ Occupation expansion. ▪ Non planned occupation ▪ Land concentration ▪ Medium and small farms
	Consolidated	▪ Large compact and continuous deforestation patches. ▪ Small Forest remnants ▪ Low density of forest patches	▪ Advanced occupation stage ▪ Land Concentration ▪ Small, Medium and Large farms ▪ Fragmentation ▪ Consolidated Occupation

Defining Cell resolution



Landscape Metrics



Implementadas em C++

Métrica	Finalidade
Class Area (CA)	Calcular a área total das "manchas" de desmatamento de uma paisagem.
Percent LAND (%LAND)	Calcular a porcentagem de área da paisagem atualmente desmatada.
Patch Density (PD)	Calcular o número de "manchas" de desmatamento por km ² da paisagem.
Mean Patch Size (MPS)	Calcular o tamanho médio das "manchas" de desmatamento da paisagem.
Landscape Shape Index (LSI)	Calcular a complexidade da forma das "manchas" de desmatamento com base no perímetro das mesmas, e na área da paisagem.

Landscape Metrics



Implementadas em C++

Métrica	Finalidade
Mean Shape Index (MSI)	Calcular a média da complexidade da forma das "manchas" de desmatamento com base no perímetro das mesmas, e na área da paisagem.
Area Weighted Mean Shape Index (AWMSI)	Calcular a média da complexidade da forma das "manchas" de desmatamento ponderada pelo tamanho da área das mesmas.
Mean Patch Fractal Dimension (MPFD)	Calcular a média da complexidade da forma das "manchas" de desmatamento utilizando logaritmos.

Data Mining Technique



Decision Tree (J48)



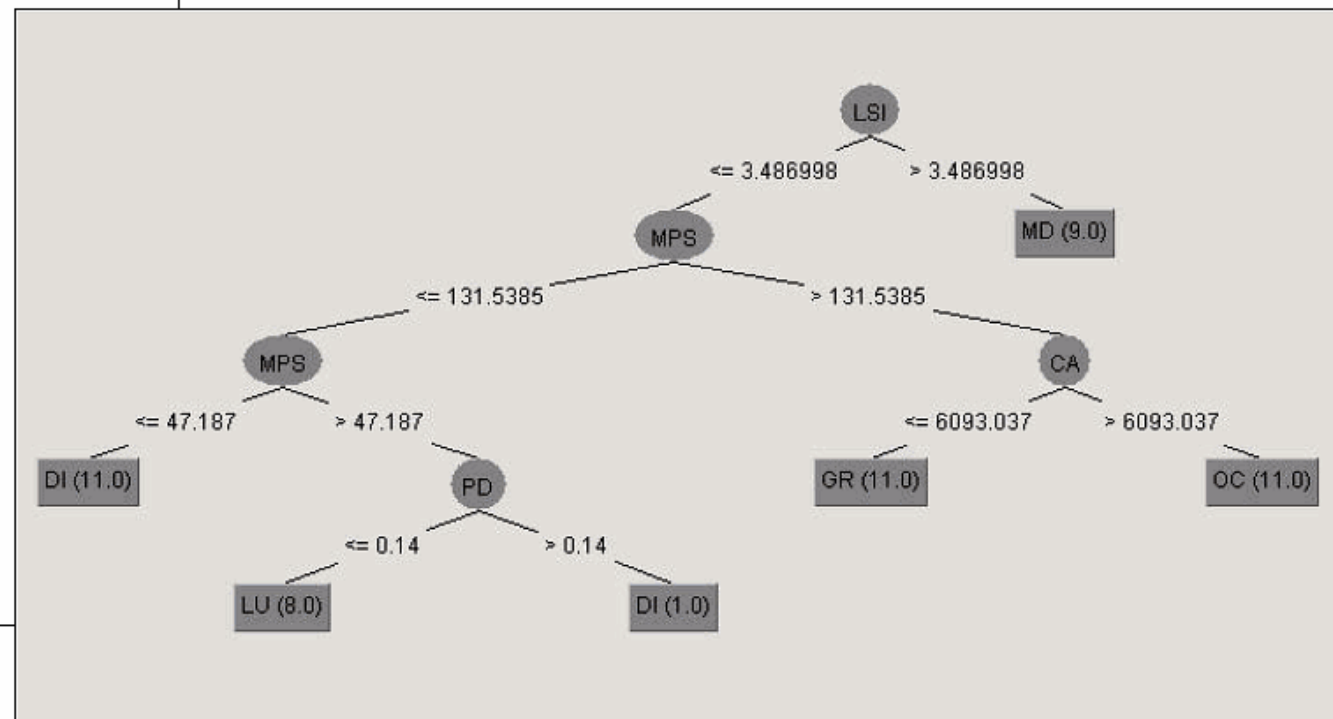
=== Classifier model (full training set) ===

J48 pruned tree

```
LSI <= 3.486998
|  MPS <= 131.5385
|  |  MPS <= 47.187: DI (11.0)
|  |  MPS > 47.187
|  |  |  PD <= 0.14: LU (8.0)
|  |  |  PD > 0.14: DI (1.0)
|  |  MPS > 131.5385
|  |  |  CA <= 6093.037: GR (11.0)
|  |  |  CA > 6093.037: OC (11.0)
LSI > 3.486998: MD (9.0)
```

Number of Leaves : 6

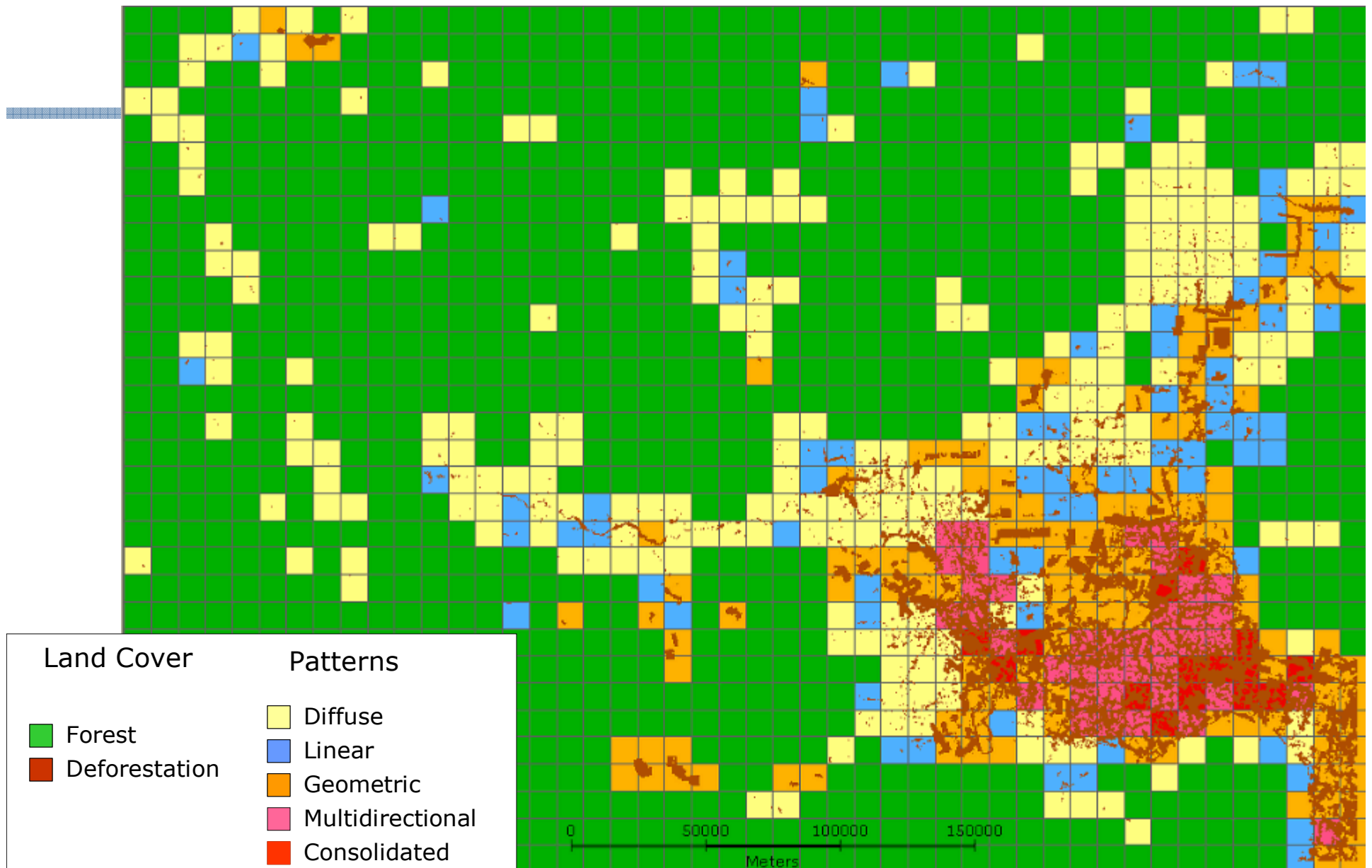
Size of the tree : 11



In construction: Escada, Azeredo, Korting, Fonseca, Monteiro

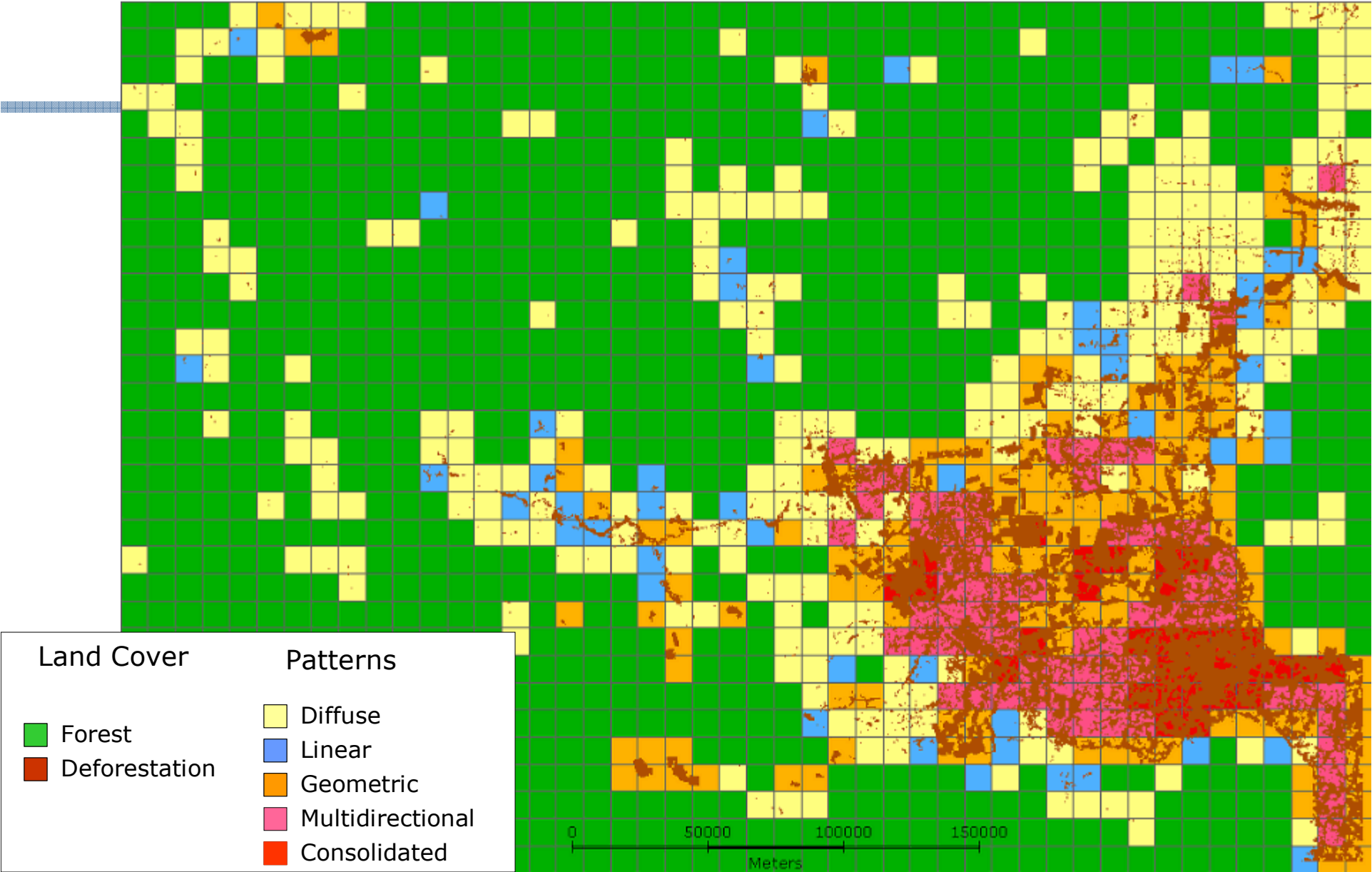
Human Occupation Patterns

1997



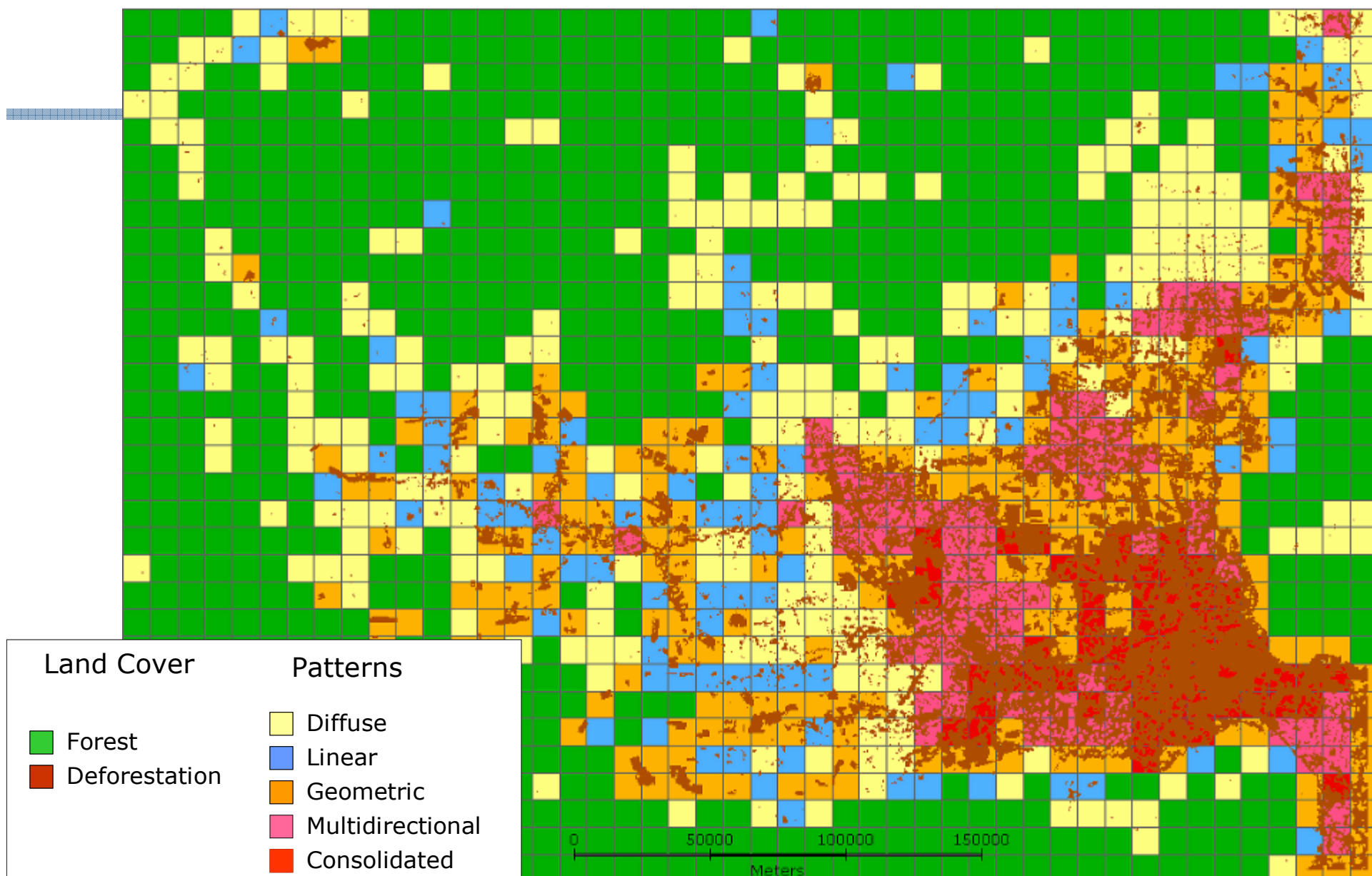
Human Occupation Patterns

2000



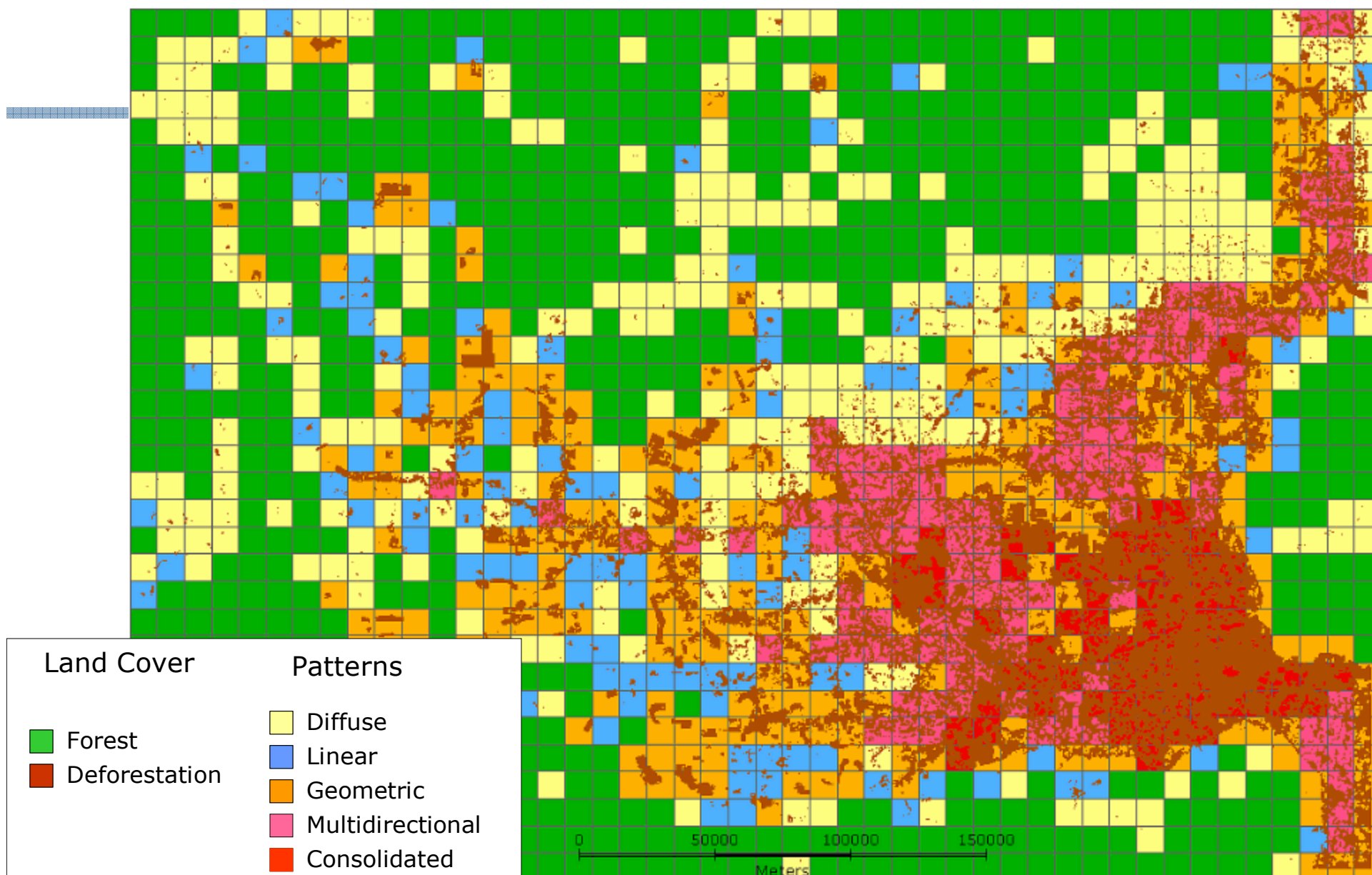
Human Occupation Patterns

2003

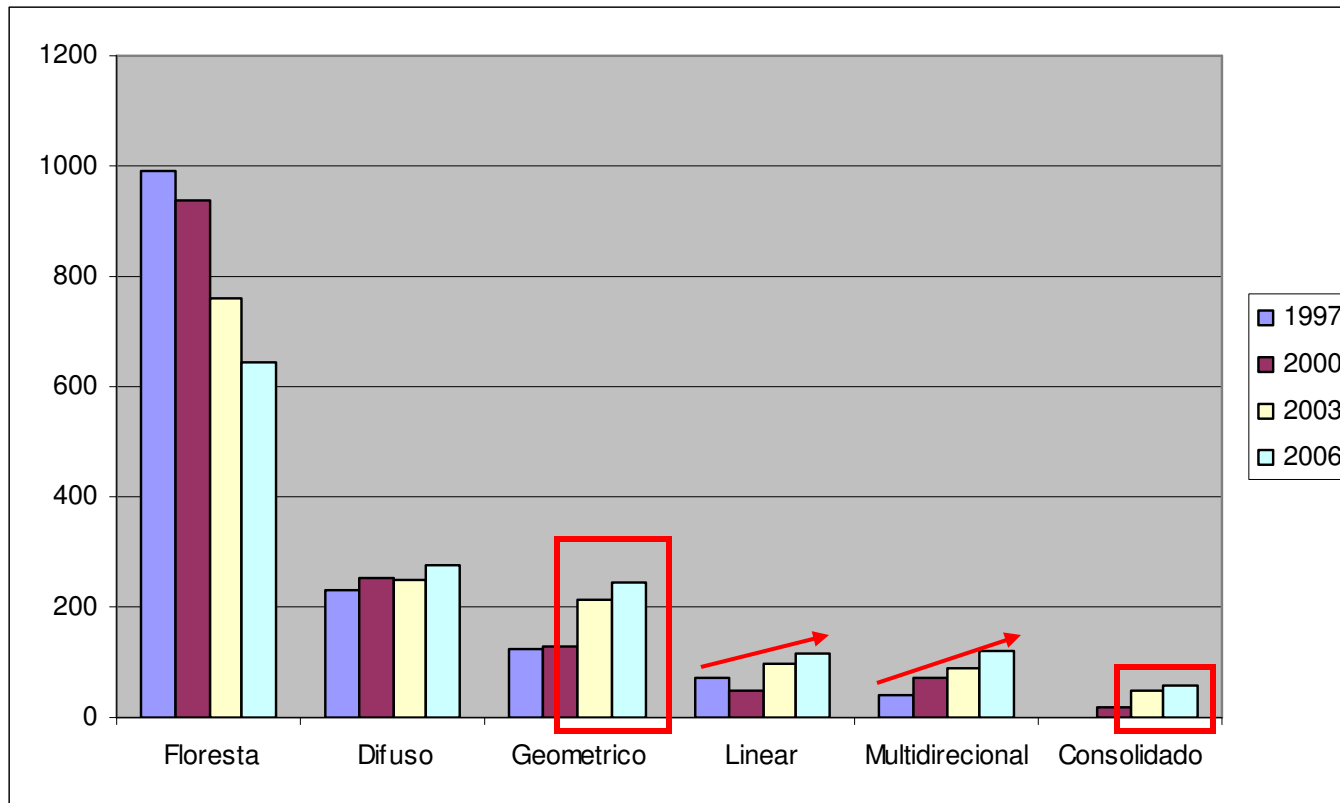


Human Occupation Patterns

2006



Occupation Pattern Evolution



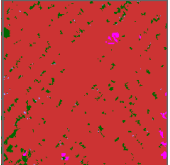
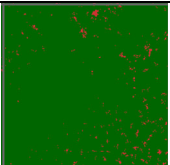
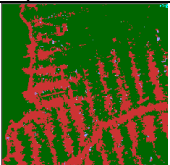
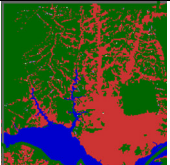
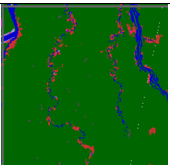
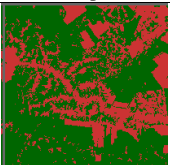
freg	1997	2000	2003	2006
103	Difuso	Difuso	Difuso	Difuso
69	Floresta	Floresta	Floresta	Difuso
61	Geometrico Regular	Geometrico Regular	Geometrico Regular	Geometrico Regular
57	Floresta	Floresta	Difuso	Difuso
51	Floresta	Floresta	Geometrico Regular	Geometrico Regular
23	Floresta	Floresta	Floresta	Linear Unidirecional
21	Linear Unidirecional	Geometrico Regular	Geometrico Regular	Geometrico Regular
20	Difuso	Multidirecional Desordenado	Multidirecional Desordenado	Multidirecional Desordenado
20	Floresta	Floresta	Floresta	Geometrico Regular
19	Difuso	Difuso	Multidirecional Desordenado	Multidirecional Desordenado
19	Floresta	Difuso	Difuso	Difuso
18	Floresta	Floresta	Difuso	Linear Unidirecional
18	Floresta	Floresta	Linear Unidirecional	Linear Unidirecional
15	Floresta	Floresta	Linear Unidirecional	Geometrico Regular
14	Difuso	Difuso	Difuso	Multidirecional Desordenado
14	Multidirecional Desordenado	Multidirecional Desordenado	Ocupacao Consolidada	Ocupacao Consolidada
12	Linear Unidirecional	Linear Unidirecional	Linear Unidirecional	Linear Unidirecional
11	Difuso	Difuso	Difuso	Linear Unidirecional
11	Difuso	Difuso	Geometrico Regular	Geometrico Regular
11	Multidirecional Desordenado	Multidirecional Desordenado	Multidirecional Desordenado	Multidirecional Desordenado
10	Geometrico Regular	Multidirecional Desordenado	Multidirecional Desordenado	Multidirecional Desordenado
9	Difuso	Linear Unidirecional	Geometrico Regular	Geometrico Regular
9	Geometrico Regular	Geometrico Regular	Ocupacao Consolidada	Ocupacao Consolidada
9	Geometrico Regular	Ocupacao Consolidada	Ocupacao Consolidada	Ocupacao Consolidada
9	Multidirecional Desordenado	Ocupacao Consolidada	Ocupacao Consolidada	Ocupacao Consolidada
8	Floresta	Floresta	Linear Unidirecional	Difuso
7	Difuso	Difuso	Linear Unidirecional	Difuso
7	Difuso	Difuso	Linear Unidirecional	Geometrico Regular
7	Linear Unidirecional	Linear Unidirecional	Geometrico Regular	Geometrico Regular
6	Difuso	Difuso	Linear Unidirecional	Linear Unidirecional
6	Floresta	Floresta	Difuso	Geometrico Regular
5	Difuso	Geometrico Regular	Geometrico Regular	Geometrico Regular
5	Floresta	Difuso	Difuso	Linear Unidirecional
5	Floresta	Difuso	Geometrico Regular	Geometrico Regular
5	Floresta	Difuso	Linear Unidirecional	Difuso
5	Floresta	Floresta	Geometrico Regular	Linear Unidirecional
5	Geometrico Regular	Geometrico Regular	Geometrico Regular	Ocupacao Consolidada
5	Linear Unidirecional	Difuso	Geometrico Regular	Geometrico Regular
5	Multidirecional Desordenado	Multidirecional Desordenado	Multidirecional Desordenado	Ocupacao Consolidada

Trajectories

- 54% Expansion
Forest > Diffuse
Forest > Geometric
Forest > Linear
- 27% No change
- 19% Consolidation

Next steps

- **Validation of the results of cell classification.**
- **Description of the patterns in terms of forest conservation, land use and forest fragmentation and degradation.**
- **We are enlarging the area to analyze the whole Amazonia region using cell approach with Prodes data.**

PRODES 2007- Amazônia Legal	Padrão de Ocupação	Descrição Escala 1:100.000	Semântica
 Jarú, Ouro Preto do Oeste, - RO	Consolidado	-Manchas grandes contínuas; -Densidade baixa e áreas pequenas de remanescentes florestais; -Manchas compactas.	-Estágios avançados de ocupação; -Concentração fundiária; -Pequenos, médios e grandes produtores rurais; -Esgotamento da floresta; -Ocupação consolidada.
 Xapuri - AC	Difuso	-Manchas pequenas; - Manchas Isoladas; -Baixa a média densidade; -Distribuição uniforme.	-Áreas de ocupação espontânea; -Áreas de extração seletiva da madeira; -Pequenos produtores.
 Placas-PA	Espinha de Peixe	-Manchas grandes alongadas e lineares com ramificações semelhantes à vértebra de peixe; -Média densidade.	-Áreas de projeto de Assentamento rural do INCRA.
 Nova Maringá-MT	Geométrico regular	-Manchas médias a grandes e isoladas; -Forma geométrica regular; -Baixa a média densidade.	-Estágios iniciais de ocupação; -Fazendas Médias e Grandes.
 Manaus- AM	Ilha	-Manchas pequenas, médias e grandes em geral, ligadas a estruturas lineares representadas por vias de acesso; -Manchas homogêneas; -Baixa, média a alta densidade.	-Manchas urbanas.
 Novo Ariapunã-AM	Irregular ao longo de hidrografia	-Manchas pequenas e médias dispostas ao longo da hidrografia; -Baixa densidade.	-Ocupação Ribeirinha.
 Rio Branco-AC	Multidirecional desordenado	-Manchas pequenas, médias e grandes; -Manchas de formas variadas; -Média, alta densidade; -Multidirecional.	-Ocupação em expansão, inicialmente espontânea; -Pode haver concentração fundiária; -Pequenos e médios produtores rurais.

Preliminar Amazonia Occupation Patterns Typology

Master thesis
Erika Akemi Sato

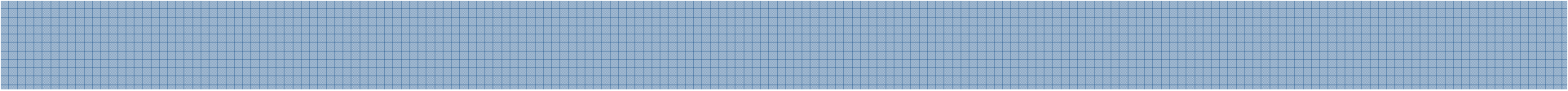
Supervisors
Leila Fonseca and Isabel Escada

Finally..

From the perspective of land use assessment:

- **We deal with temporal data**
- **We work in large areas**
- **Difficult to access**

Data from environmental network sensors can be useful to detect changes in narrower time intervals and to improve model land use process.



Thanks!

