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INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

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Divisão de Processamento de Imagens

The Social-Economical-Political Drivers Behind the Land Use Change: An Integrated Approach


Amazônia Probio Project (FUNCATE/INPE, 2005)

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Rede Temática de Pesquisa em Modelagem Ambiental da Amazônia

geoma

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GEOMA/DPI Team

Staff:

- Ana Paula Dutra Aguiar
- Antônio Miguel Vieira Monteiro
- Diógenes Alves
- Gilberto Câmara
- Maria Isabel Sobral Escada
- Silvana Amaral Kampel

Partner:

- Tiago Garcia de Senna Carneiro (UFPO)

Research Assistant

(GEOMA Grant):

- Felix Carriello

About our team

- **We are involved with**
  - Biodiversity studies
  - Deforestation monitoring
  - Land use and land cover change pattern analysis and modeling
  - Population and settlement dynamics analysis and modeling
  - Regional planning analysis
  - Computational tools development (TerraMe/TerraLib/Image data Mining)
  - Remote sensing (Modis, Landsat, Cbers, DMSP/OLS)
  - GIS (SPRING/TerraView)
- **Main Projects**
  - Prodes, Deter, Spring, TerraLib, Cbers
  - GEOMA

About this lecture

- **To discuss LUCC patterns and processes in Amazonia pointing out economic, political and social drivers.**
  1. **Regional level**
  2. **Local level: Case studies**

Regional Level

1. **Amazonian Frontier Expansion**
   - The 50's expansion frontier of occupation
   - New frontier context
     - Becker´s new frontier hypothesis (2004, 2005)
2. **Using satellite Deforestation to Detect Land Cover Dynamics in Amazonian Frontier Expansion**
   - PRODES and DETER
     - New data and methodologies
   - Land Use/Cover, Socio-Economic and Environmental Data Base
3. **Land Cover Change Patterns**
4. **Using computational models to explore Amazon heterogeneity**

Local Level

5. **Rondônia**
   - Land use and actors typology
   - Detecting deforestation patterns and their land use semantic
   - Modeling land cover dynamics
6. **Terra do Meio – São Félix do Xingu (PA)**
   - Land appropriation model formulation
   - Land use and actors typology
   - Infrastructure and social networks structuring the territory
   - Detecting deforestation patterns and their land use semantic
   - Modeling land use change based on integrated approaches: a challenge

1. Amazonian Occupation Frontier Expansion

Amazonian occupation

- **Up to the 50's**
  - Almost undisturbed
  - Extractive activities (rubber, nut, timber)
  - Mainly riverside occupation
  - Two important urban centers: Manaus and Belém

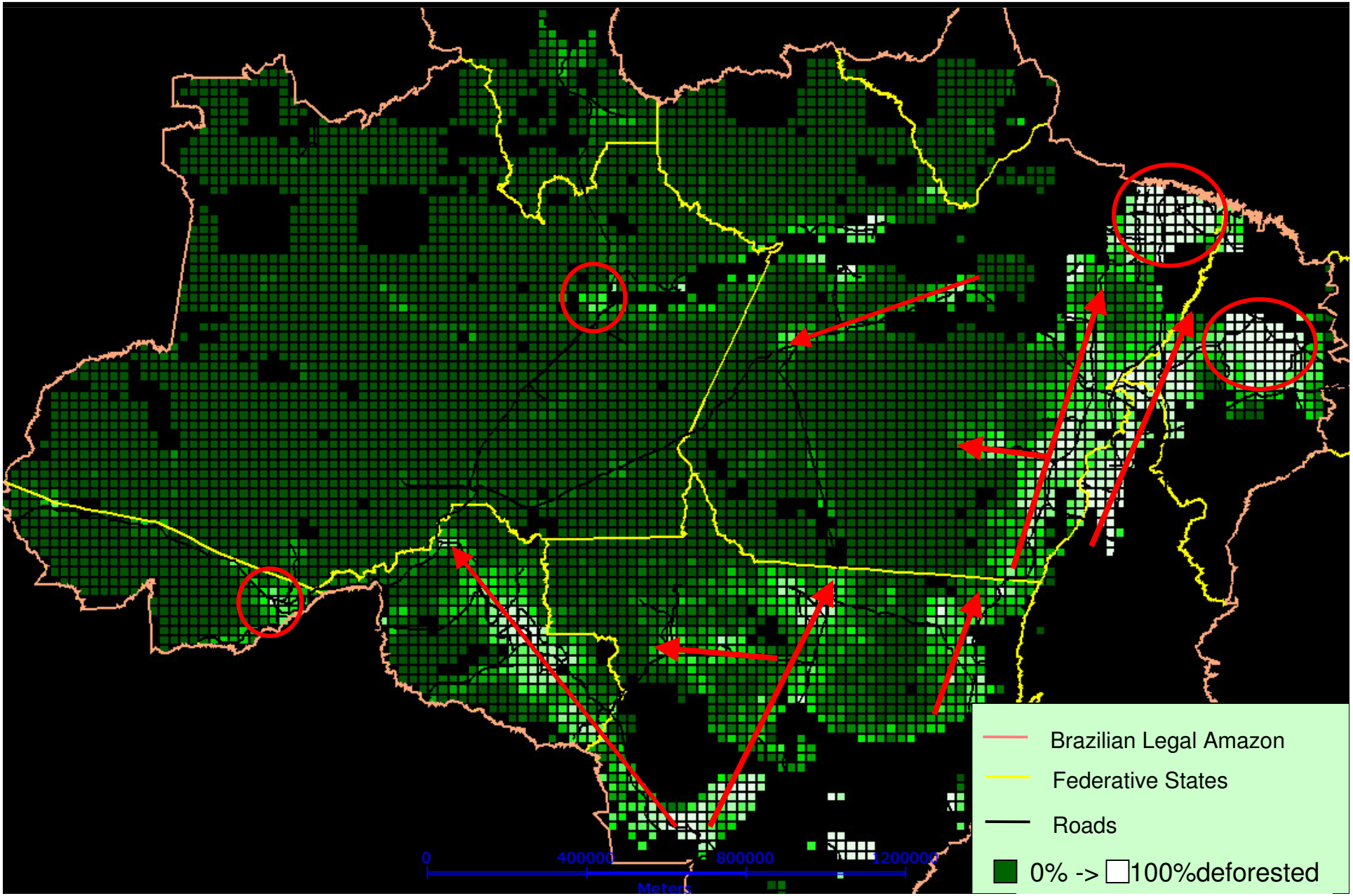
From the 50's to the 80's: Amazonian occupation strategy

- **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.

Costa, 1998; Becker, 1997; Machado, 1998, Kitamura, 1994

Deforestation pattern in 1997 INPE/PRODES 1997

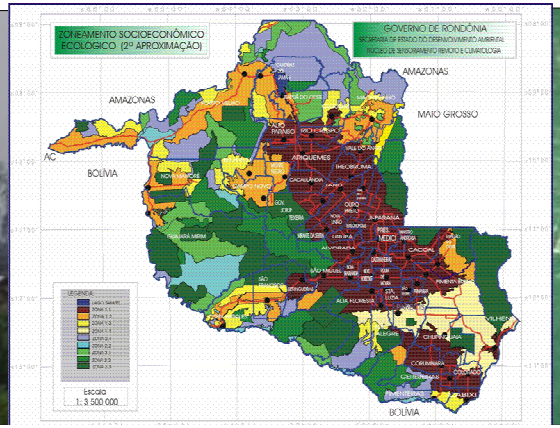
The 90's deforestation spatial pattern: near roads, pioneer colonization and some Poles
(Alves, 2001; Machado, 1998)



The 90's and 2000: New scenarios

- New axes of integration and development (Avança Brasil - http://www.abrasil.gov.br)
- Soybean expansion, primarily in savanna;
- Urban population growth (IBGE, 2000);
- Sustainable development projects (PPG7);
- Policy of forest conservation and monitoring
- Territorial planning


Foto: Escada, 2004 – PA -150




Geoma's overfly 2006 - Santarém

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"Current and future development axes"

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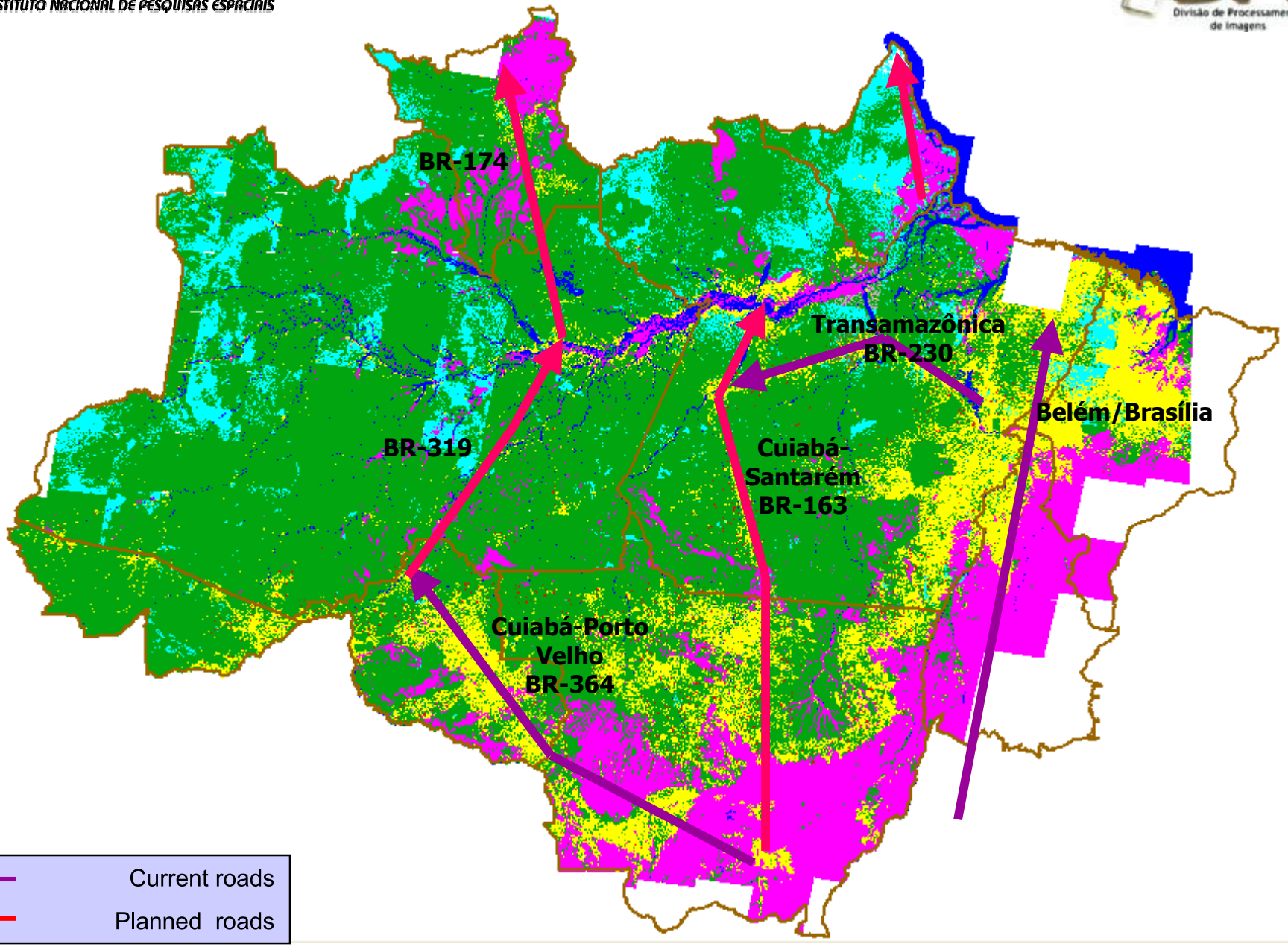


Prodes 2003/2004 (INPE, 2005)

Estudos Avançados nº 53 (Théry, H.; 2005)

Amazonian new frontier hypothesis

(Becker, 2004;2005)

- **"The actual frontiers are different from the 60's and the 70's"**
  - In the past it was induced by Brazilian government to expand regional economy and population, aiming to integrate Amazônia with the whole country.
  - Today it´s induced mostly by private economic interests and it's concentrated on focus areas in different regions.

Amazonian new frontiers Hypothesis

(Becker, 2004;2005)

- **Characteristics of XXI Century Amazonian frontiers:**
  - They are more concentrated
  - Activated by new actors with their own capital and land use strategies
  - Different patterns of migration (intra-regional and rural-urban);
  - **Motivation**
    - Agroindustry : Soybean, Logging, Cattle Ranching;
    - Land market;
    - Expectation of new transportation network establishment

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

Amazonian new frontiers context

(Becker, 2004;2005)

- **Different context from past, in terms of…**
  - Connectivity and accessibility
  - Private and endogenous roads (Imazon, 2004; Castro, 2002; Geoma, 2004, 2005);
  - Population migration patterns
  - Urban growth
  - Amazonia under local, regional and international pressure

- **Different space-time patterns (velocity, rhythm, start point, spatial configuration)**

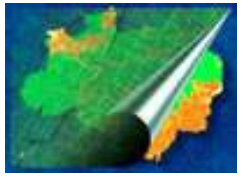
2. Using satellite data to detect Amazonian land cover dynamics

Data - Using satellite deforestation to detect land cover dynamics

- **Monitoring Amazônia Land Cover Change**

  - PRODES Started in 1989. Using TM/Landsat, 5, 4, 3 channels. Products:
    - **Annual deforestation rate estimative per Landsat scene or State;**
    - **Digital database 1997 – 2005.**

  - SISPRODES –Amazonia Legal Deforestation Detection System - TerraLIB – Aims to:
    - **Improve methodology to detect deforested areas and to automate deforestation rate estimative.**



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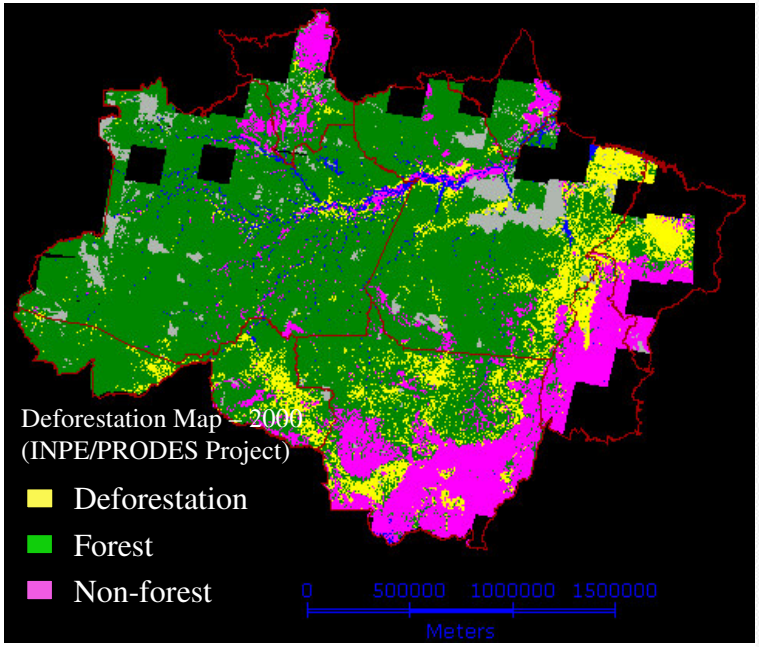
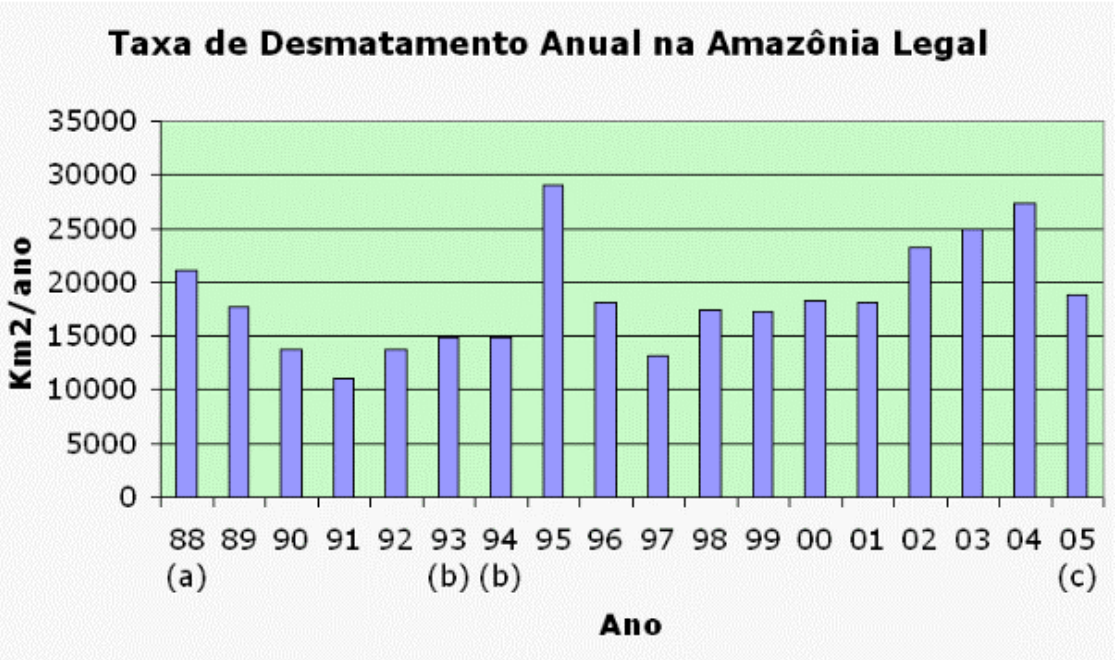
Amazonia Deforestation Monitoring

- **Prodes (INPE)**

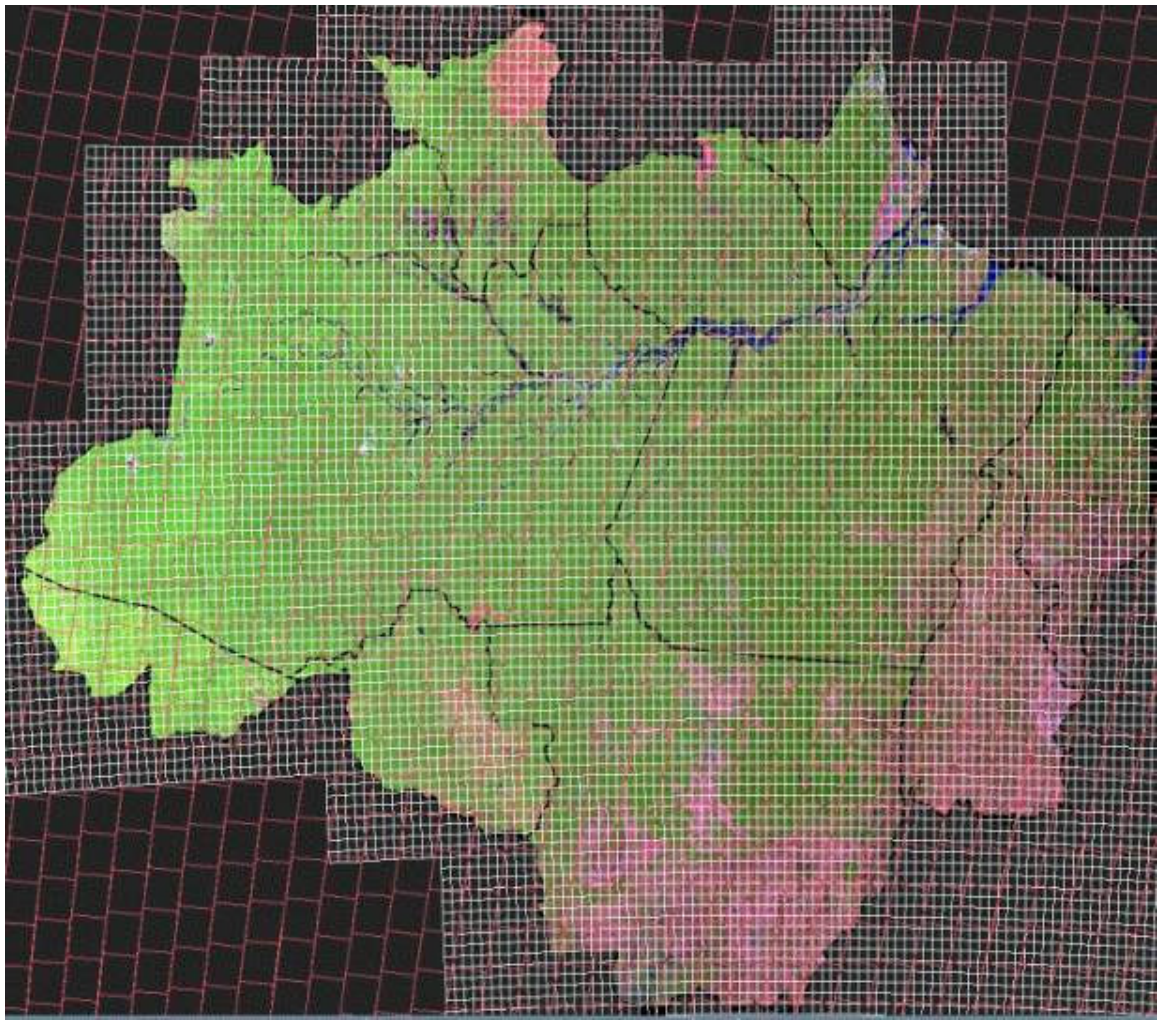




http://www.dpi.inpe.br/prodesdigital

Amazonia Deforestation Monitoring

- **ISPRODES**
  - Legal Amazônia (2000)
  - CBERS Grid
  - Cells
- **Characteristics**
  - Multi-sensor
  - Multi-user
  - 25 X 25 km cells
  - Available at internet



Amazonia Deforestation Monitoring

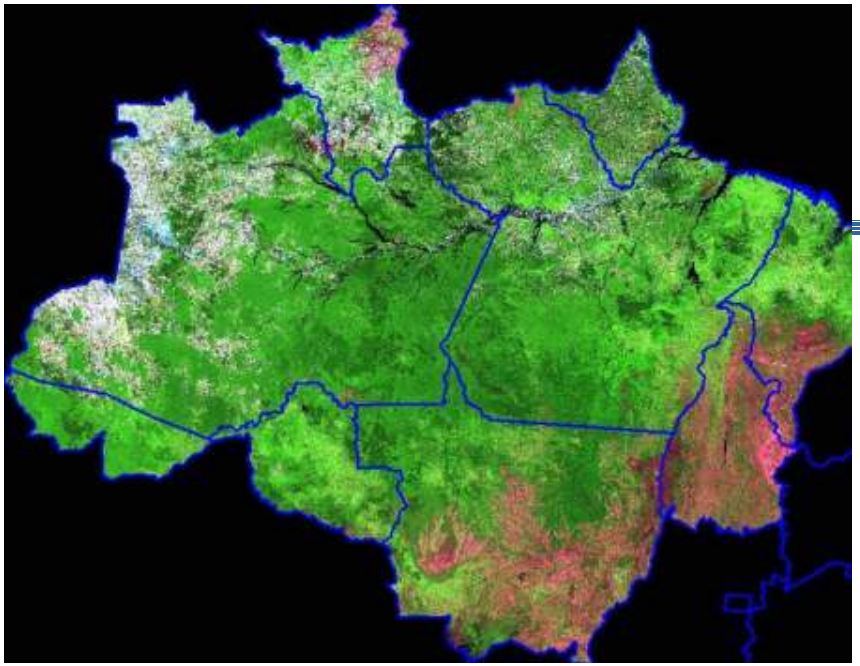
- **DETER**
  - **Detects deforestation in "quasi" real time using Modis (Aqua, Terra) and WFI (Cbers) sensors with 250 m resolution in periods of 2 to 5 days.**
  - **Builds mosaics for Amazônia Legal with images acquired from a period of 15 days minimizing clouds coverage.**
  - **Uses PRODES deforestation maps as reference to detect new cleared land (> 25 ha).**
  - **It´s a powerful product being used to combat illegal deforestation activities.**
  - **Available at internet since 2004.**

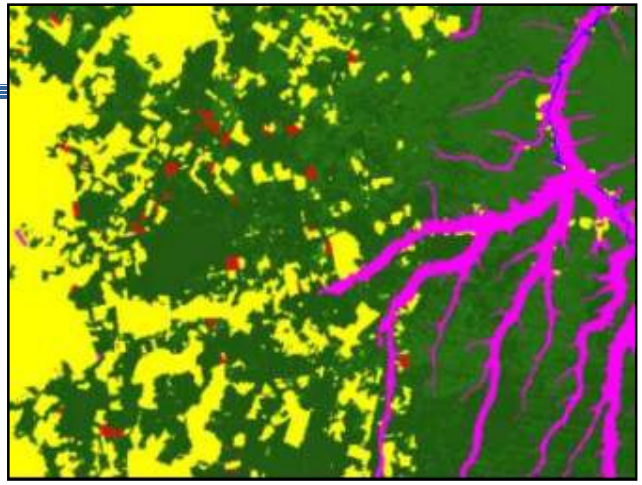
http://www.obt.inpe.br/deter

DETER

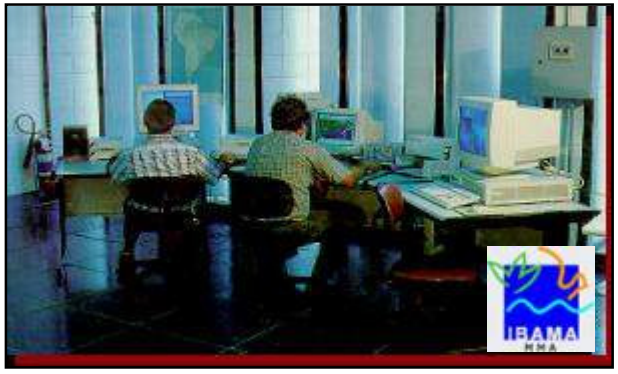
Image Processing : SPRING

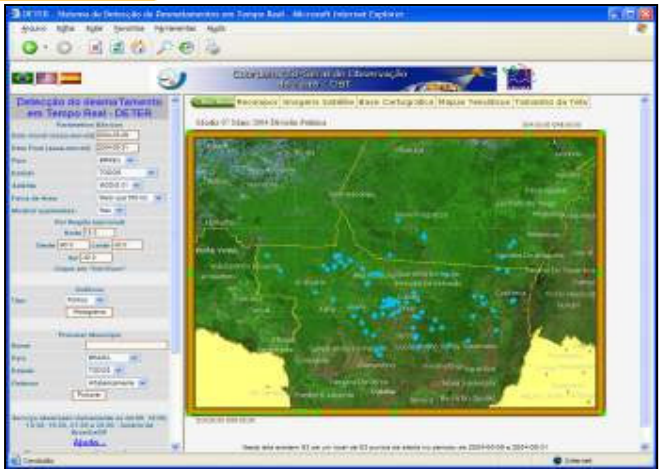
New Forest Clearing Detection





Products: Internet Geographic Data Base - TERRALIB

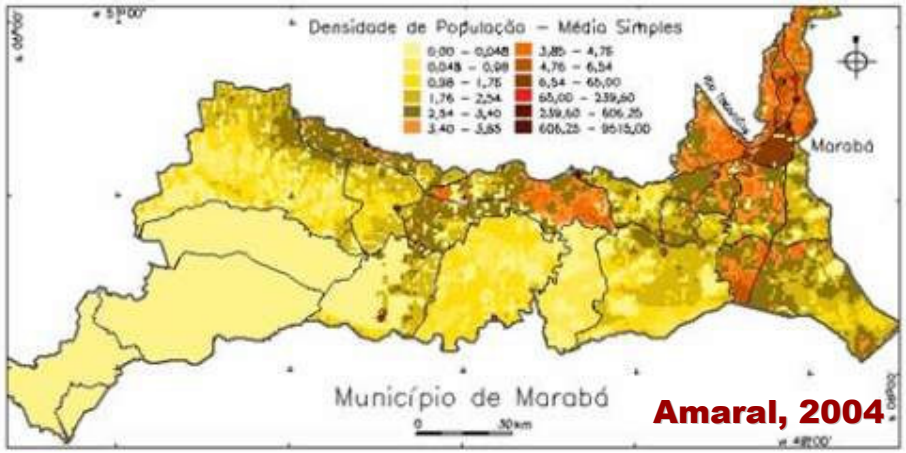




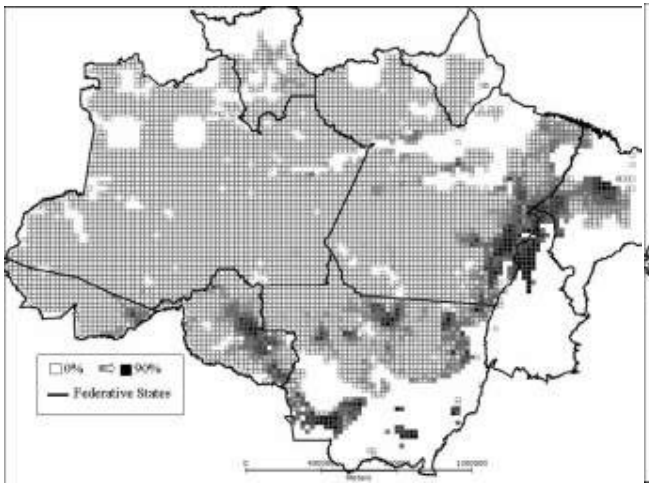
Land Use/Cover, Socio-Economic and Environmental Data Base

IBGE DATA BASE

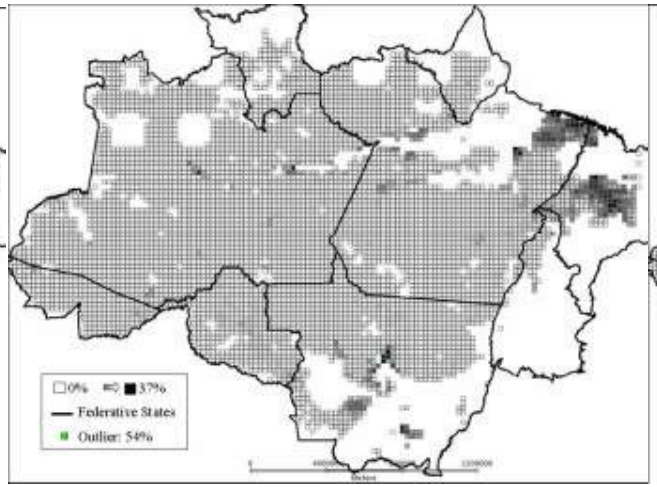
- Agricultural Census
- Populational Census
- Environmental maps



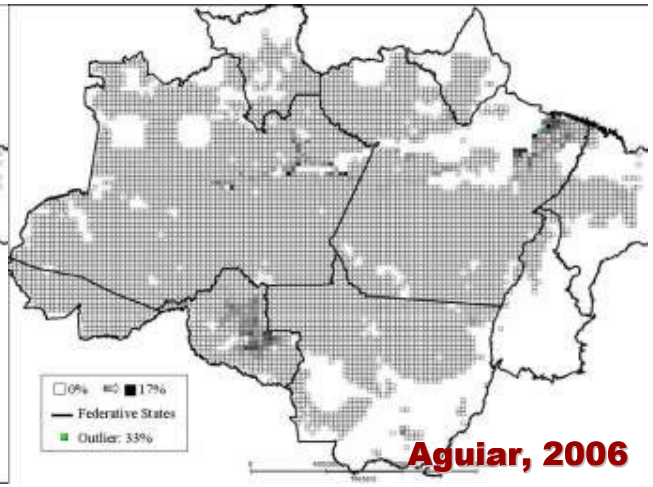
Pasture pattern in 1996/1997 (25 x 25 km2).



Temporary agriculture pattern in1996/1997 (25 x 25 km2).

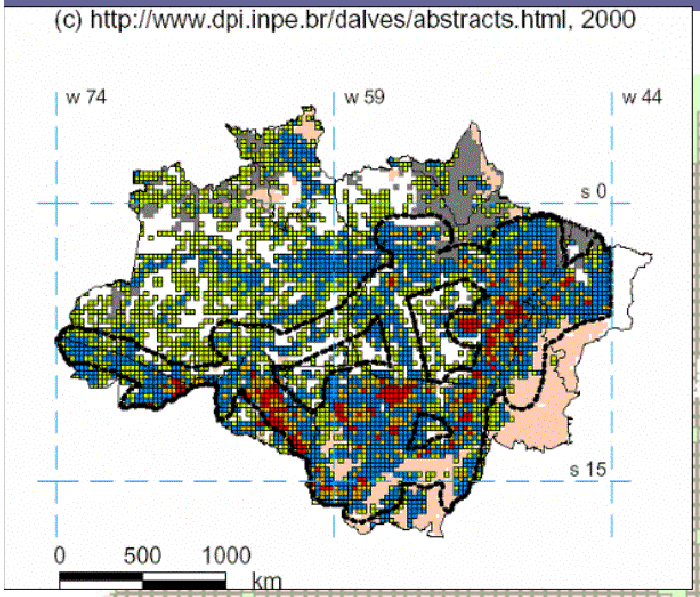


Permanent Agriculture pattern in 1996/1997 (25 x 25 km2).



3. Land Cover Change Patterns

Deforestation spatial pattern- PRODES 1997-2000 (INPE)



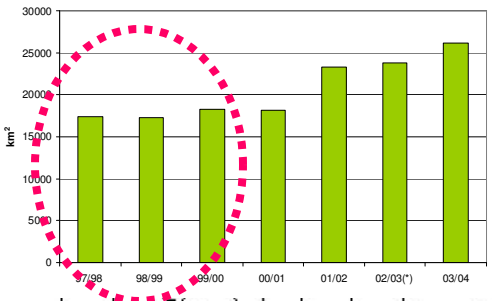
Percent cleared 1997-2000

- 0 - 06%
- 06 - 11%
- 11 - 17%
- 17 - 22%
- 22 - 28%

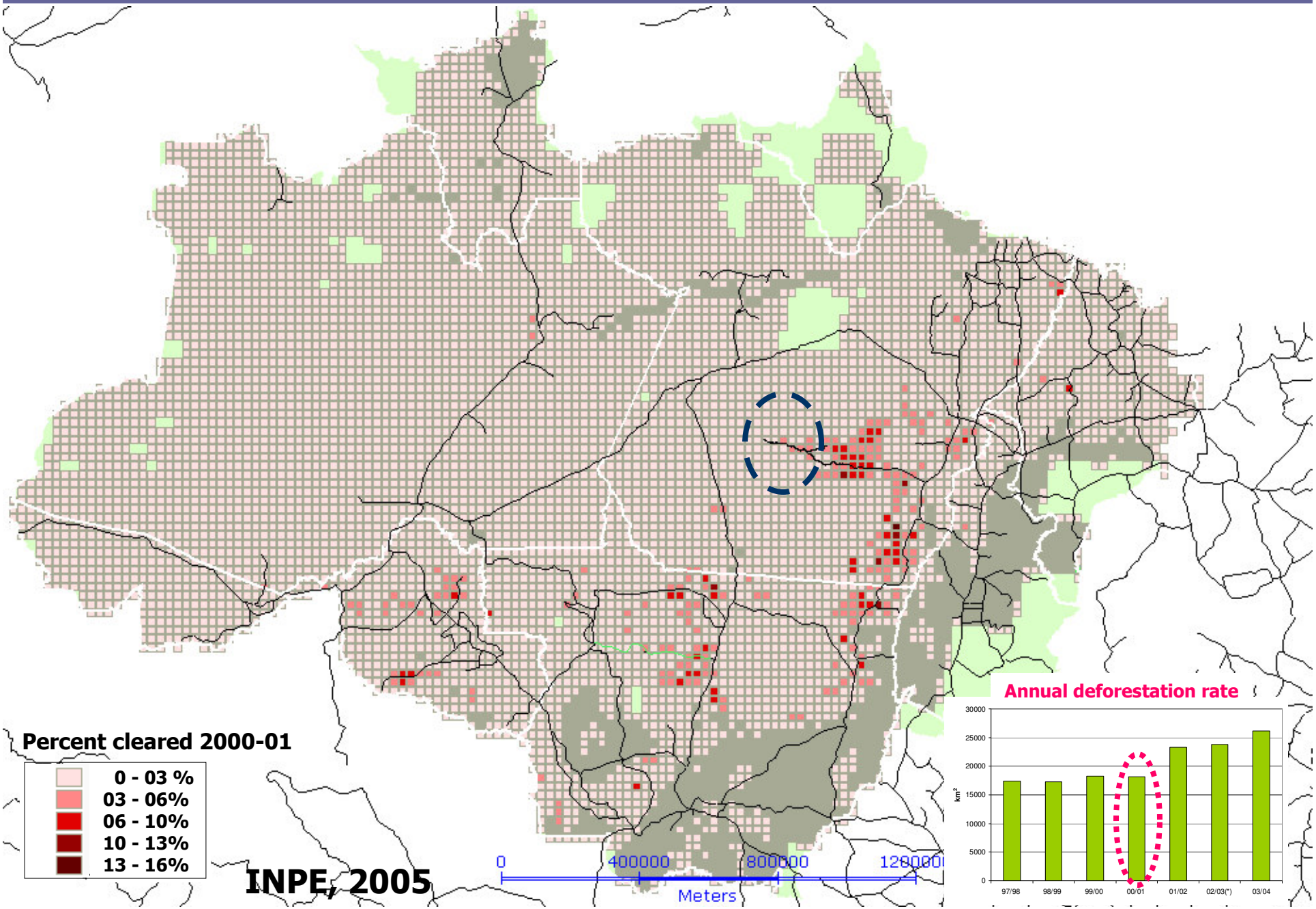
INPE, 2005

0 400000 800000 1200000
Meters

Annual deforestation rate

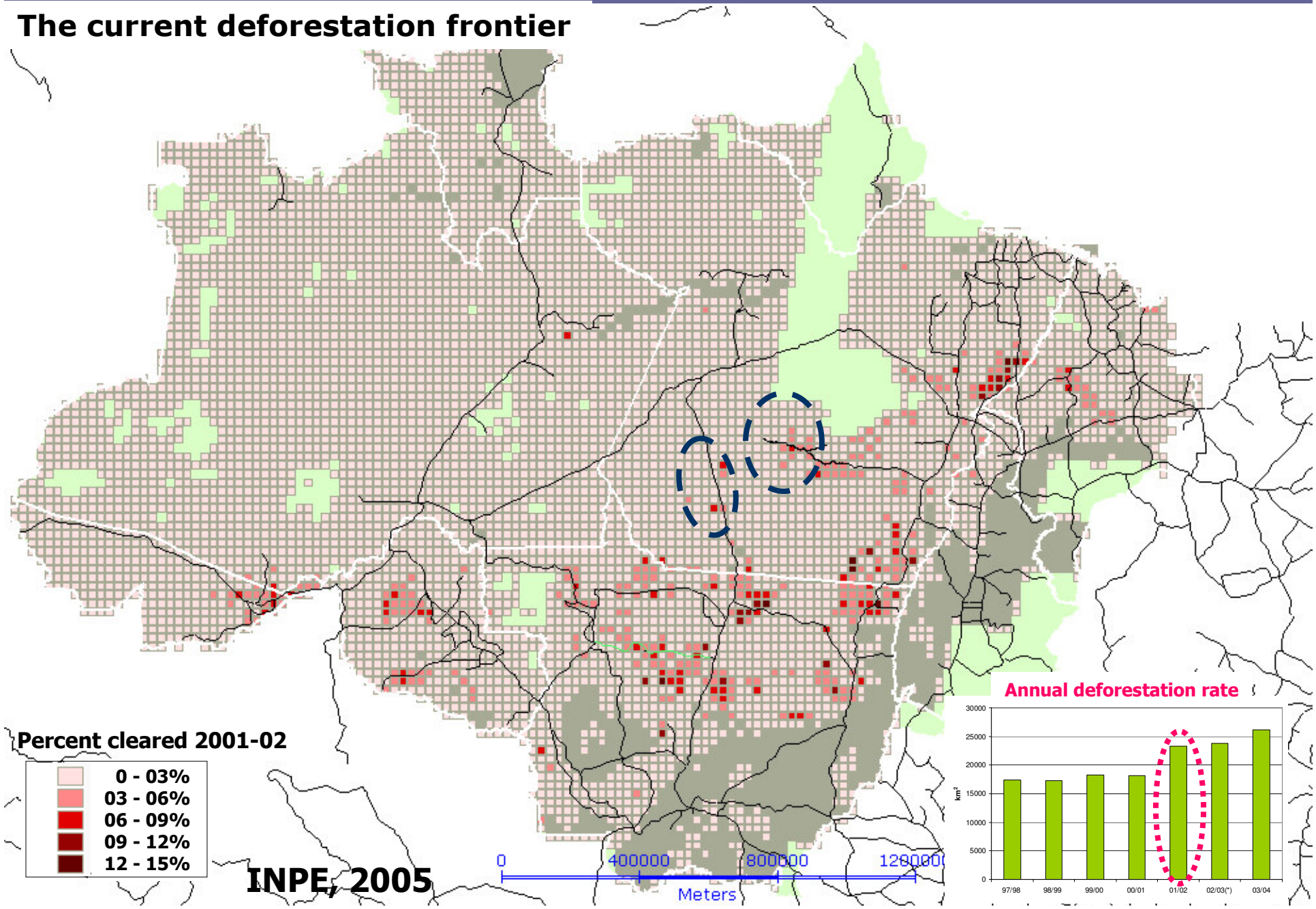


Deforestation spatial pattern - PRODES 2000-2001



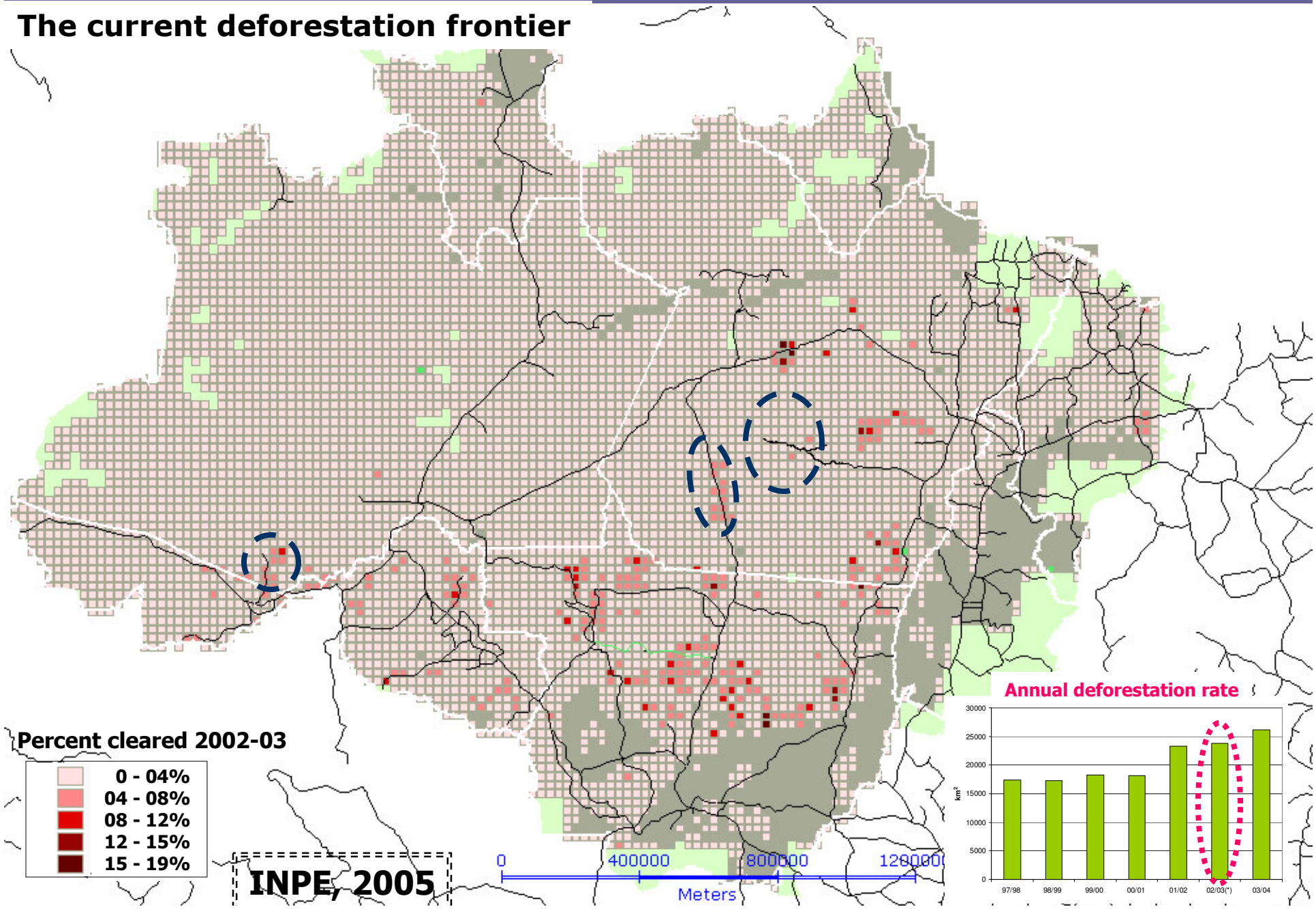
Deforestation spatial pattern - PRODES 2001-2002

The current deforestation frontier



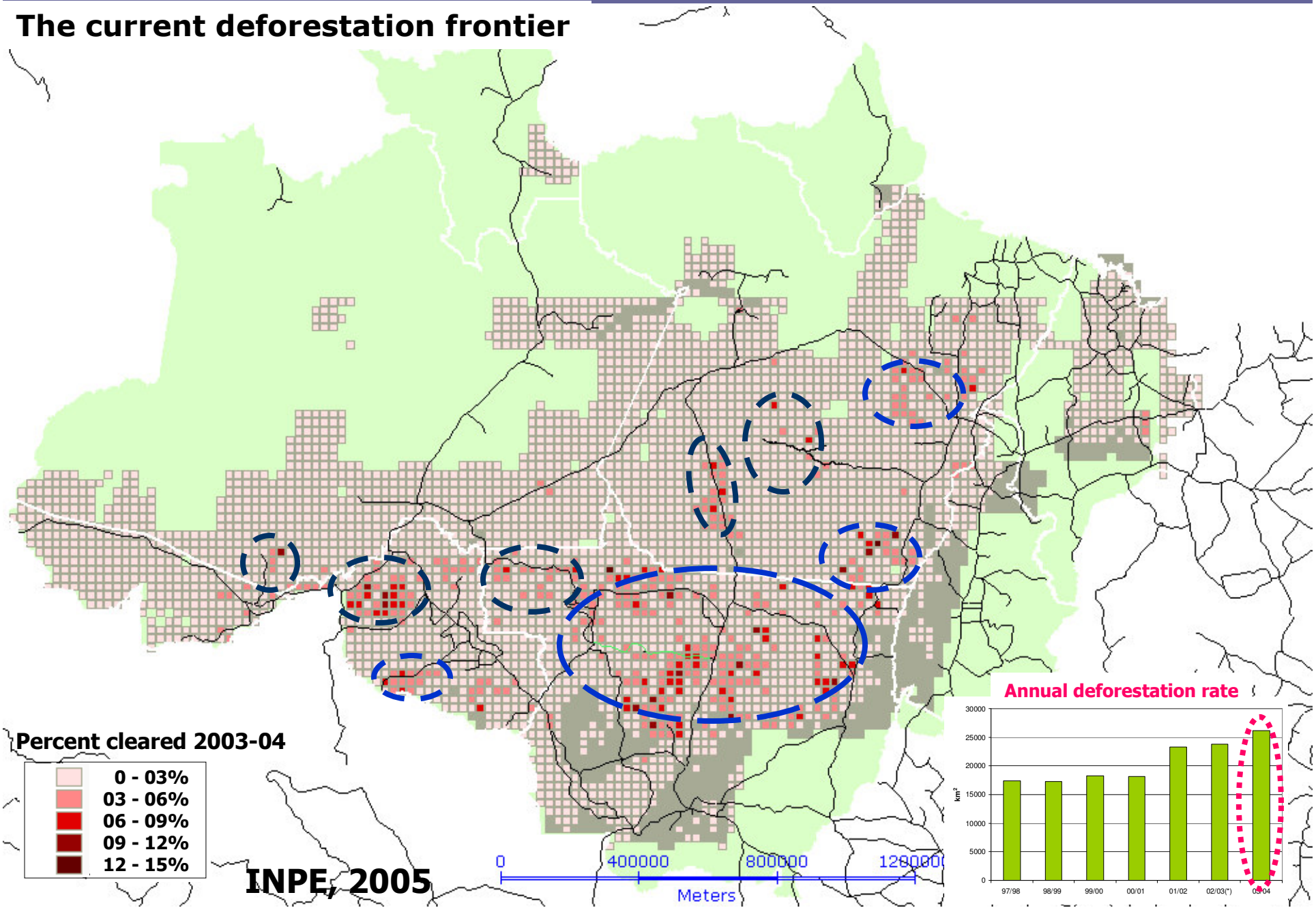
Deforestation spatial pattern - PRODES 2002-2003

The current deforestation frontier



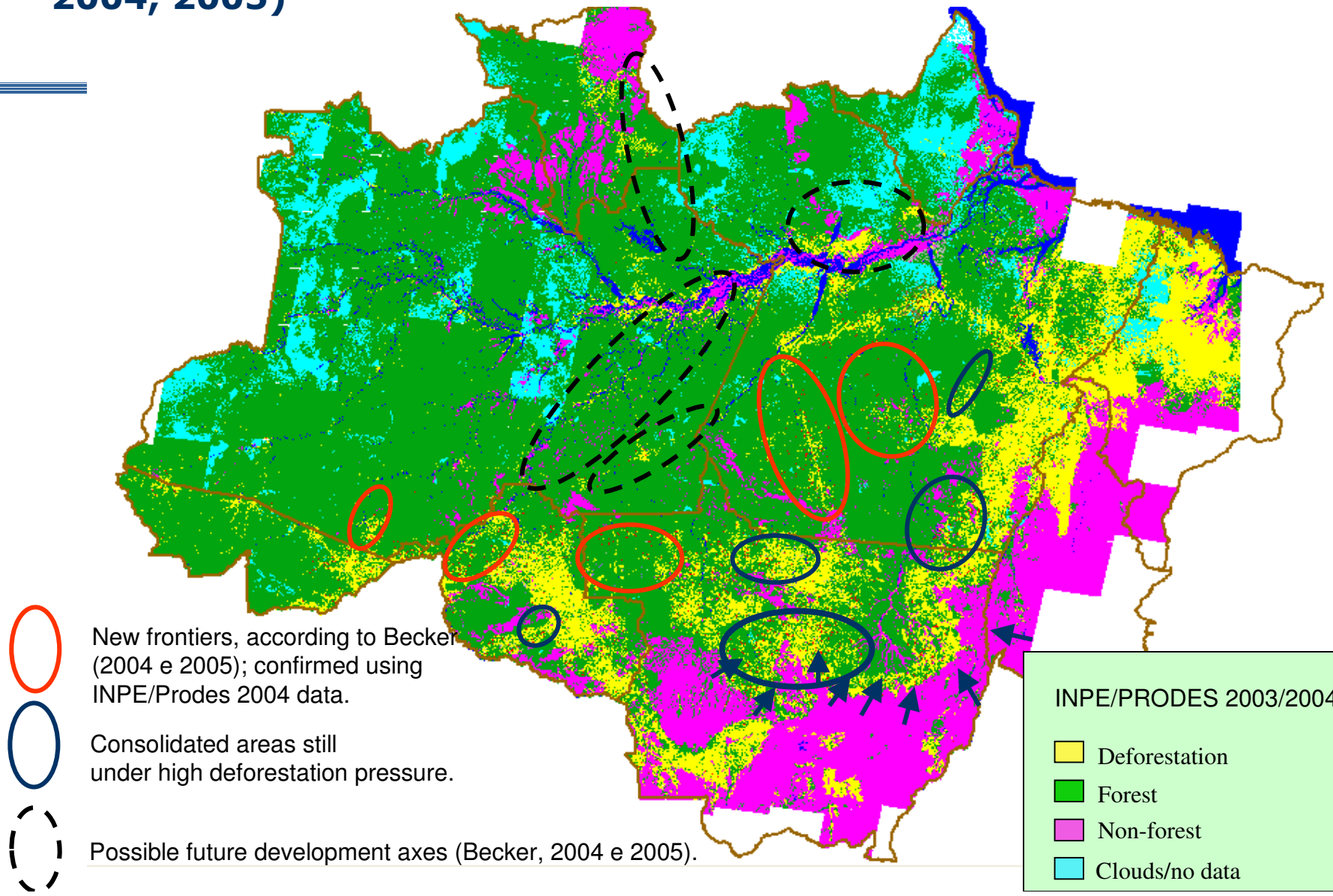
Deforestation spatial pattern - PRODES 2003-2004

The current deforestation frontier

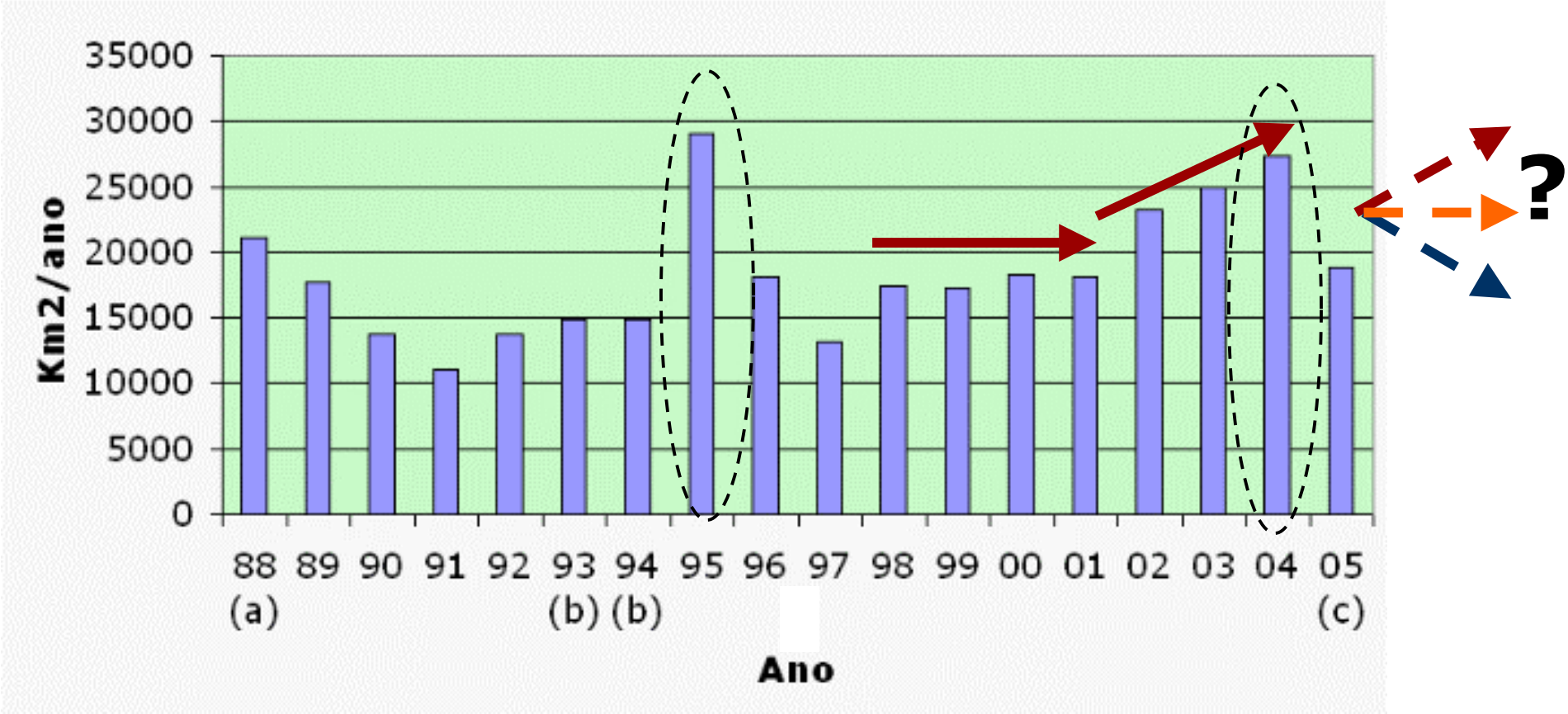


Dynamic areas (current and future)

Source: Escada et al. (2005a, 2005b); Becker (2001, 2004, 2005)



Annual Deforestation rate 1977-2005



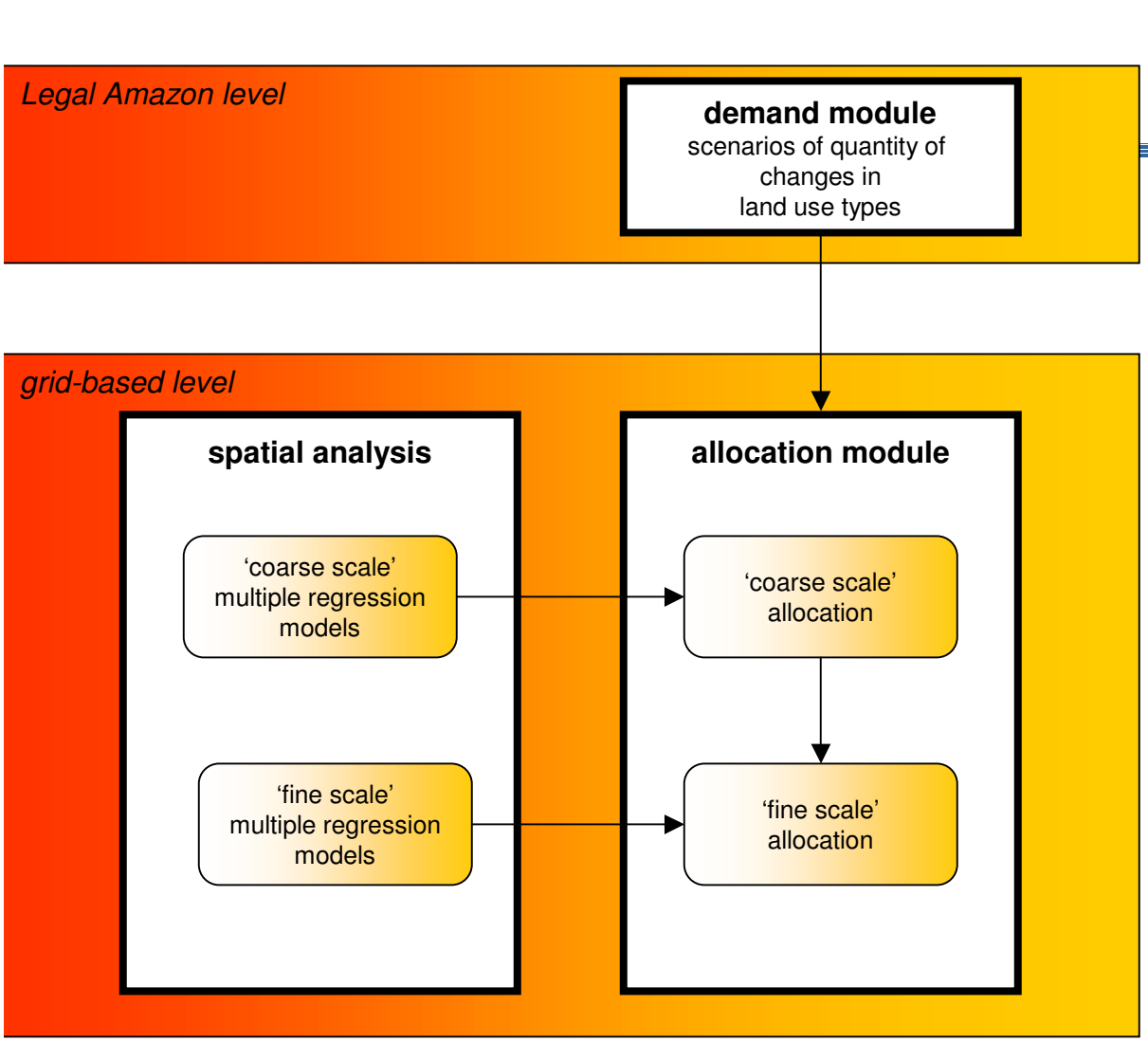
4. Using computational models to explore hypothesis

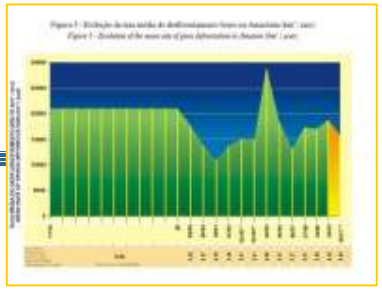
Based on the diagnosis Clue framework was used...(Aguiar et al, 2006)

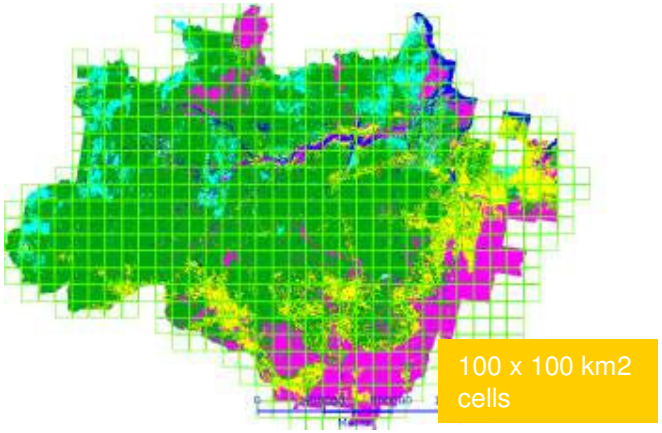
- To explore patterns of land-use change in the Brazilian Amazon
- To explore model behavior in relation to the use of alternative environmental and socio-economic factors and space partitions (Becker, 2004; 2005)
- To compare CLUE generated patterns to real data and knowledge about the new Amazonian frontiers in order to refine and select appropriated statistical models to perform policy scenario analysis.

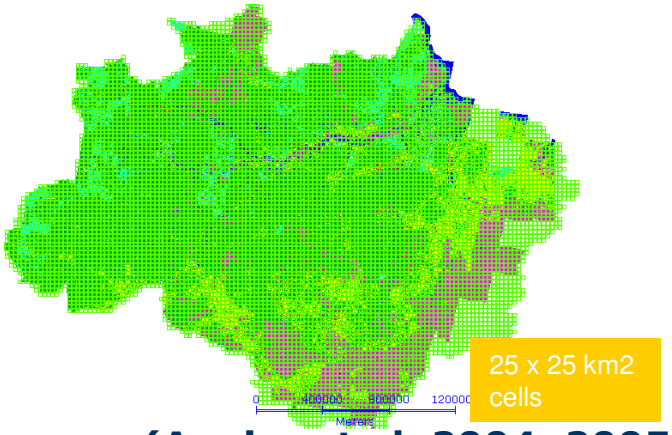
(Aguiar et al, 2004; 2005)

CLUE modeling framework
Brazilian Amazon version









(Aguiar et al, 2004; 2005)

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Test 13: Arc model applied to Central area

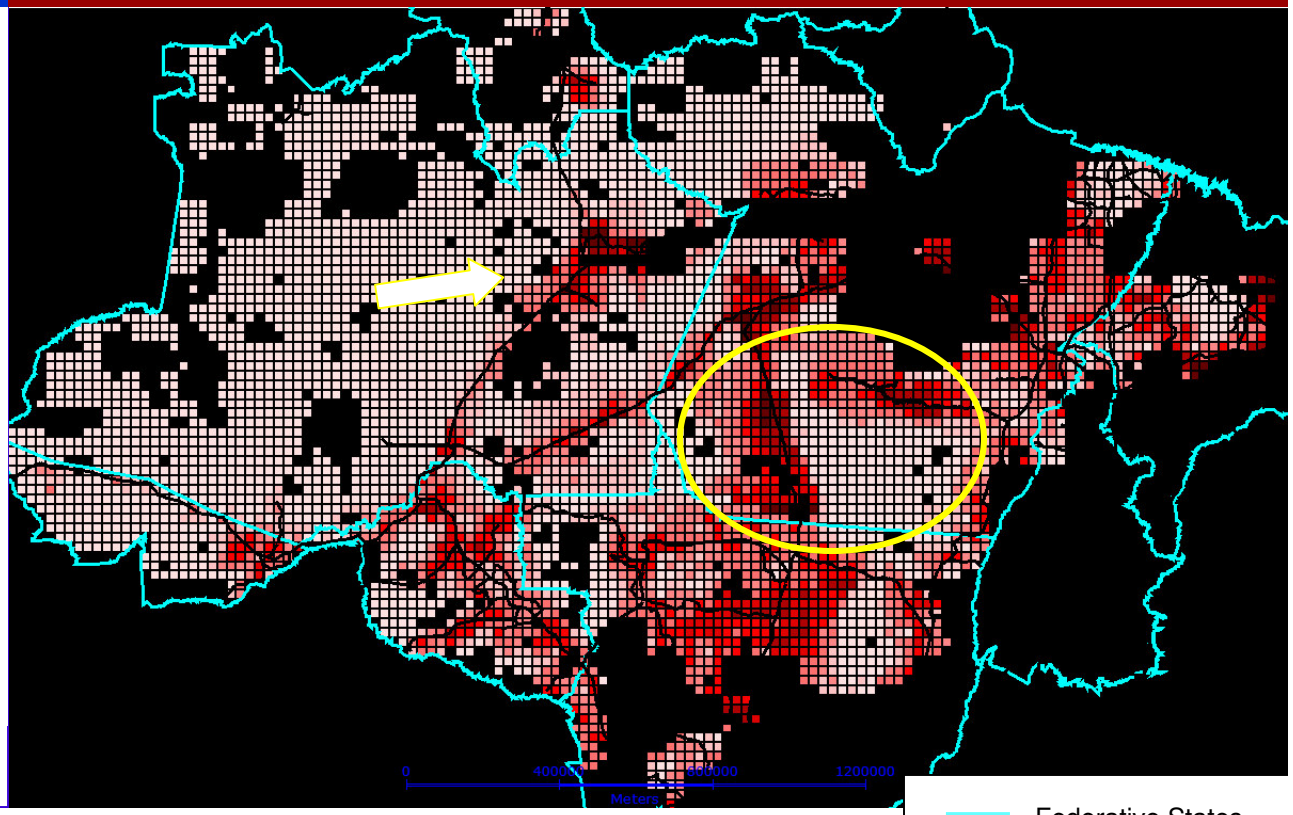
with demand regionalization, and different groups at different scales

Factors:

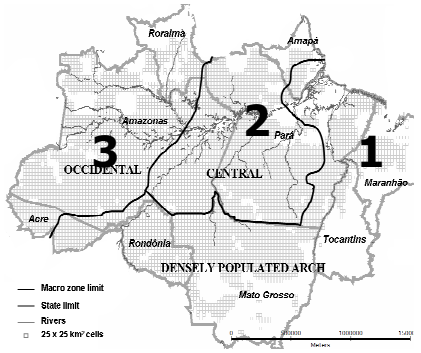
urban+conn

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

Projected hot spots of deforestation from 1997 to 2015:



Models for three Amazon Macro-zones (Becker, 2004)



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.

(Aguiar et al, `2006)

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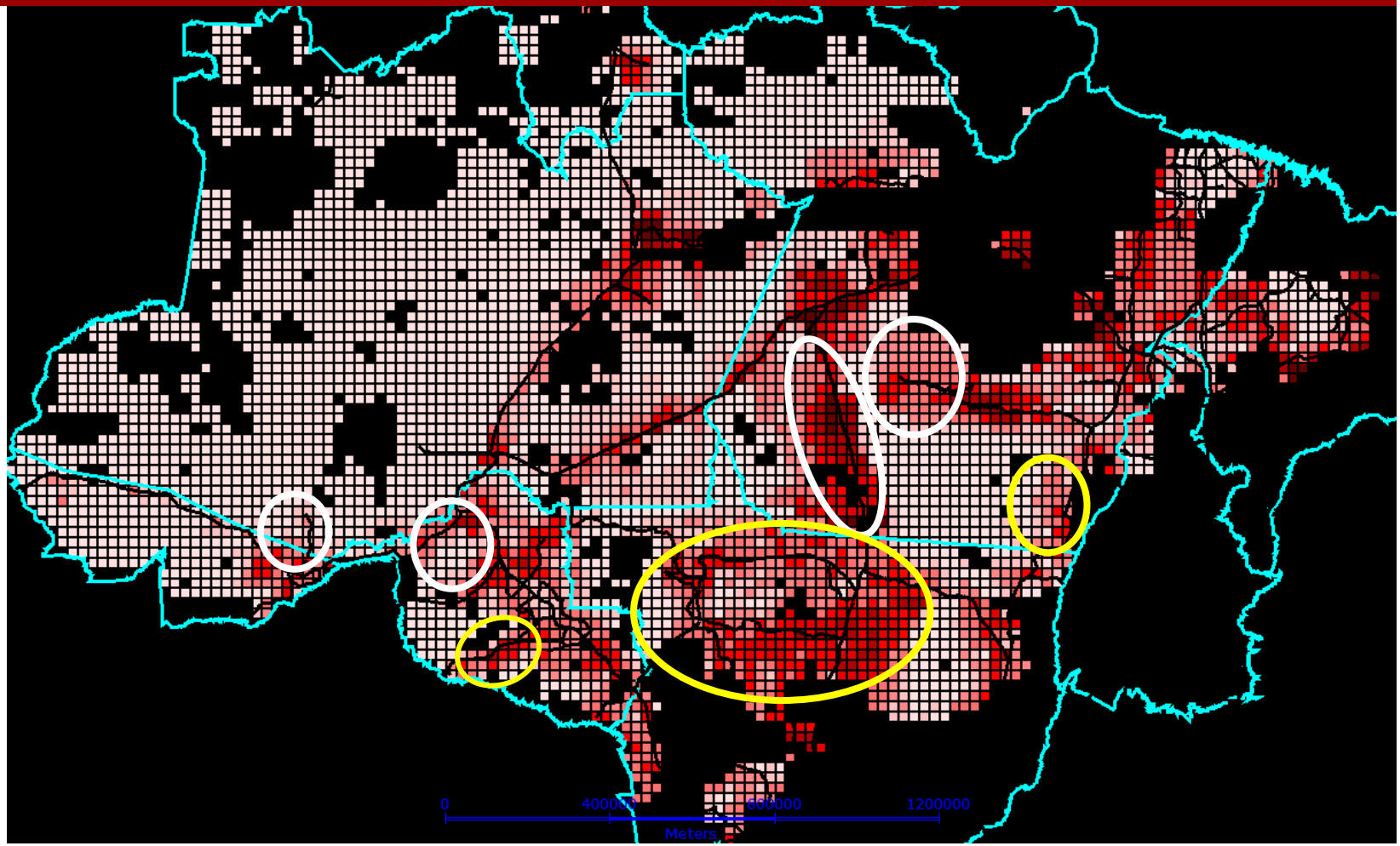
Results and dynamic areas (test 13)

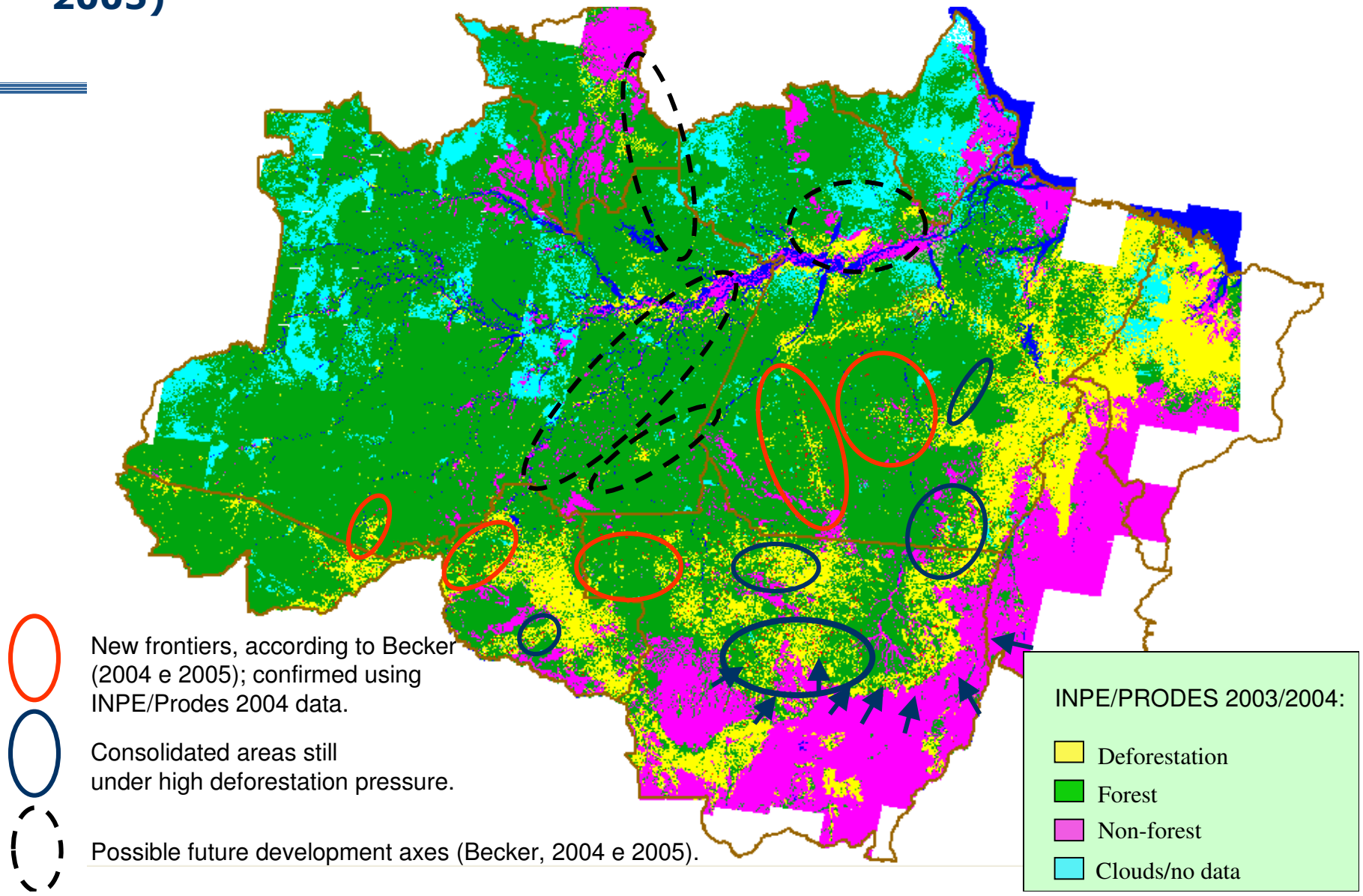
Projected hot spots of deforestation from 1997 to 2015:



(Aguiar et al, 2004; 2005)

Dynamic areas (current and future)

Source: Escada et al. (2005a, 2005b); Becker (2004, 2005)



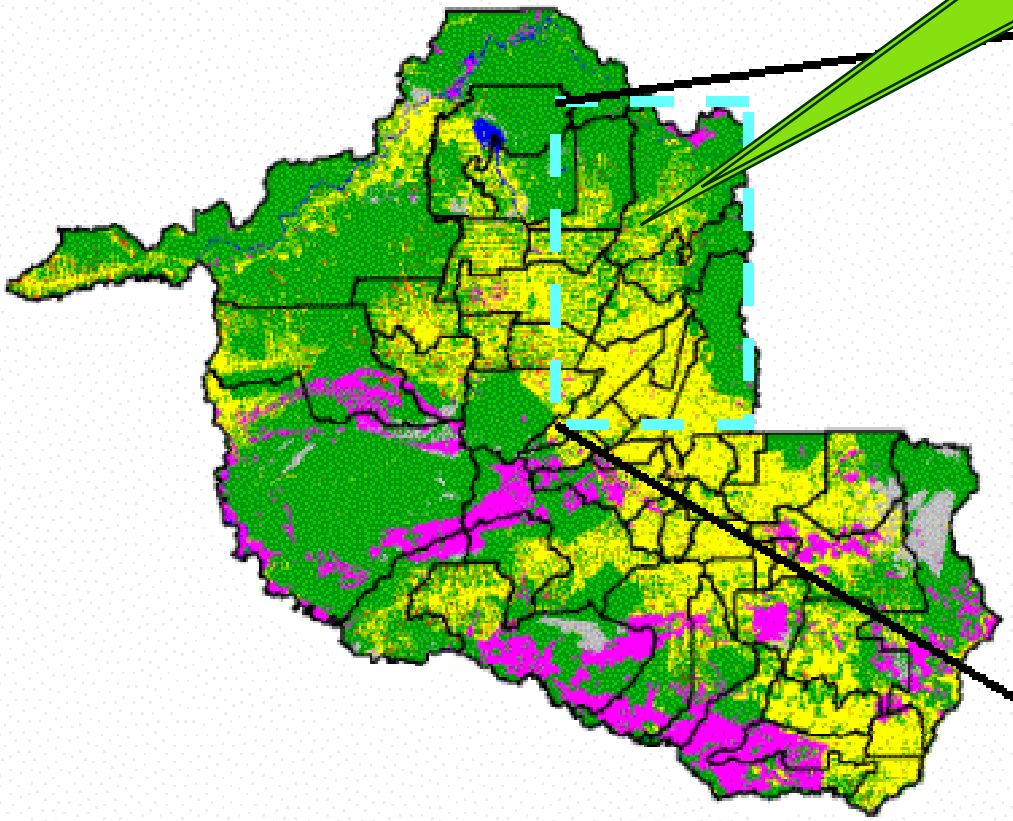
Local Level Case Studies

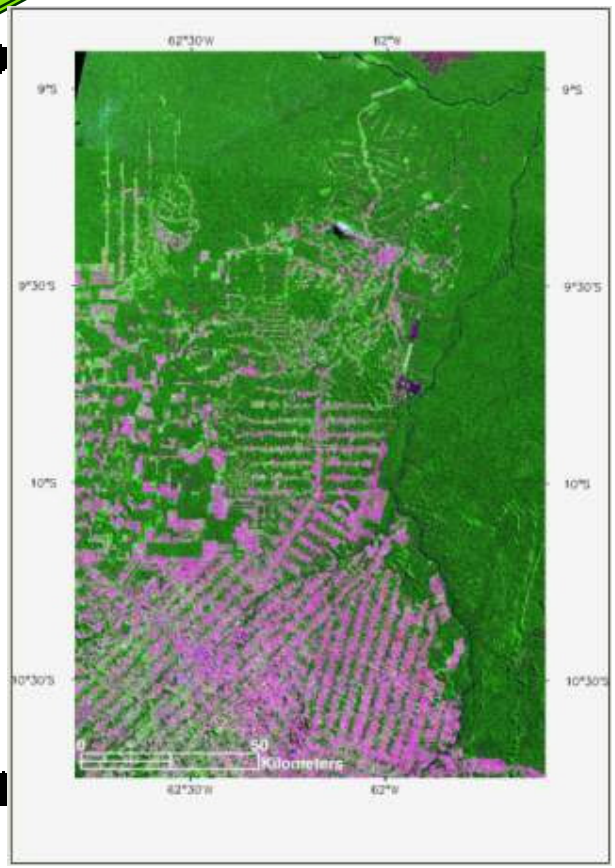
5. Rondônia

Study Case: Rondônia

- Incra settlement projects
- Small, medium and large farms
- Started in the 70's
- Different spatial and temporal patterns
- Lots size of 25 ha to 100 ha – Farms from 500 ha.
- Cattle ranching

<u>Objective:</u> To capture patterns and to characterize and model land use change processes



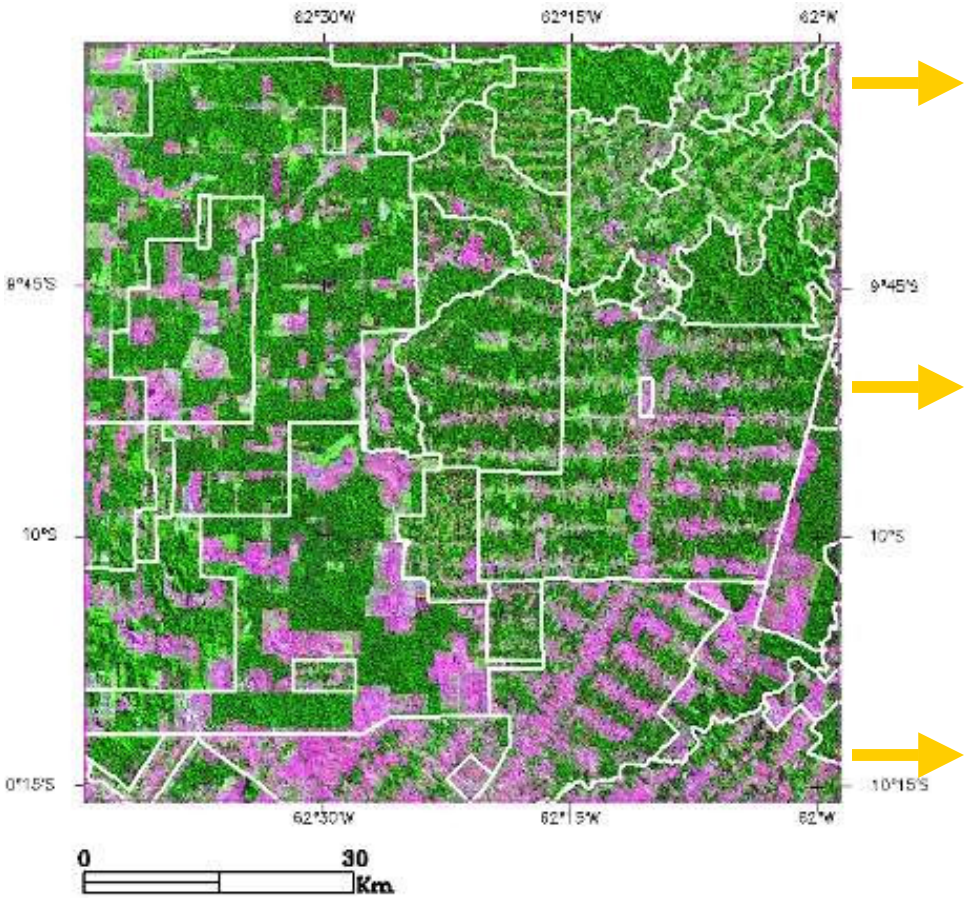


Escada, 2003. *Prodes (INPE, 2000)*

TM/Landsat, 5, 4, 3 (2000)

Landscape Analysis: Land units associated to different actors, occupation history, spatial configuration, land use dynamic, relief, land cover, rivers and roads network.
UOP- Unidades de Ocupação

Space Segmentation in Rondônia (Escada, 2003).

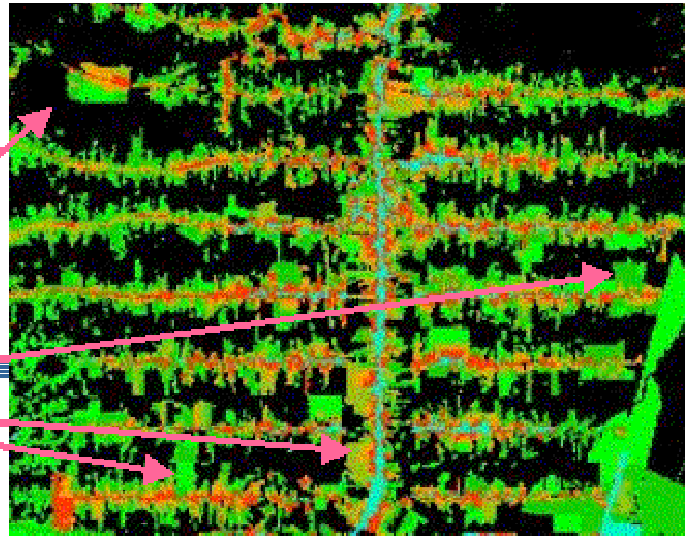


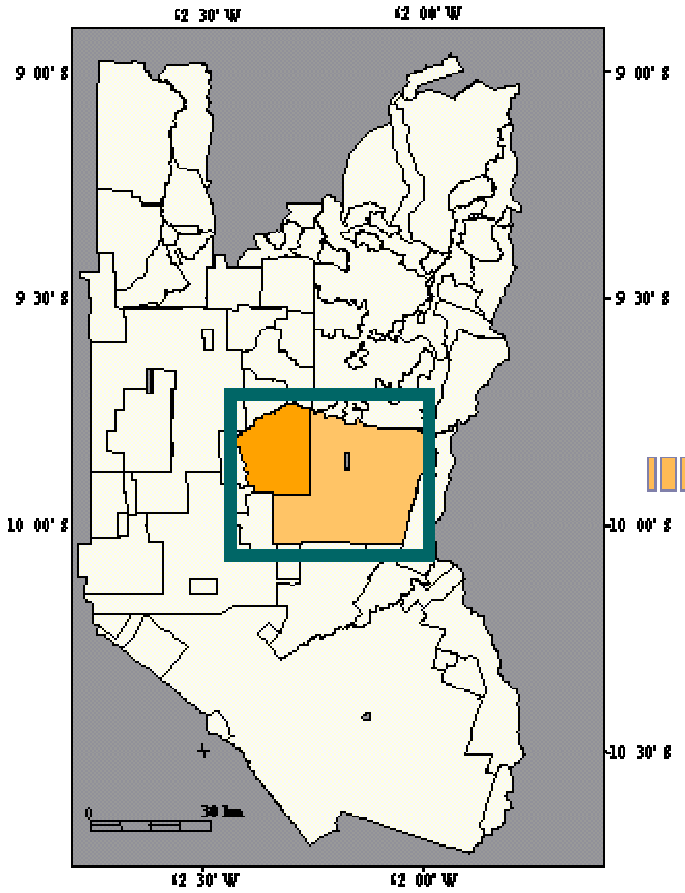
...helping to build a typology linking human settlements and their activities to the landscape Transformation.

Detecting deforestation patterns and their land use semantic

Changes in Incra parcels configuration by (Coy, 1987; Pedlowski e Dale, 1992; Escada 2003):

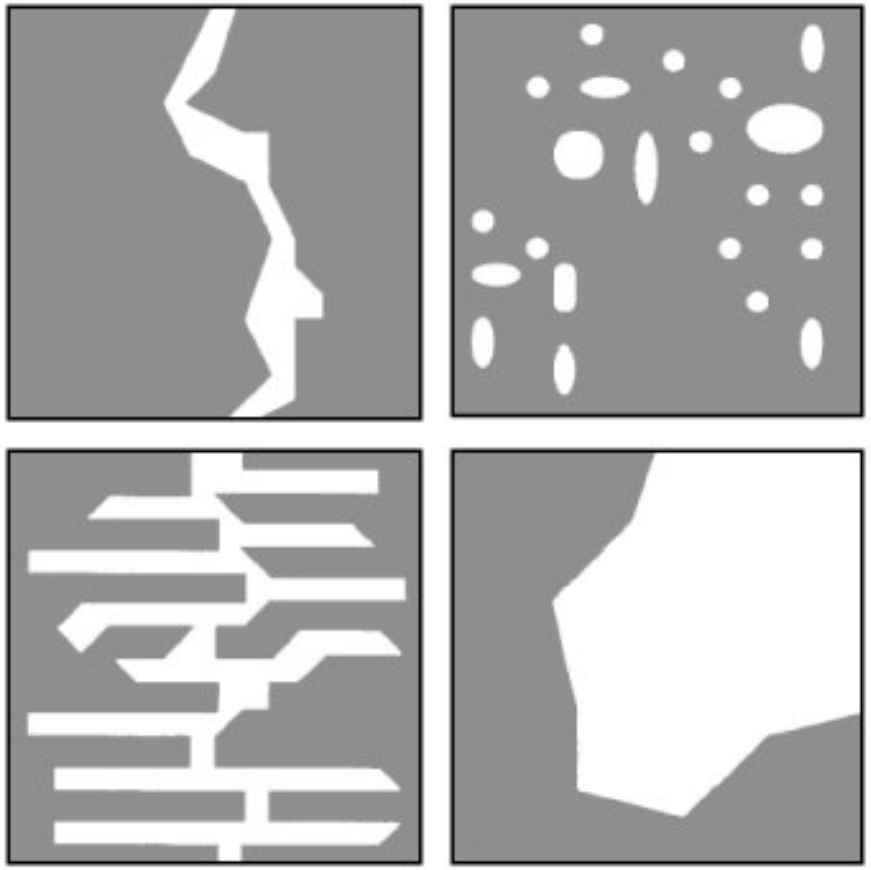
- Fragmentation
- Transference
- Land concentration





1. What was the predominant clearing pattern ?
2. How did it evolutes?
3. When did land parcels concentration process started to emerge?
4. In which proportion has this process happened?”

Spatial Pattern Typology



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

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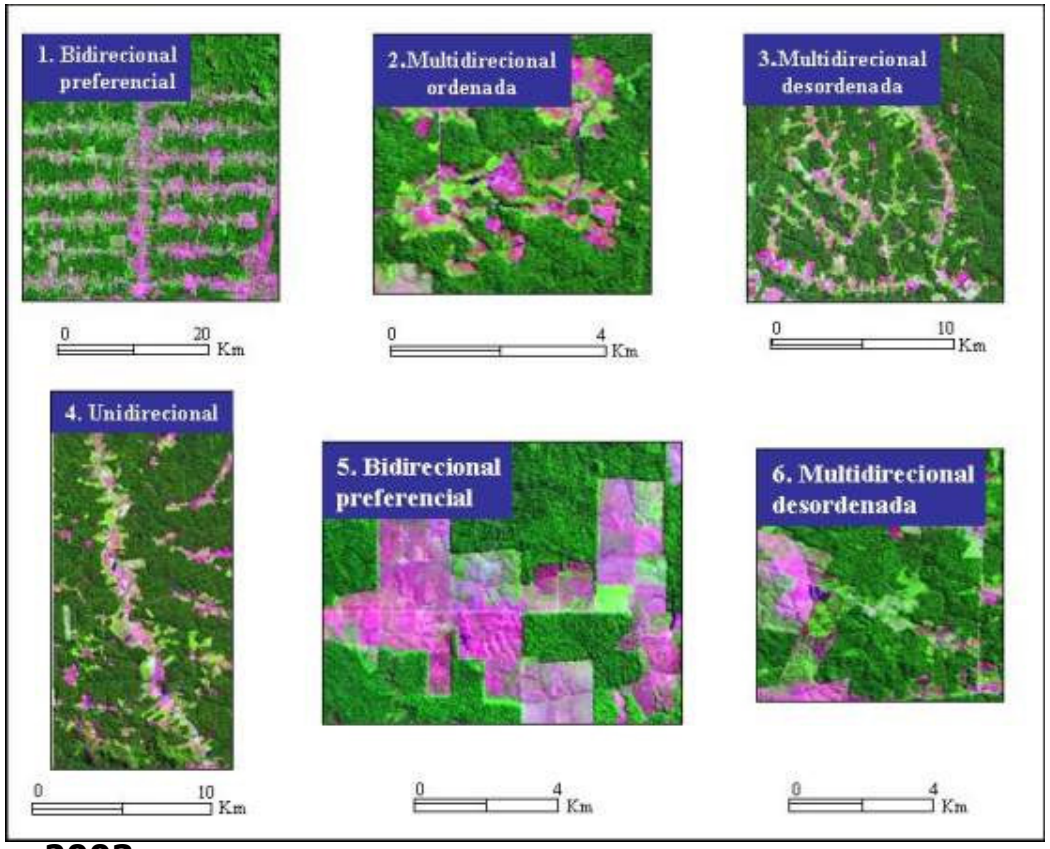
Image interpretation method to map and to establish land use typology

1. Spatial Analysis



Escada, 2003.

2. Temporal Analysis

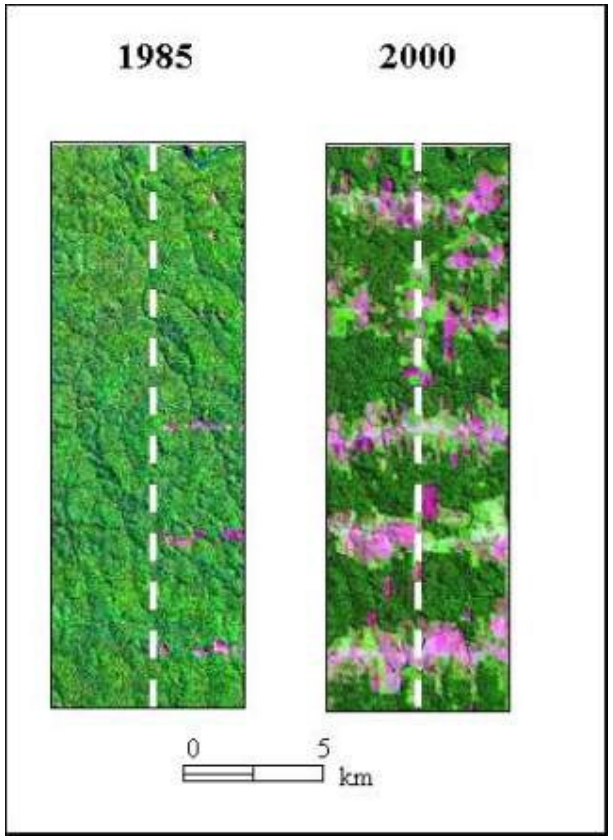
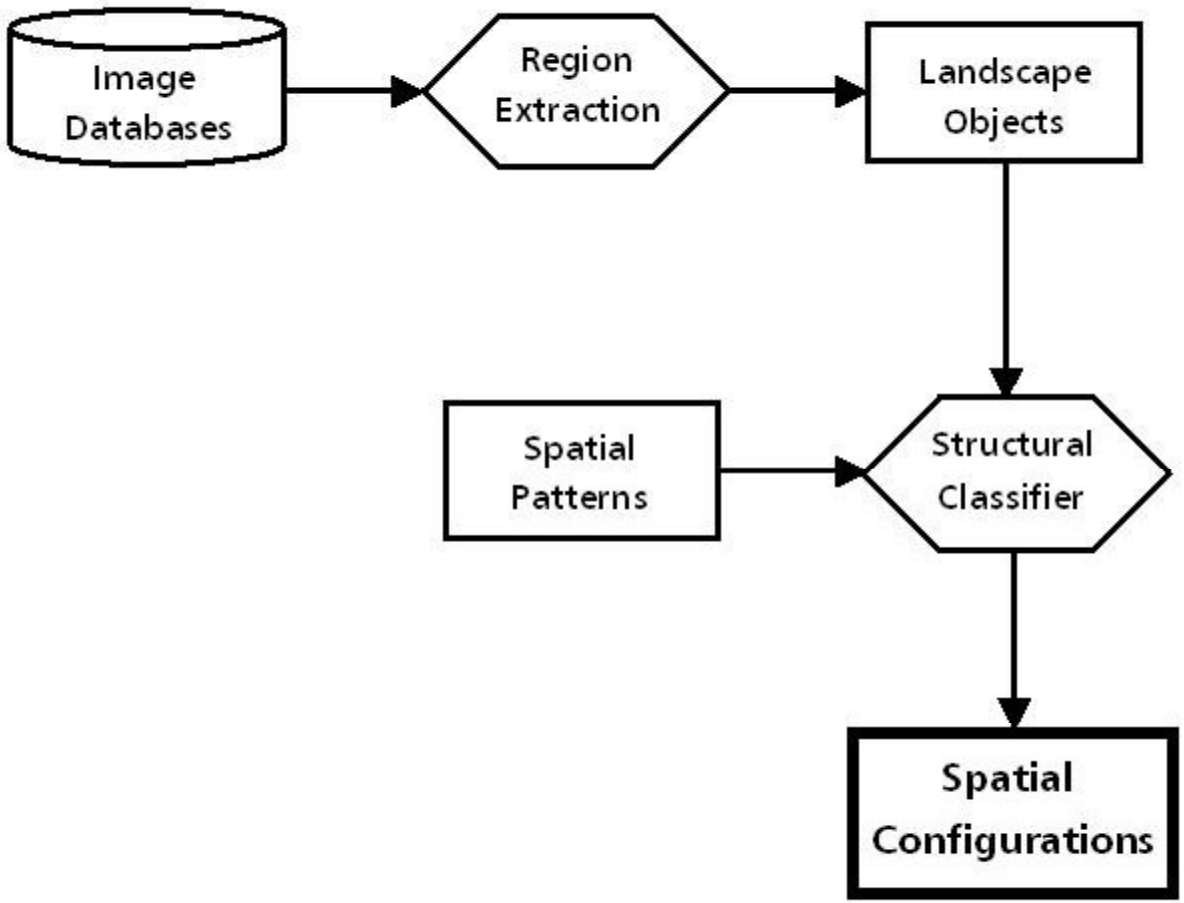


Image Data Mining

- **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**

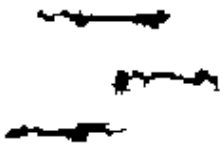
Silva et al, 2005; 2006

Obtaining Spatial Configurations



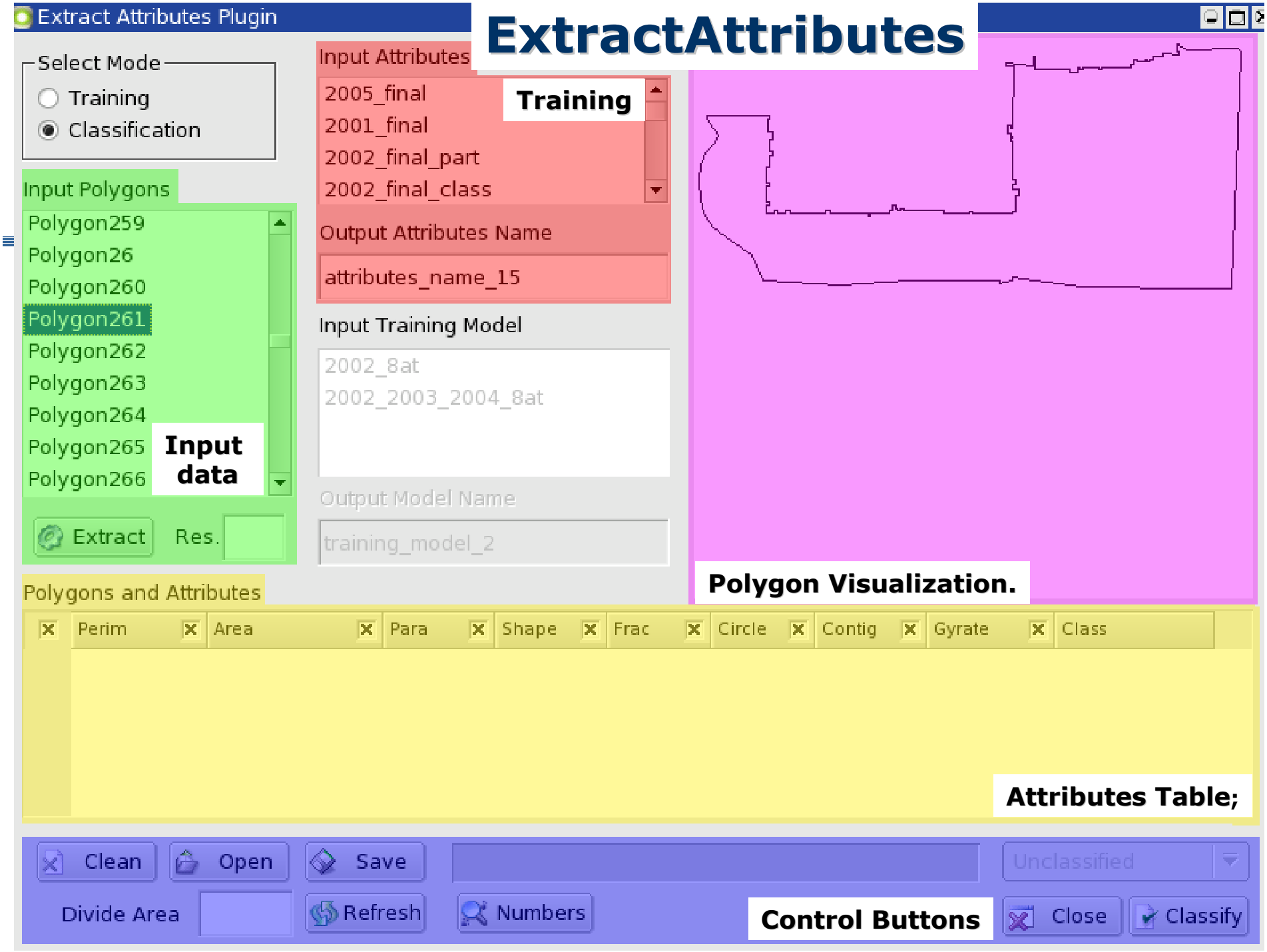
Silva et al, 2005

Spatial Patterns typology – Vale do Anari

Clearing Patterns	Spatial Distribution	Clearing size	Actors	Main land use	Description
1. Linear 	Roadside	Variable	Small household colonist	Family labor, subsistence crop and/or cattle ranching	INCRA settlement scheme 50 ha land parcel. Roadsided clearings, with linear pattern following Incra´s planned roads corresponding to the earlier stages of colonization.
2.Irregular 	Near main roads and populational nucleous	Small (< 50ha)	Small household colonist	Family labor, subsistence crops and/or cattle ranching	INCRA settlement scheme 50 ha land parcels. Irregular clearing near roads following INCRA parcels configuration.
3.Geometric 	Near roads and populational nucleous	medium and large (> 50 ha)	Medium to large farmers	Cattle ranching, mainly	Located near roads, following INCRA parcels configuration. Geometric pattern originated from concentration of more than one parcel.

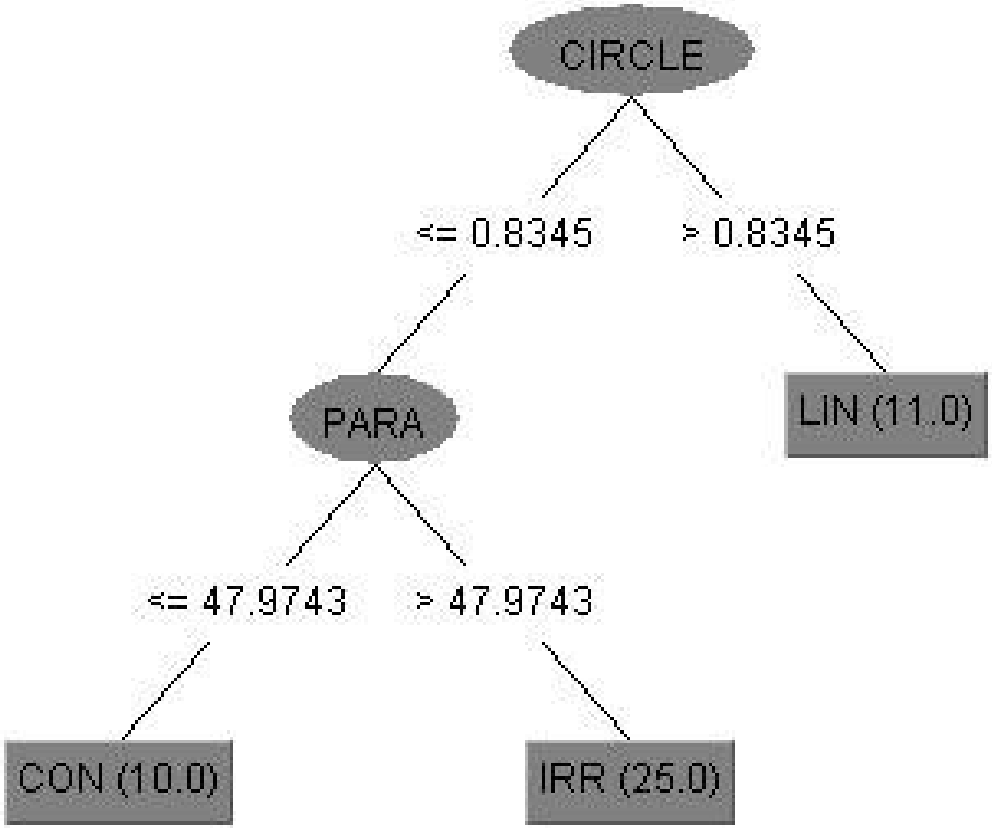
Extraction of Attributes Steps

- 1. Extration of the attributes
- 2. Training
- 3. Classification


Extract Attributes Plugin
ExtractAttributes
Select Mode
Training
Classification
Input Attributes
2005_final
2001_final
2002_final_part
2002_final_class
Training
Output Attributes Name
attributes_name_15
Input Polygons
Polygon259
Polygon26
Polygon260
Polygon261
Polygon262
Polygon263
Polygon264
Polygon265
Polygon266
Input data
Input Training Model
2002_8at
2002_2003_2004_8at
Output Model Name
training_model_2
Extract
Res.
Polygon Visualization.
Polygons and Attributes
Perim
Area
Para
Shape
Frac
Circle
Contig
Gyrate
Class
Attributes Table;
Clean
Open
Save
Unclassified
Divide Area
Refresh
Numbers
Control Buttons
Close
Classify

Mining Model

J48 – Cross Validation – 98% - 46 samples



Patterns

IRR: Irregular (areas < 84 ha)

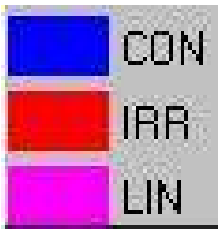
LIN: Linear (continuous structures)

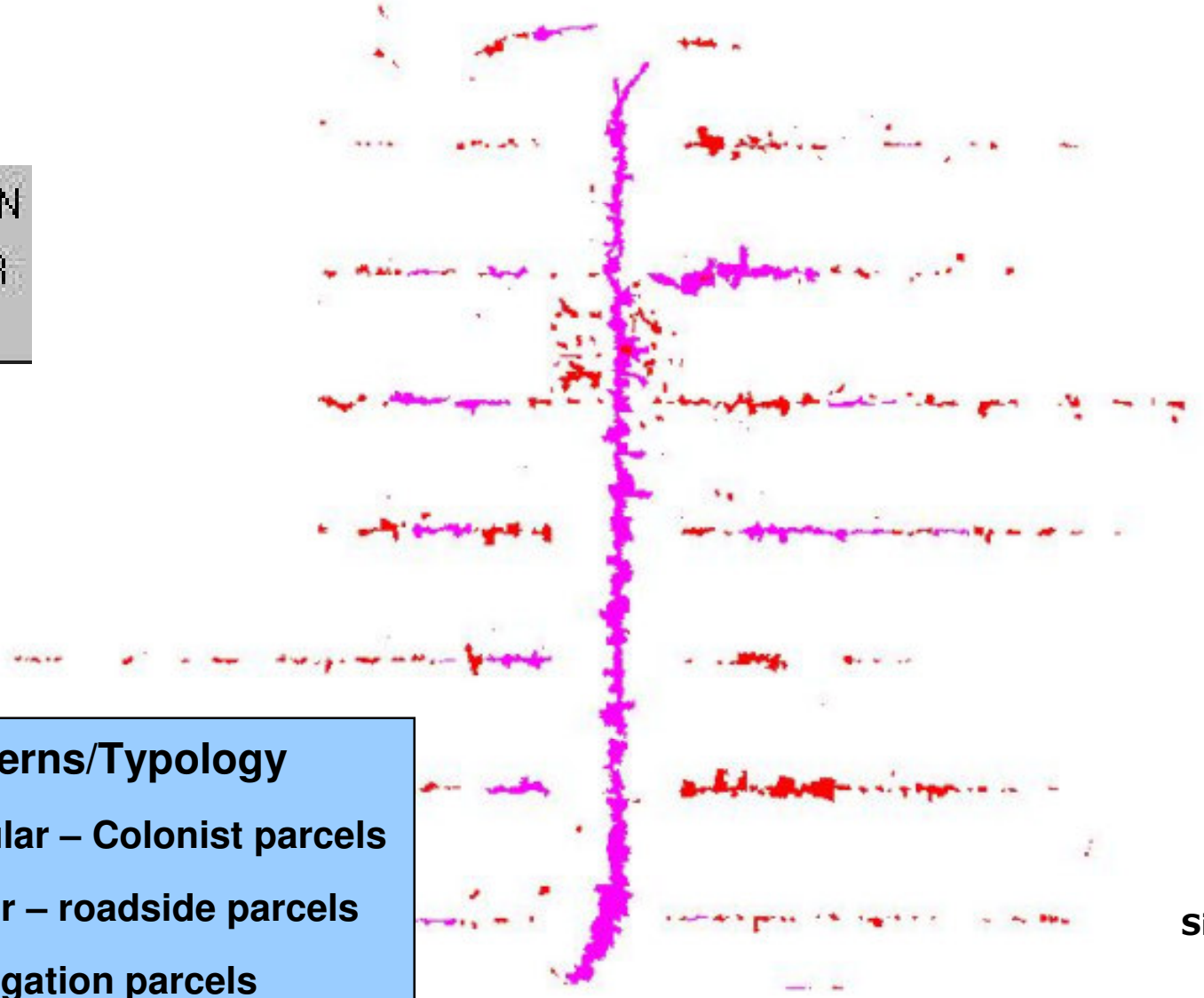
CON: Concentration (settlements)

```
=== Confusion Matrix ===

  a   b   c   <-- classified as
 10   0   0   |   a = CON
  0  11   0   |   b = LIN
  0   1  24   |   c = IRR
```

Vale do Anari – 1982 -1985





Patterns/Typology

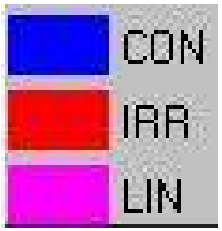
IRR: Irregular – Colonist parcels

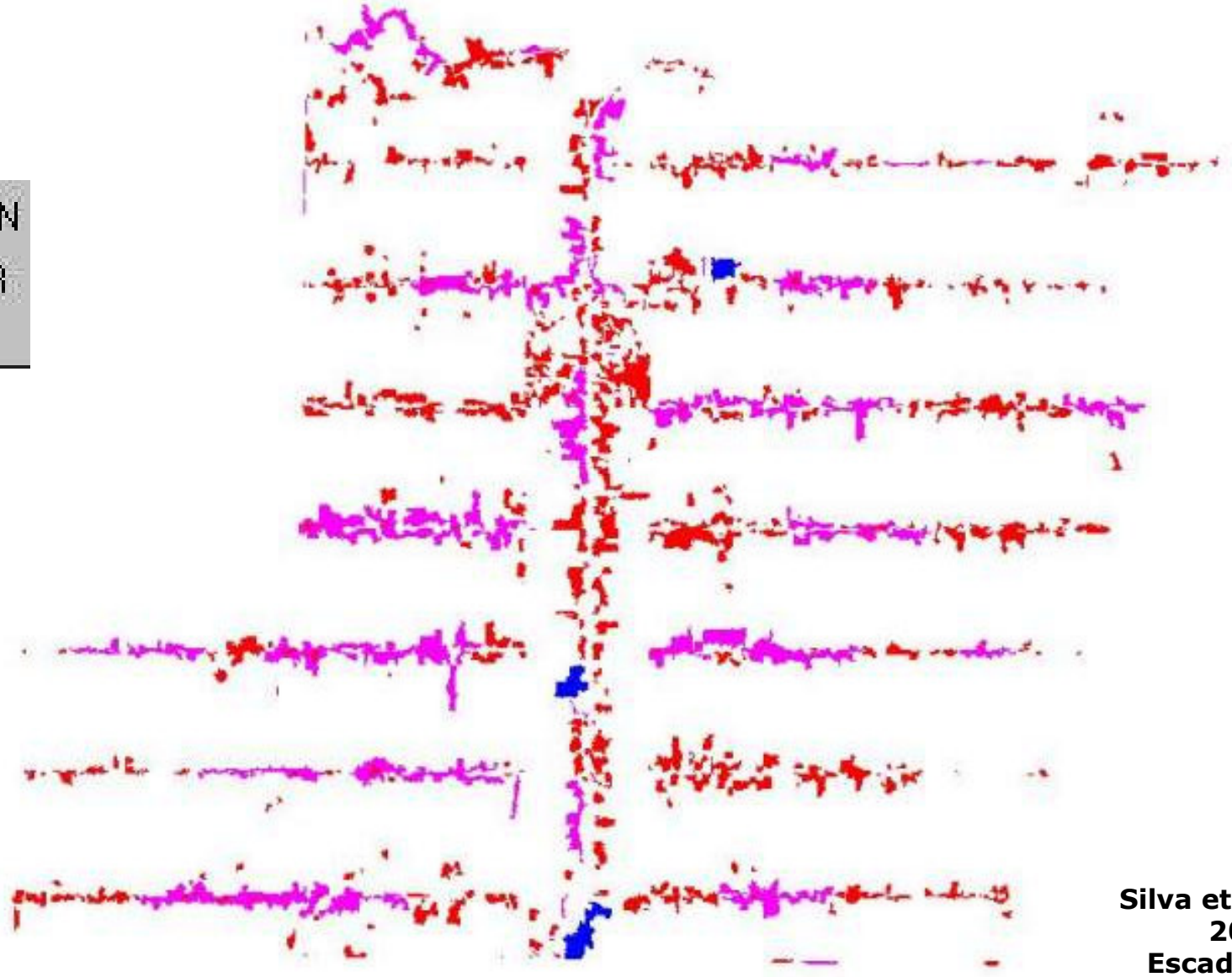
LIN: Linear – roadside parcels

CON: Agregation parcels

Silva et al, 2005; 2006
Escada, 2003

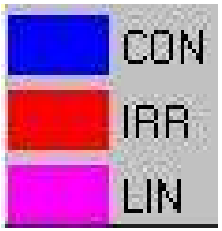
Vale do Anari – 1985 - 1988

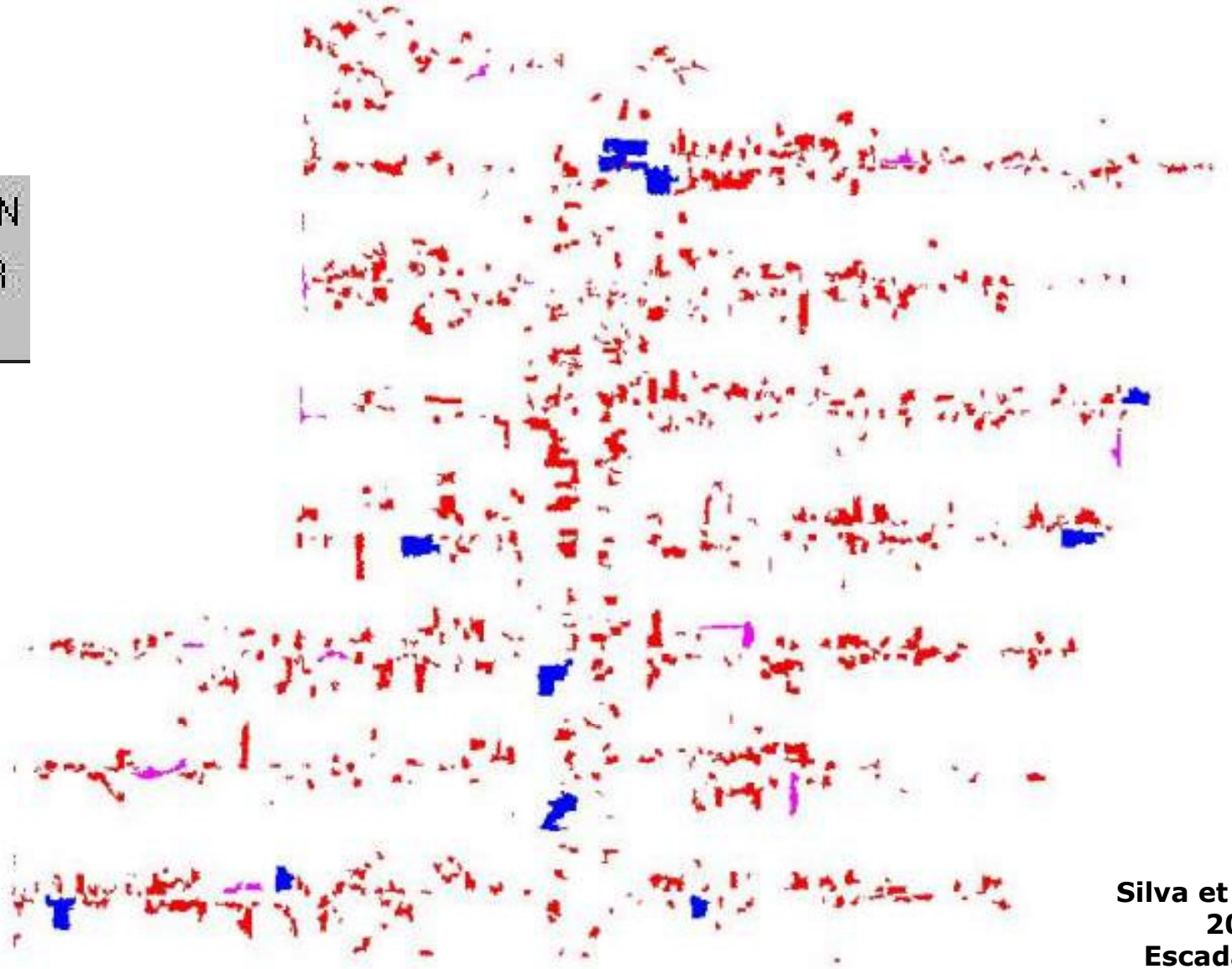




Silva et al, 2005; 2006
Escada, 2003

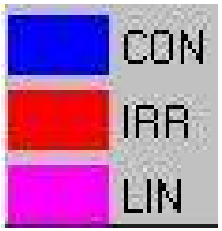
Vale do Anari – 1988 - 1991

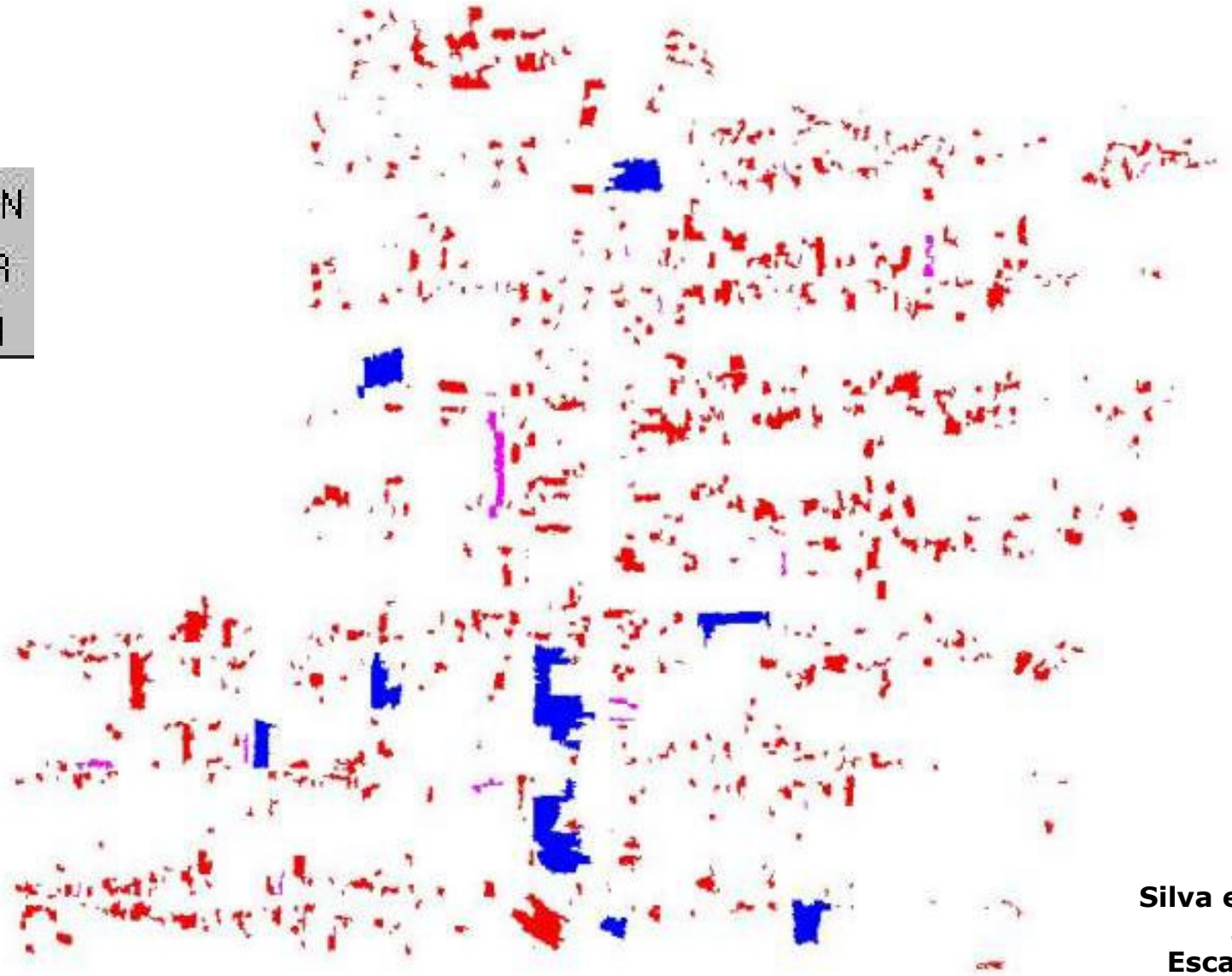




Silva et al, 2005; 2006
Escada, 2003

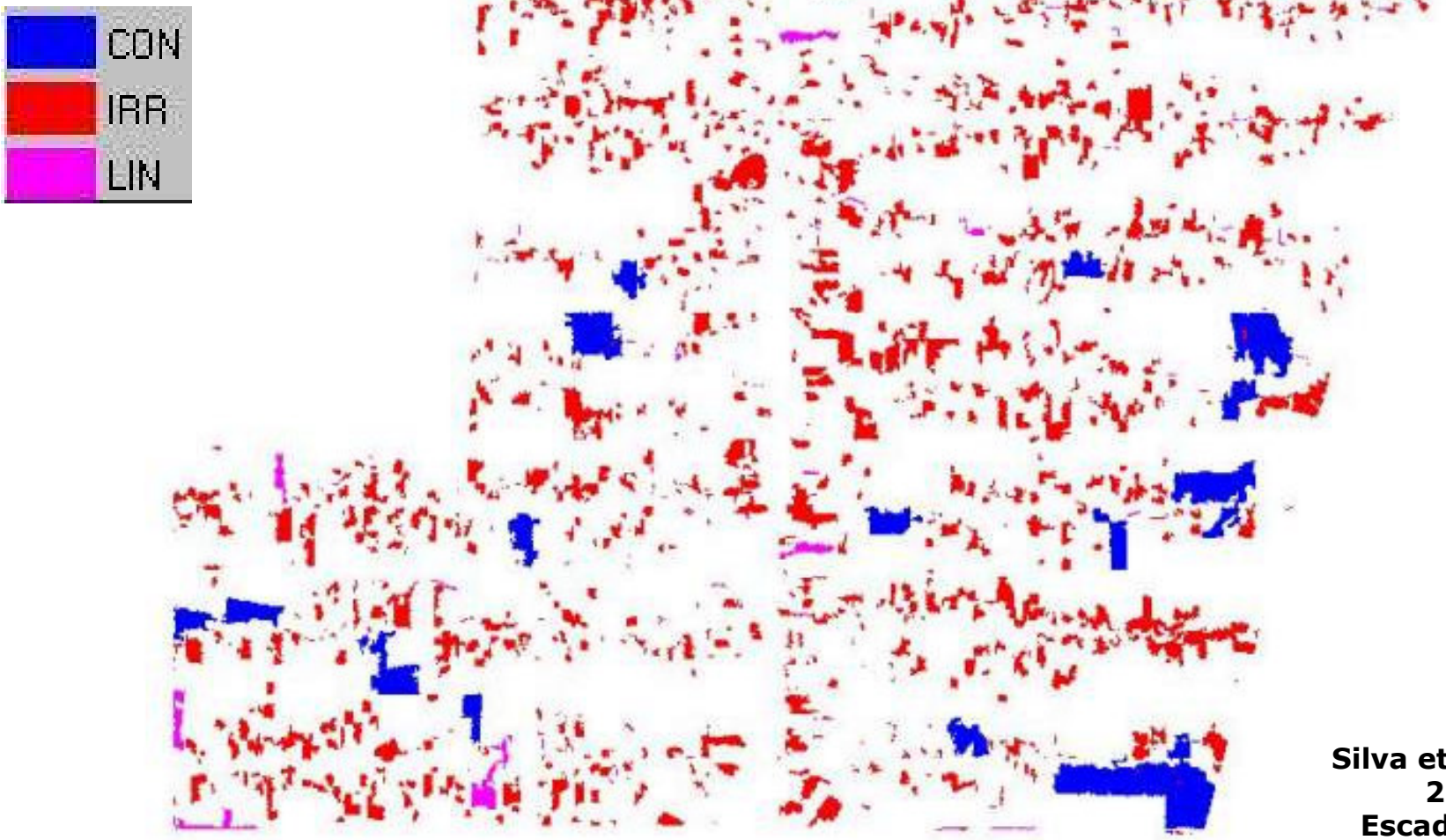
Vale do Anari – 1991 - 1994





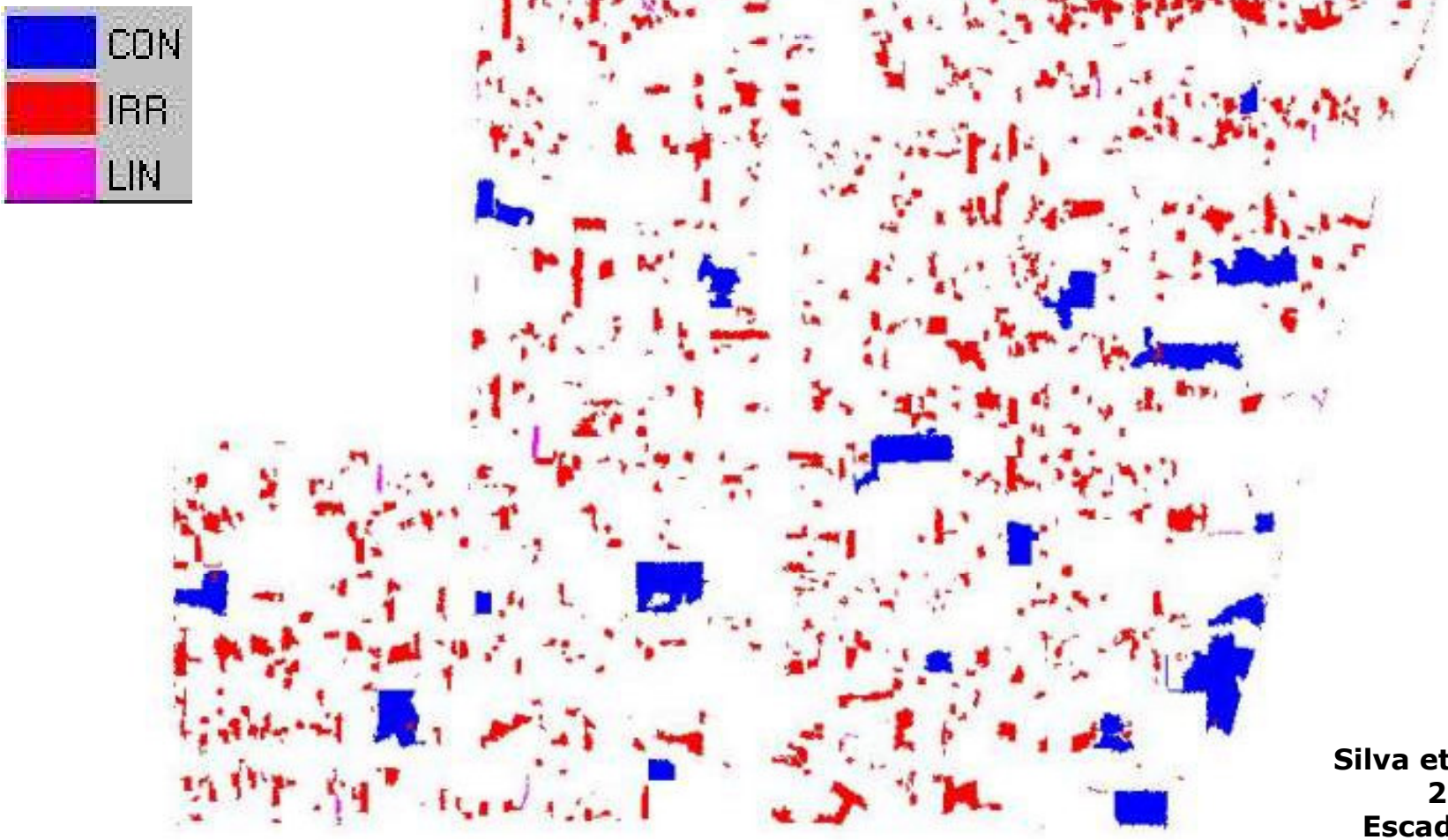
Silva et al, 2005; 2006
Escada, 2003

Vale do Anari – 1994 - 1997



Silva et al, 2005; 2006
Escada, 2003

Vale do Anari – 1997 - 2000



Silva et al, 2005; 2006
Escada, 2003

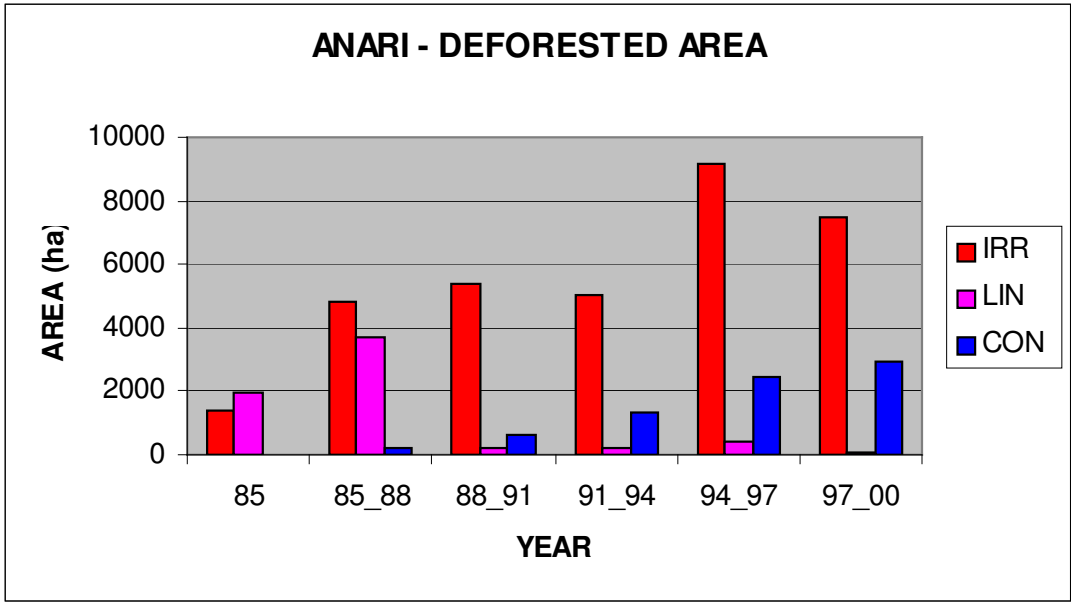
Vale do Anari – 1985 - 2000

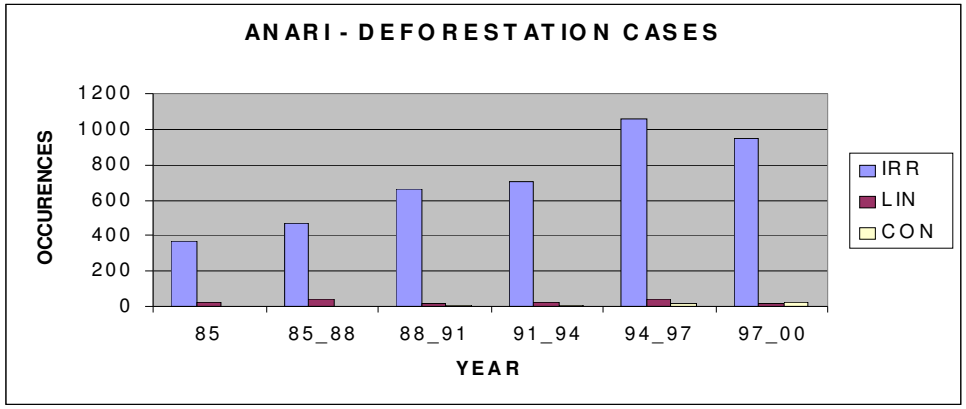
Confirmed by field work

CON
IRR
LIN

Silva et al, 2005
Escada, 2003

Spatial Pattern Evolution





The results allowed to answer the questions...

1. What was the predominant clearing pattern ?
2. How did it evolutes?
3. When did land parcels concentration process started to emerge?
4. In which proportion has this process happened?”

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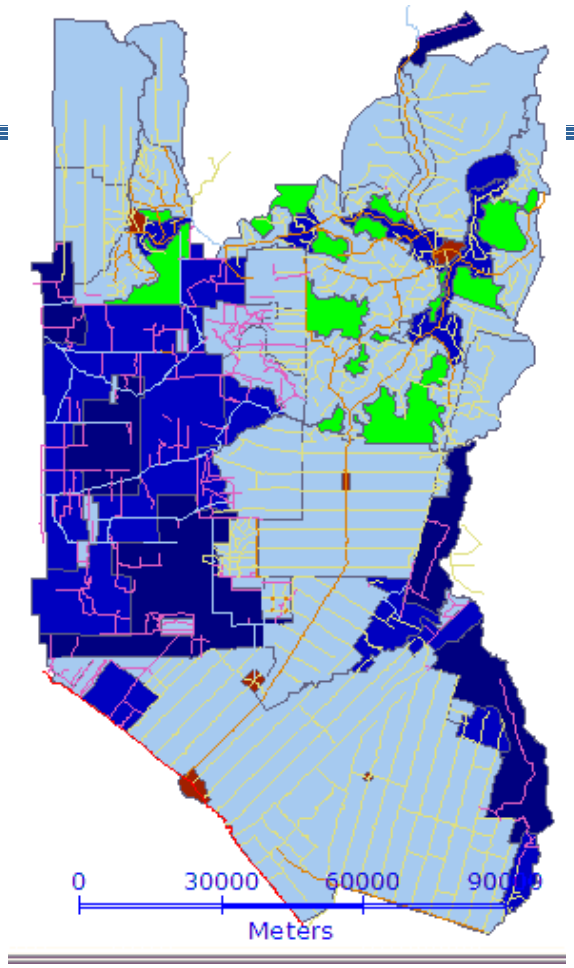
DPI
Divisão de Processamento de Imagens

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

TIAGO GARCIA CARNEIRO
ANA PAULA AGUIAR
MARIA ISABEL ESCADA
GILBERTO CÂMARA
ANTÔNIO MIGUEL MONTEIRO

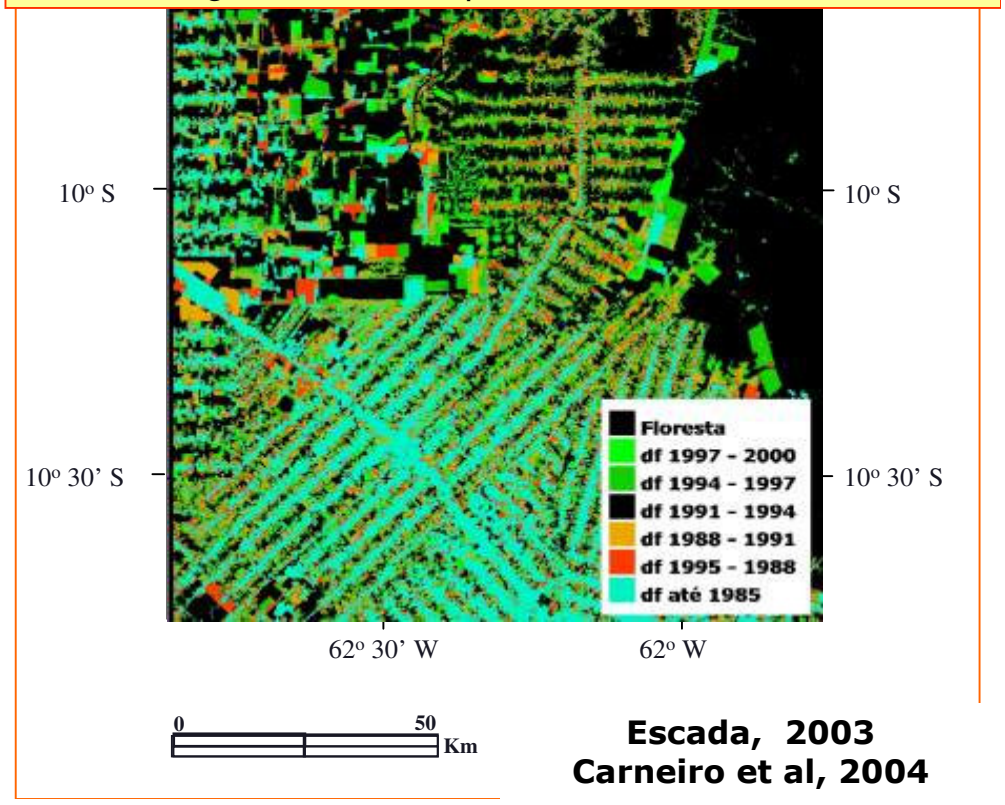
LUCC Workshop
Amsterdam, October 2004

Actors and patterns



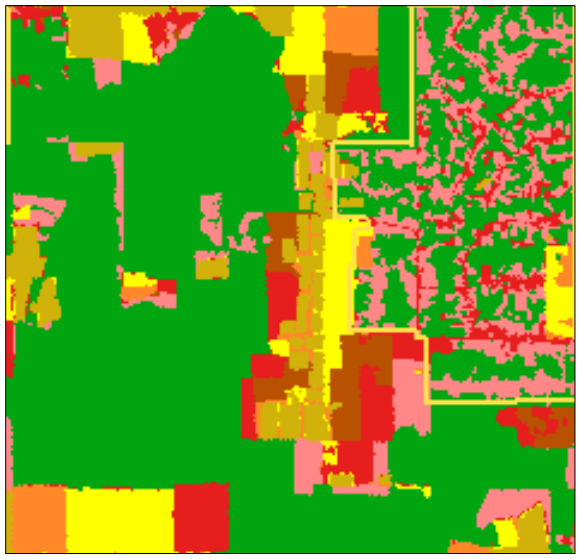
Model hypothesis:

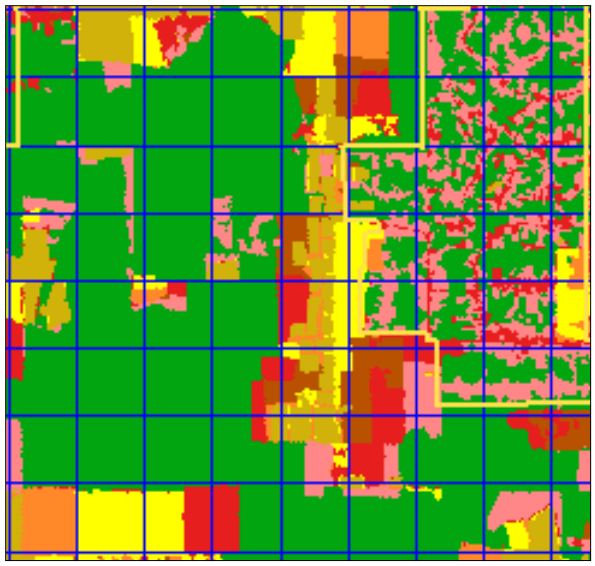
- **Occupation processes are different for Small and Medium/Large farms.**
- **Rate of change is not distributed uniformly in space and time:** rate in each land unit is influenced by settlement age and lot size; for small farms, rate of change in the first years is also influenced by installation credit 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.



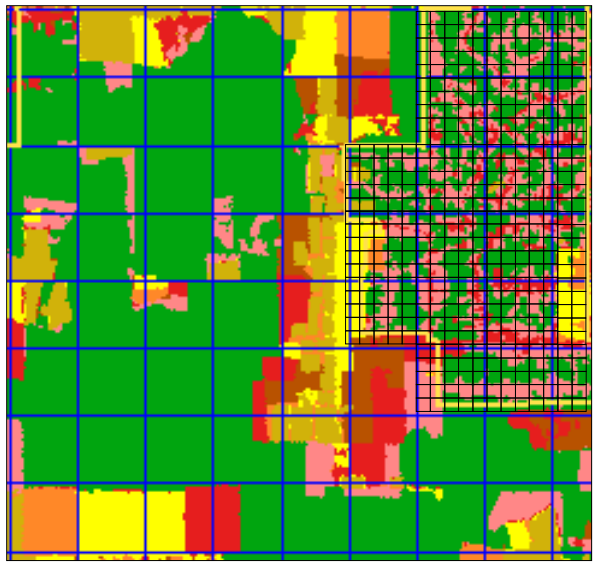
Escada, 2003
Carneiro et al, 2004

1. Establishing Cellular Data Base Resolution





2500 m



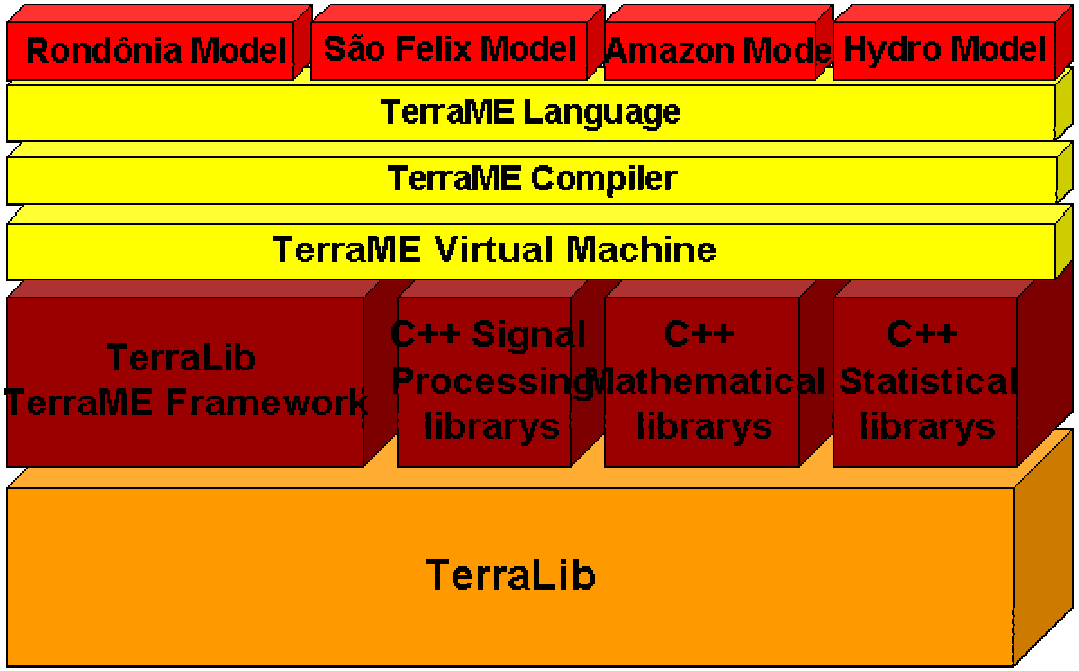
2.500 m e 500 m

2. Specification of the Model Atributtes

2.500 m cell resolution

Atributo	Tipo	Valores	Operação	Dados de entrada
Atributos estáticos				
cell_id				
categoria_produtor_UOP	categorico		agrega	layer de UOPs(poligonal) com atributo identificador único
ano_criacao_UOP	inteiro		agrega	layer de UOPs com atributo ano de criacao
codigo_UOP	inteiro		agrega	
densidade_lotes_UOP	double		agrega	layer de UOPs(poligonal) com atributo identificador único
dist_nucleo_urbanos	double		TeMinimumDistancetoLines (spatial)	layer com centros urbanos (pontos? Poligonos?)
protected		percentage	TeCategoryAreaPercentage (spatial)	
soil_fert_(alta, media, baixa)	double	percentage	TeCategoryAreaPercentage (spatial)	layer de solos (poligonal) com atributo identificador único
declividade	double		agrega (media)	layer de declividade (poligonal) com atributo identificador único
Atributos dinâmicos (85 - 88 - 91 - 94 - 97 - 00)				
attr_id				
initial_time				
final_time				
cover_deforest				
transition_deforest				
dist_364	double		TeMinimumDistancetoLines (spatial)	layers com estradas (linhas) para cada ano, com atributo tipo (364, principais ou secundaria)
dist_ramal_princ	double		TeMinimumDistancetoLines (spatial)	layers com estradas (linhas) para cada ano, com atributo tipo (364, principais ou secundaria)
dist_ramal_sec	double		TeMinimumDistancetoLines (spatial)	layers com estradas (linhas) para cada ano, com atributo tipo (364, principais ou secundaria)
dist_vicinais				
dist_mancha_desflorestamento	double		Implementar algo específico para busca de célula desflorestada mais proxima.	n/a - calculado pelo modelo

Framework Implementation to support Land Cover Modeling



Carneiro et al, 2004

- **This 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 assynchronous processes**
  - **Alternative neighborhood relationships**
  - **Continuous and discrete behavior**

TerraLib: INPE Open source Library for GIS application

http://www.terralib.org/

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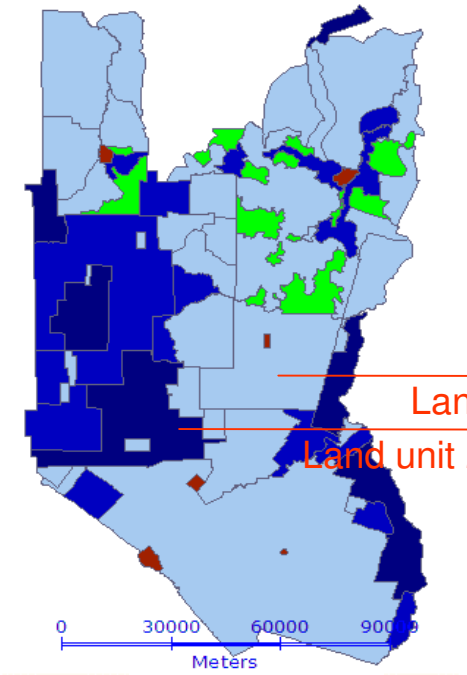
Deforestation Rate Distribution from 1985 to 2000 - Land Units Level:

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

Allocation of changes - Cellular space level:

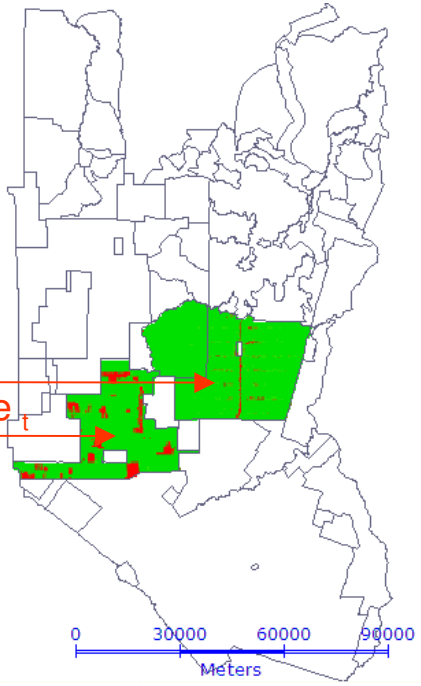
- Large/Medium allocation sub-model
- Small allocation sub-model

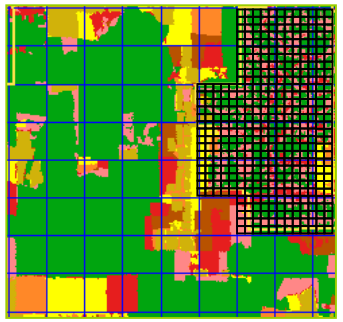
Global study area rate in time



Land unit 1 rate $_t$

Land unit 2 rate $_t$





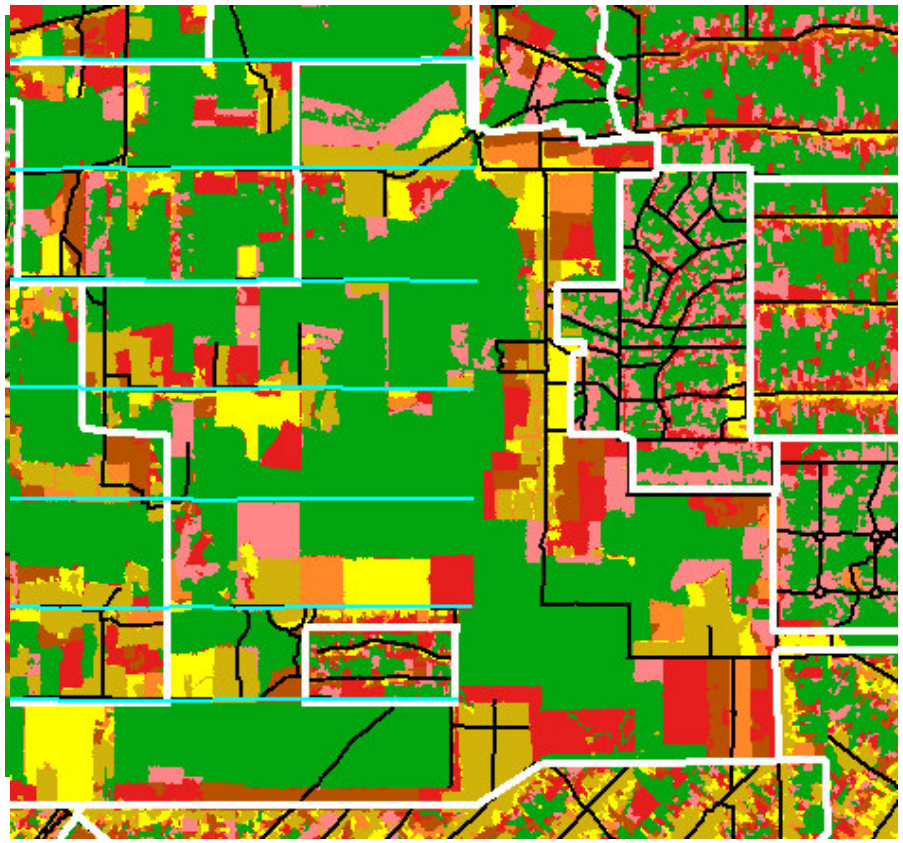
2.500 m (large and medium)

500 m (small)

Large farms
Medium farms
Urban areas
Small farms
Reserves

Carneiro et al, 2004

Allocation Module: different factors and rules



Factors affecting location of changes:

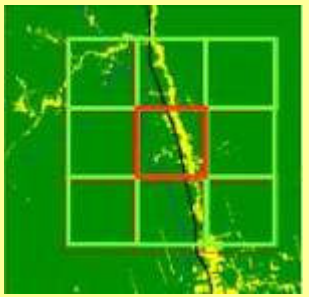
Small Farmers (500 m resolution):

- **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**

Alternative neighborhood examples:



Carneiro, T. G. et al, 2004

Allocation Module: different resolution, variables and neighborhoods

Small farms environments:

500 m resolution

Categorical variable:
deforested or forest

One neighborhood relation:
•connection through roads

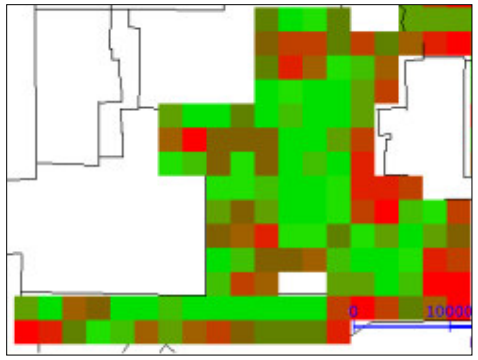
1997

Large farm environments:

2500 m resolution

Continuous variable:
% deforested

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



Adapted from Carneiro, T. G. et al, 2004

CLUE-S - Modelling land use and land cover change dynamics in Rondônia State.

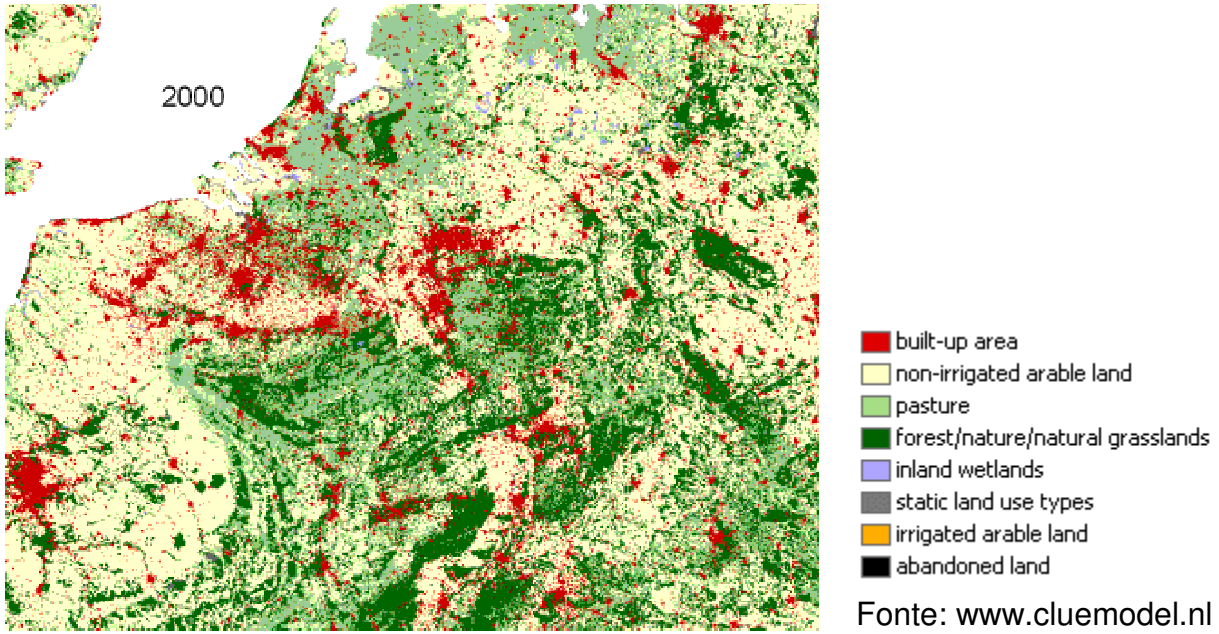
Análise empírica *histórico de uso* e dos seus *fatores forçantes*

Simulação de mudanças espaciais *explícitas* de uso/cobertura

modelagem dinâmica *competição da dinâmica espacial e temporal entre as classes de uso*

Aplicável à <u>escalas locais/regionais</u>, imagem classificada

Ex. Greenheart Holanda
0.5 x 0.5 km



Fonte: www.cluemodel.nl

CT BRASIL
Ministério da Ciência e Tecnologia

6. Integrated Land Use and Land Cover Change Modeling in Pará

Estudos Avancados

Land Use and Land Cover Dynamic
Population Dynamic and Human Settlements
Data Base and Integrated Modeling

Institutes: **INPA, MPEG, INPE, UFRJ (LAGET)**
Partners: **EMBRAPA Oriental , UFPA (LASAT, NEAF)**

Institutos MCT

Museu Paraense Emilio Goeldi

Instituto Nacional de Pesquisas Espaciais

Instituto Nacional de Pesquisas da Amazônia

Parcerias

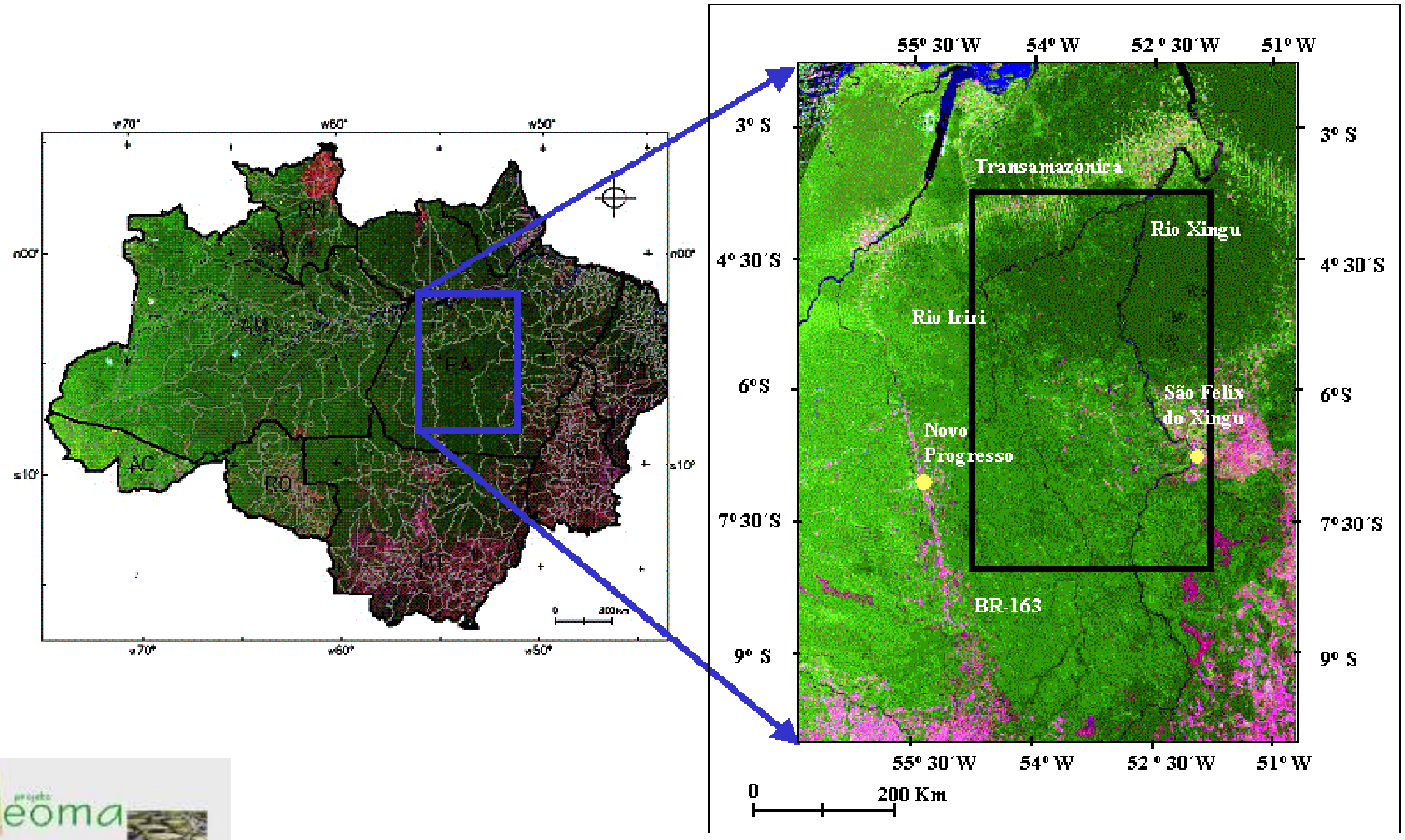
Embrapa Amazônia Oriental

Universidade Federal do Pará/ LASAT e NEAF

Universidade Federal do Rio de Janeiro/ LAGET

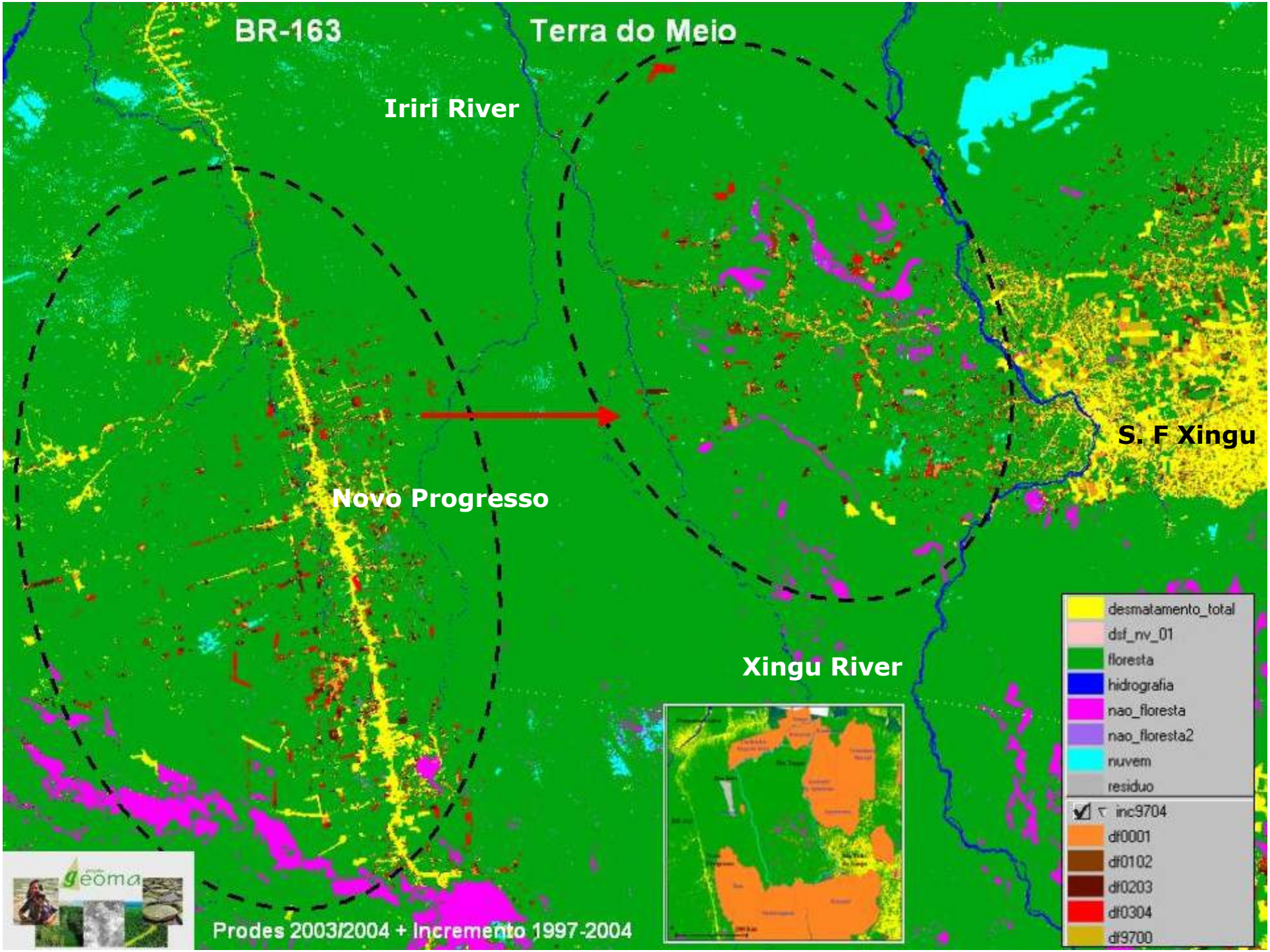
http://www.geoma.lncc.br

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

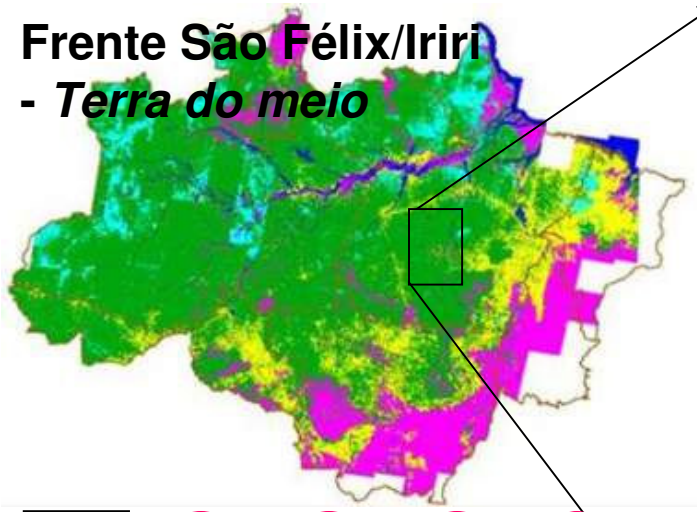


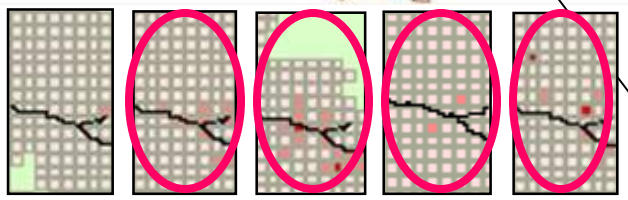
Main Goals

- **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.**

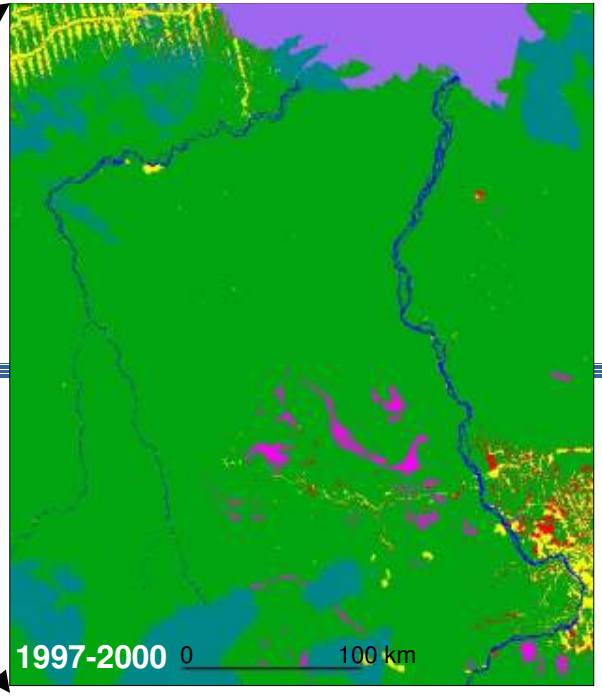

BR-163
Terra do Meio
Iriri River
S. F Xingu
Novo Progresso
Xingu River
desmatamento_total
dsf_nv_01
floresta
hidrografia
nao_floresta
nao_floresta2
nuvem
residuo
inc9704
df0001
df0102
df0203
df0304
df9700
Prodes 2003/2004 + Incremento 1997-2004

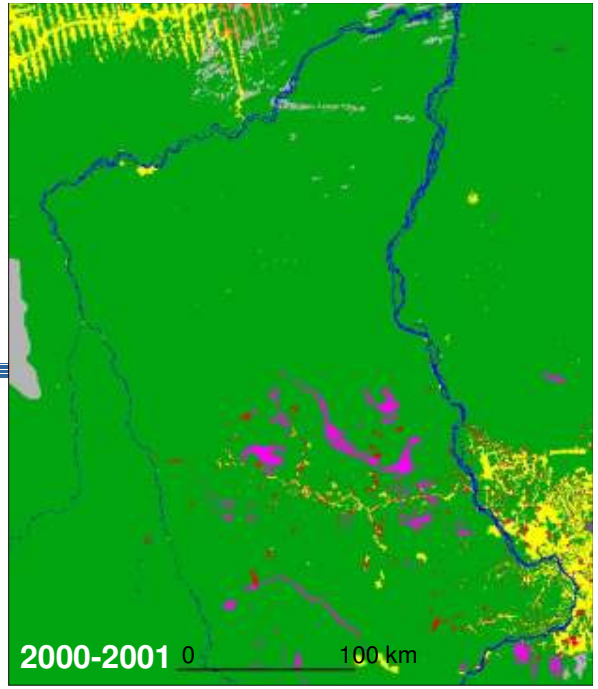
Frente São Félix/Iriri
- *Terra do meio*

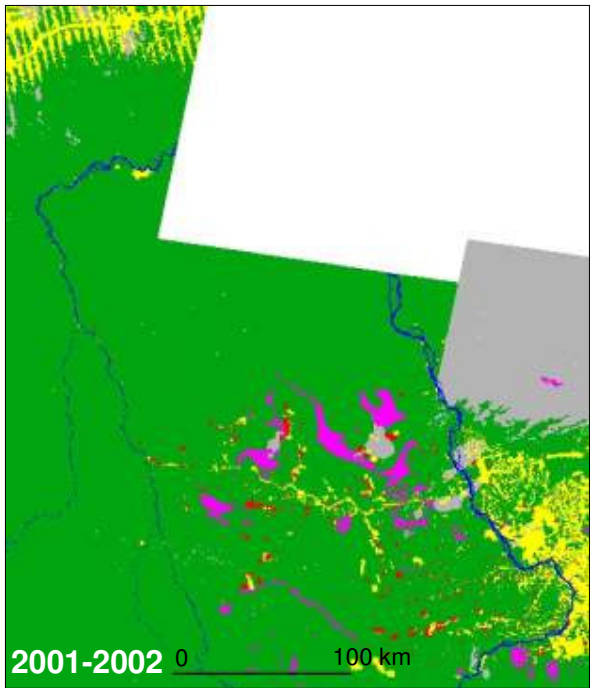


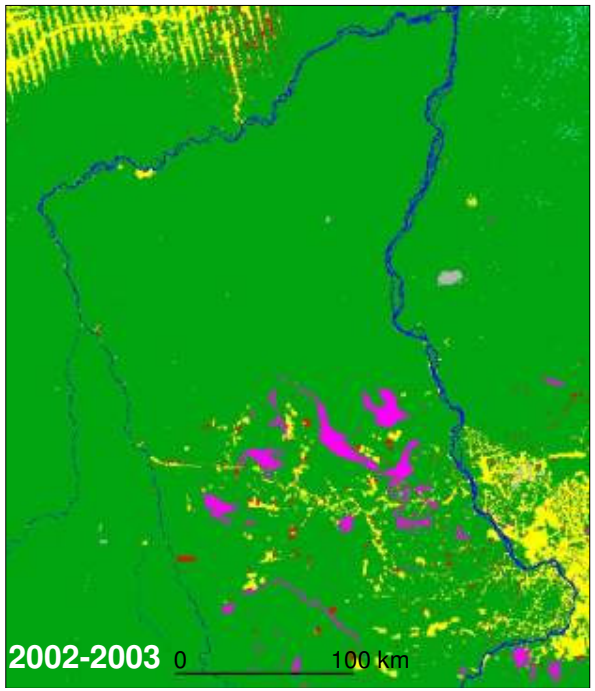


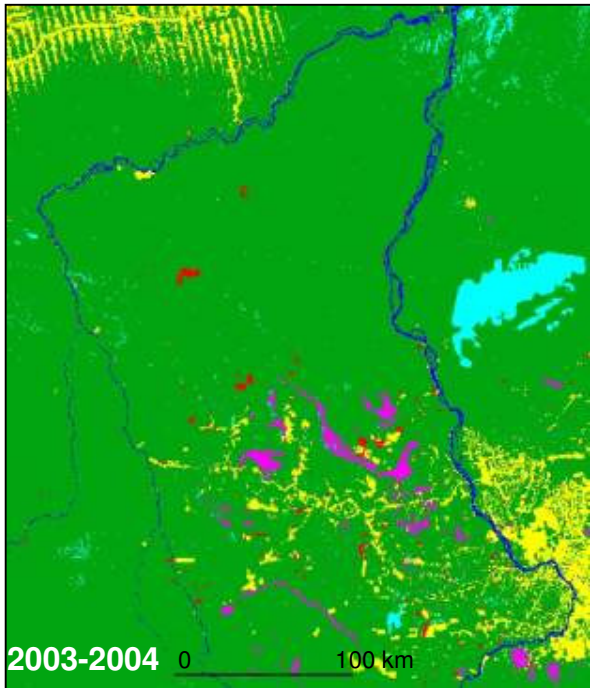
1997_00 2000_01 2001_02 2002_03 2003_04

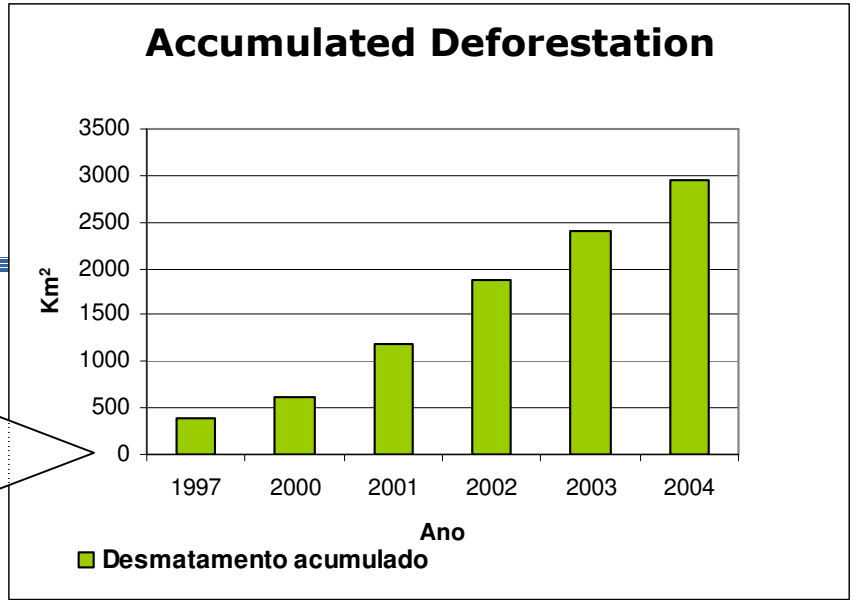


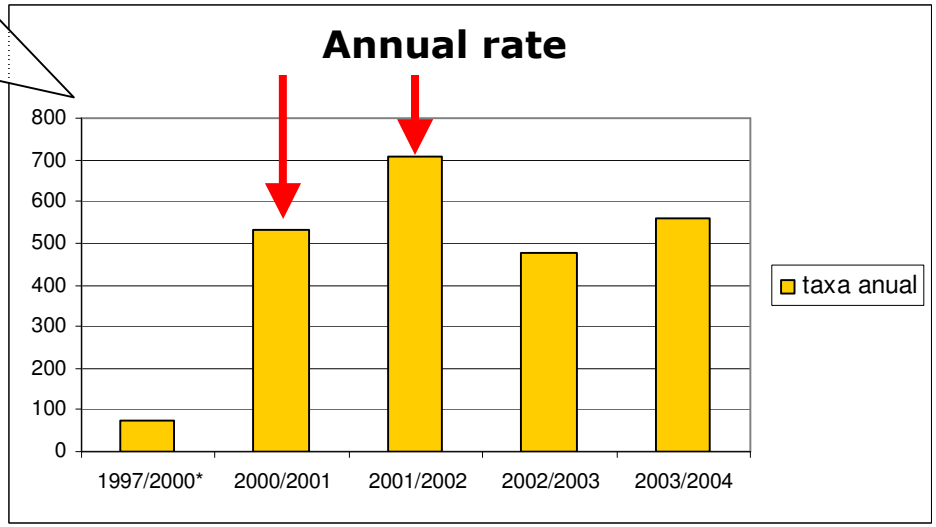






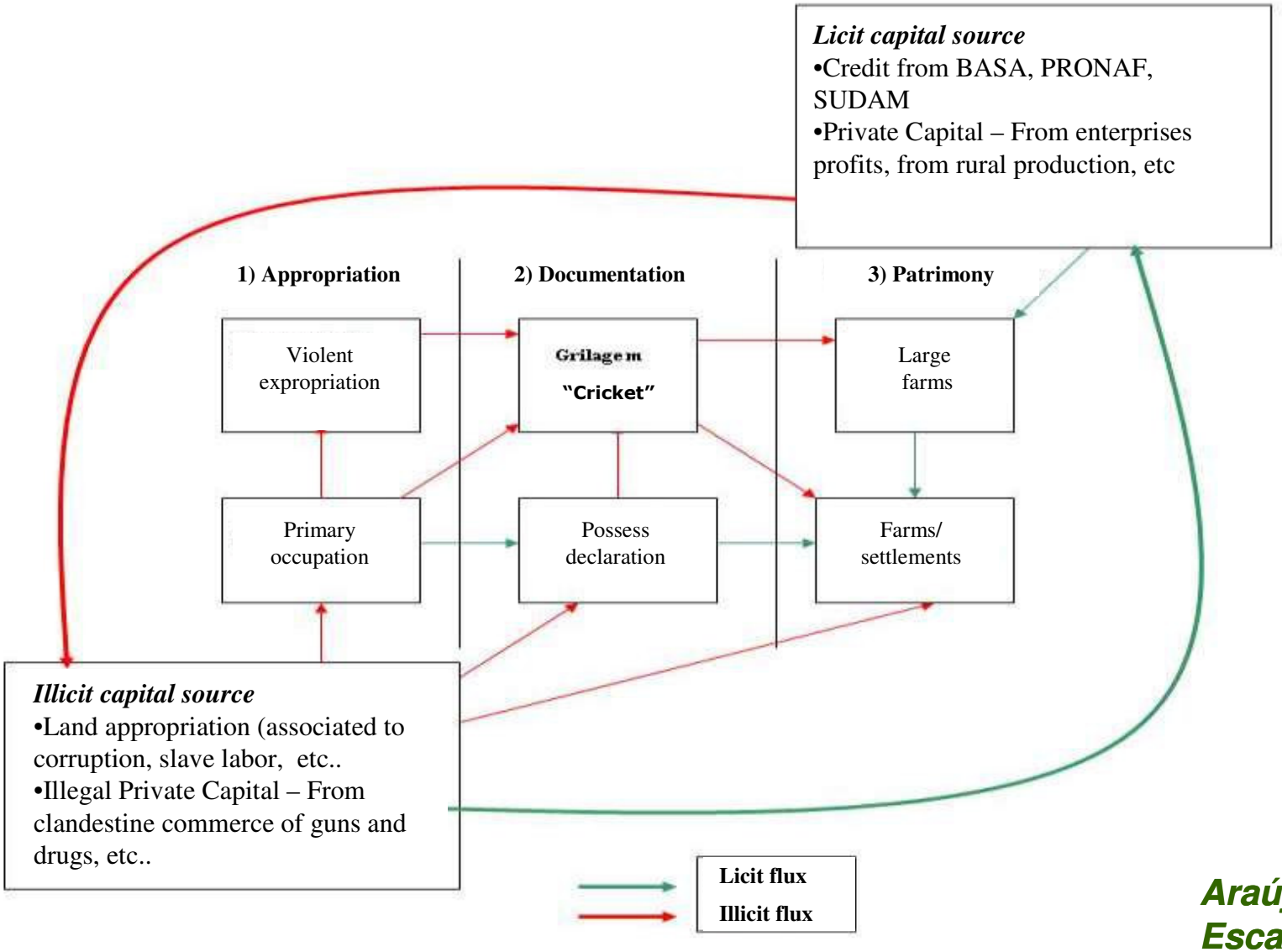






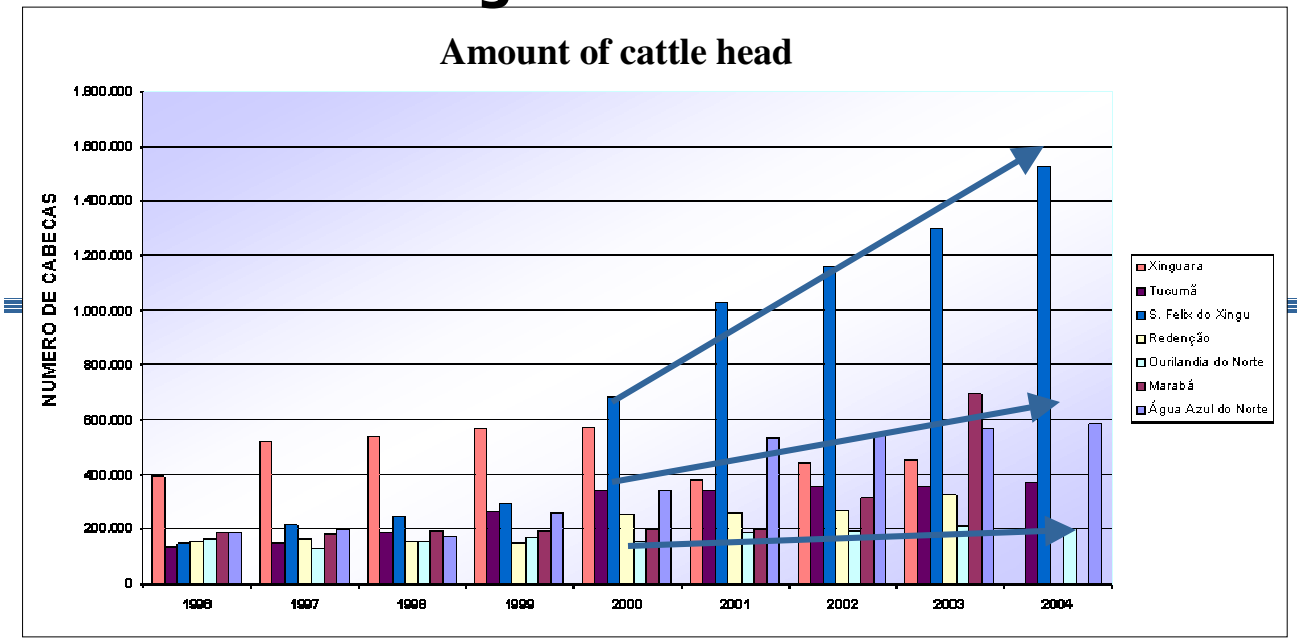
Escada et al, 2005 – Estudos Avançados , Nº 54

Land Appropriation Model



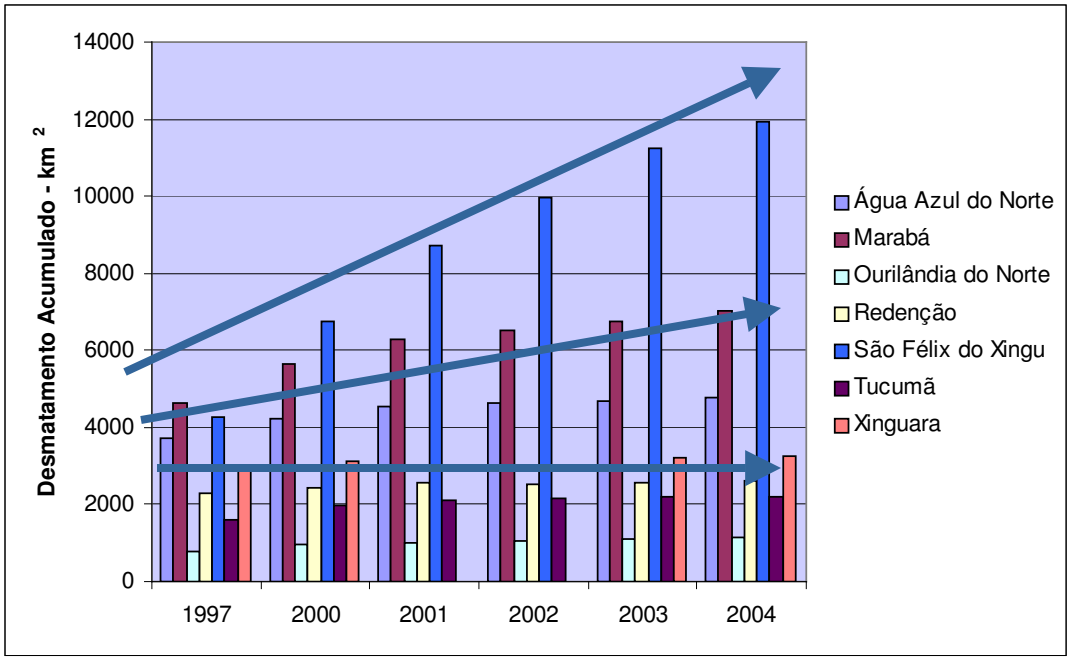
Araújo (2004)
Escada et al (2005)

Cattle ranching and deforestation



Source: DePará, 2005

Accumulated Deforestation

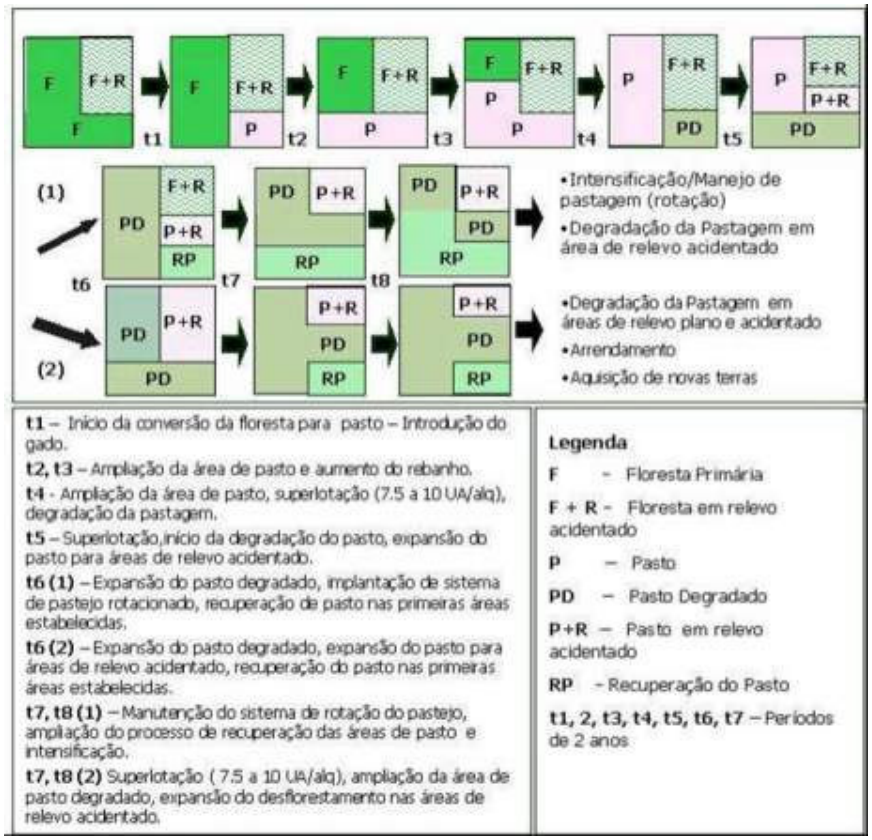


Museu Paraense Emílio Goeldi e Embrapa Oriental

Escada et al, 2005 – Estudos Avançados , Nº 54

Cattle Ranching Model

- **The connection between São Félix do Xingu and Xingu/Iriri region: The role of Cattle Ranching in the frontier and land cover change**



Cattle Ranching Model

Factors:

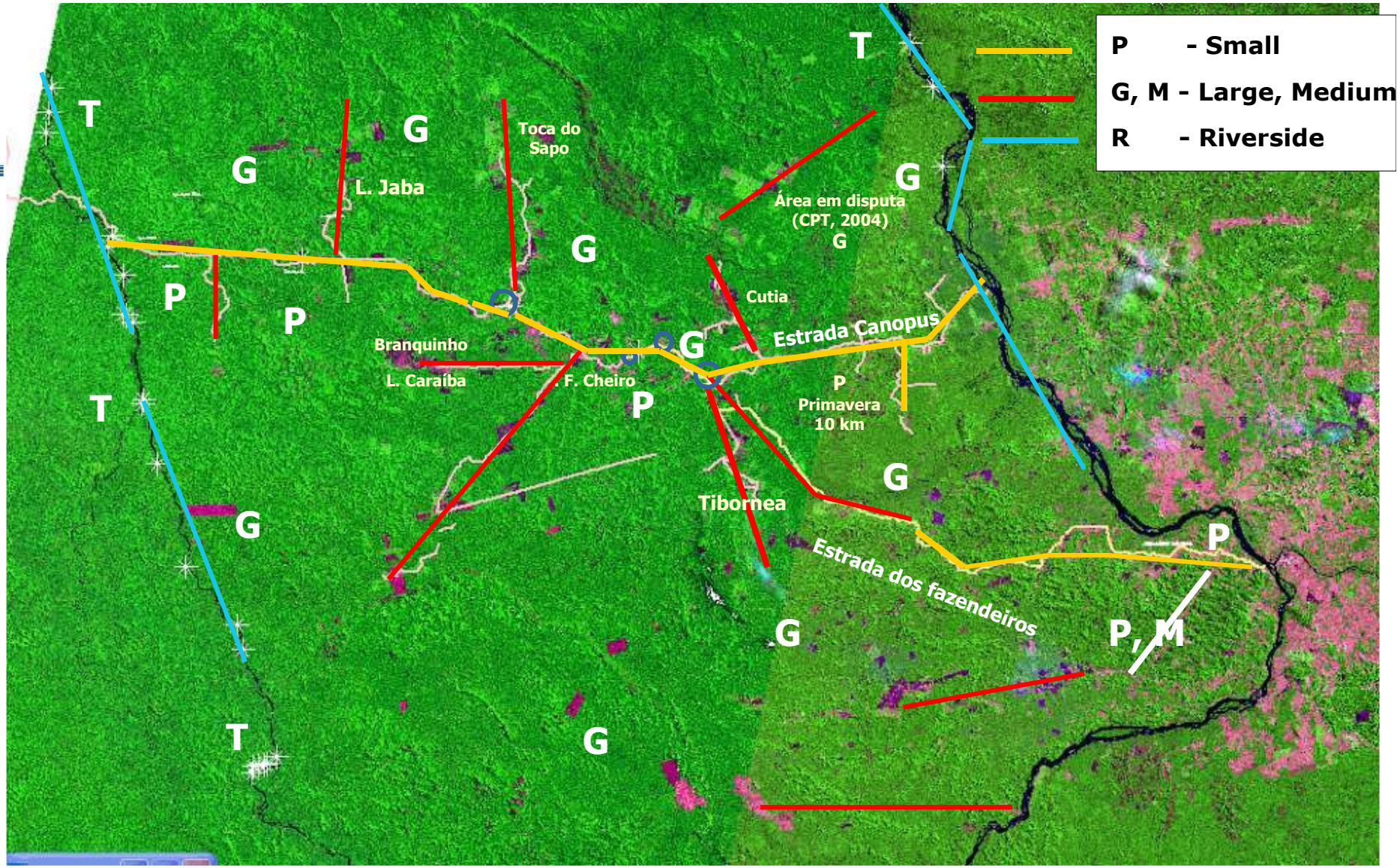
- Land appropriation;
- Cattle raising expansion;
- Pasture degradation;
- Sanitary barrier – "Represamento do gado" – Confinement in the region

The role of cattle ranching in the expansion of the frontier

- **Cattle ranching is the main land use activity, and the main driver of land use and cover change in the region**
- **This activity has been structured and expanded regionally**
- **It's not only this activity that is growing up but the whole market chain: Beef industry, milk, services, transportation. etc**

…So, we need to understand the organization of bovine chain to understand the mechanisms linked to the frontier expansion.

The actors Spatial Distribution



TM Landsat7, 543 (2003)

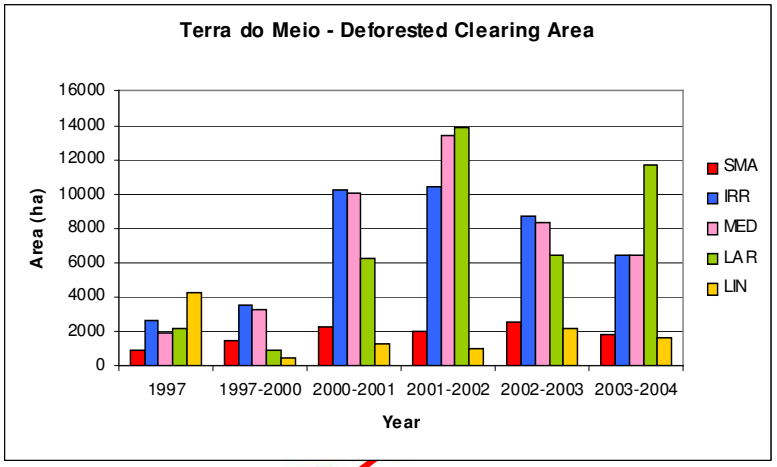
Source: CPT(2004) , Taravello, R. (2004), Isa (2001) , Geoma(2004), Escada et al (2005)

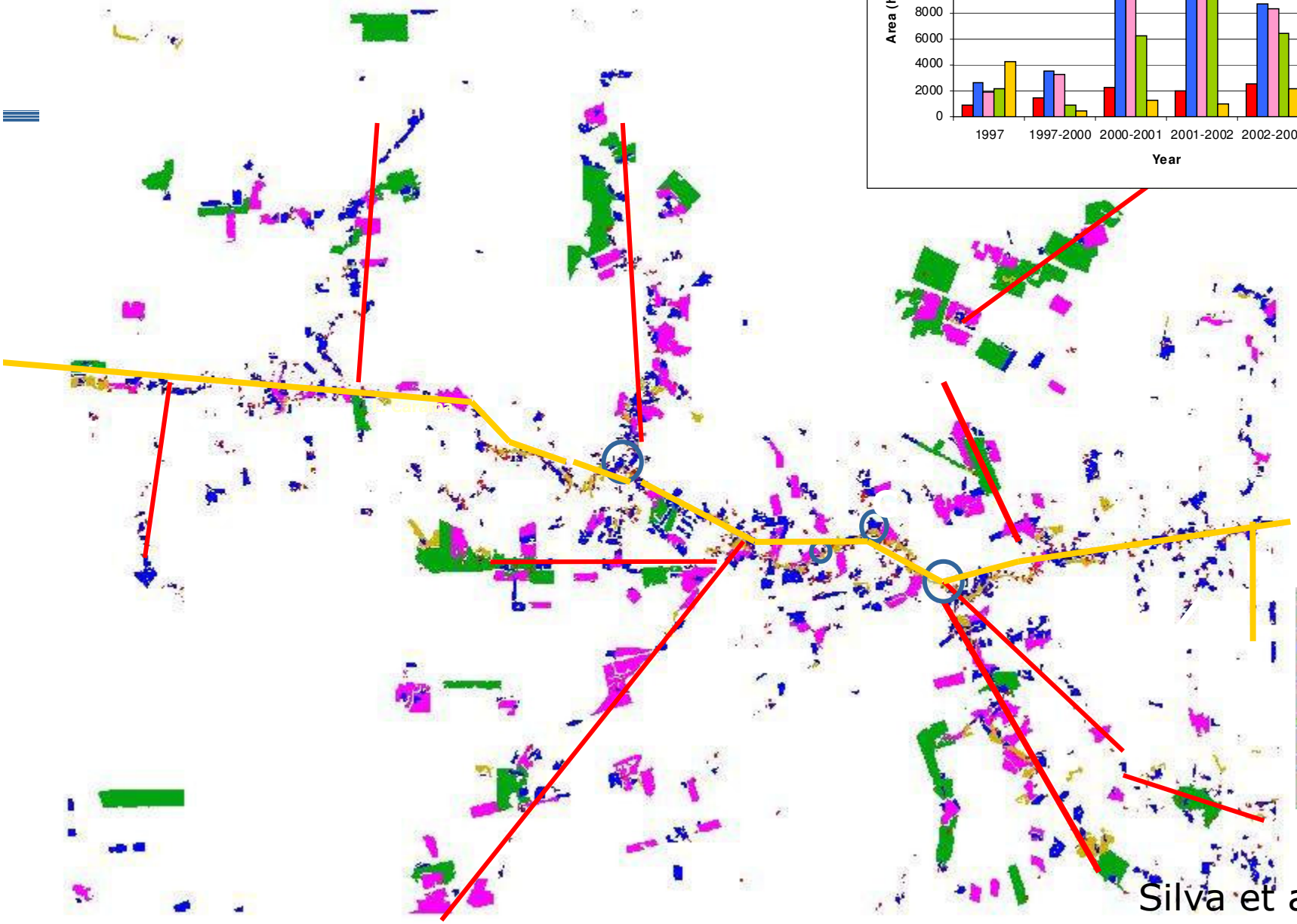
Image Data Mining – Patterns and Typology

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 liear pattern following main roads corresponding to the earlier stages of colonization.
2.Small Irregular 	Near main roads and populational nucleous	Small (< 35 ha)	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 nucleous	Small (35-190 ha)	Small farmers	Cattle ranching mainly	Located near roads, associated to small family household. These actores often have another incoming source from salary, comercial 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.

Silva et al, 2005

Terra do Meio 1997 - 2004

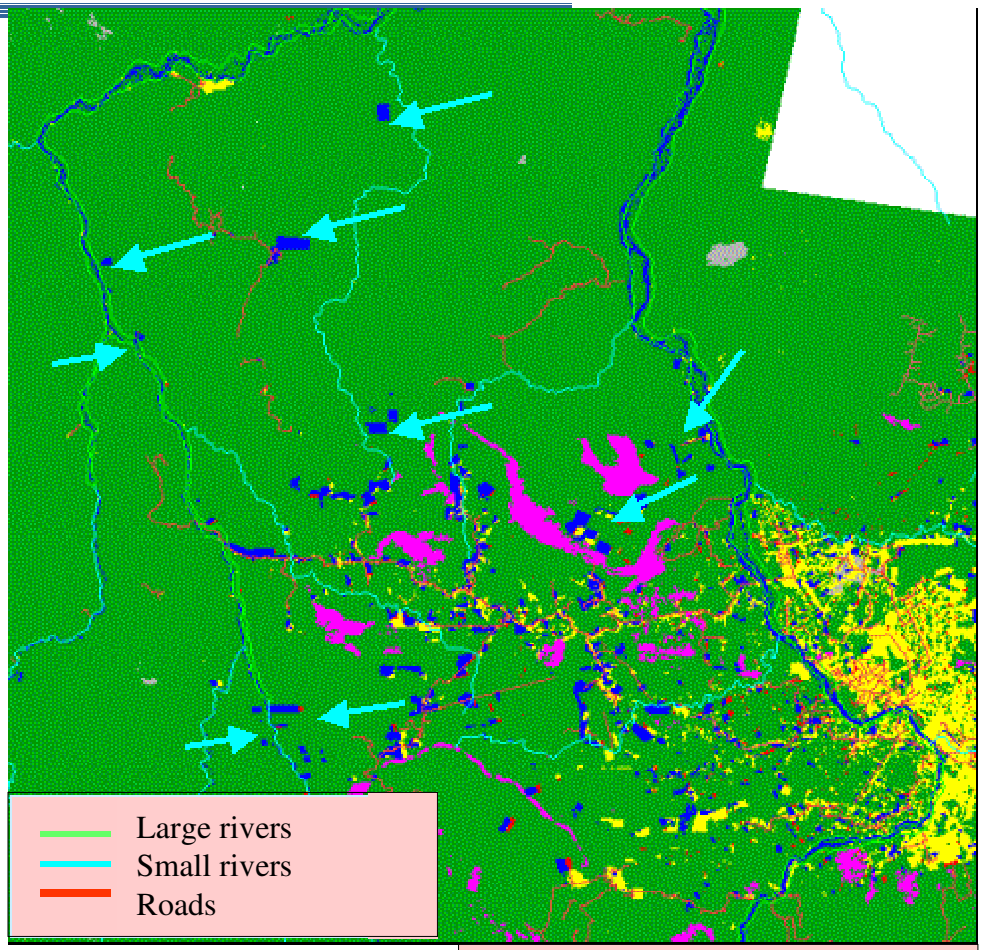




Silva et al, 2005

The role of the physical networks shaping the territory: against the "only roads*" approach

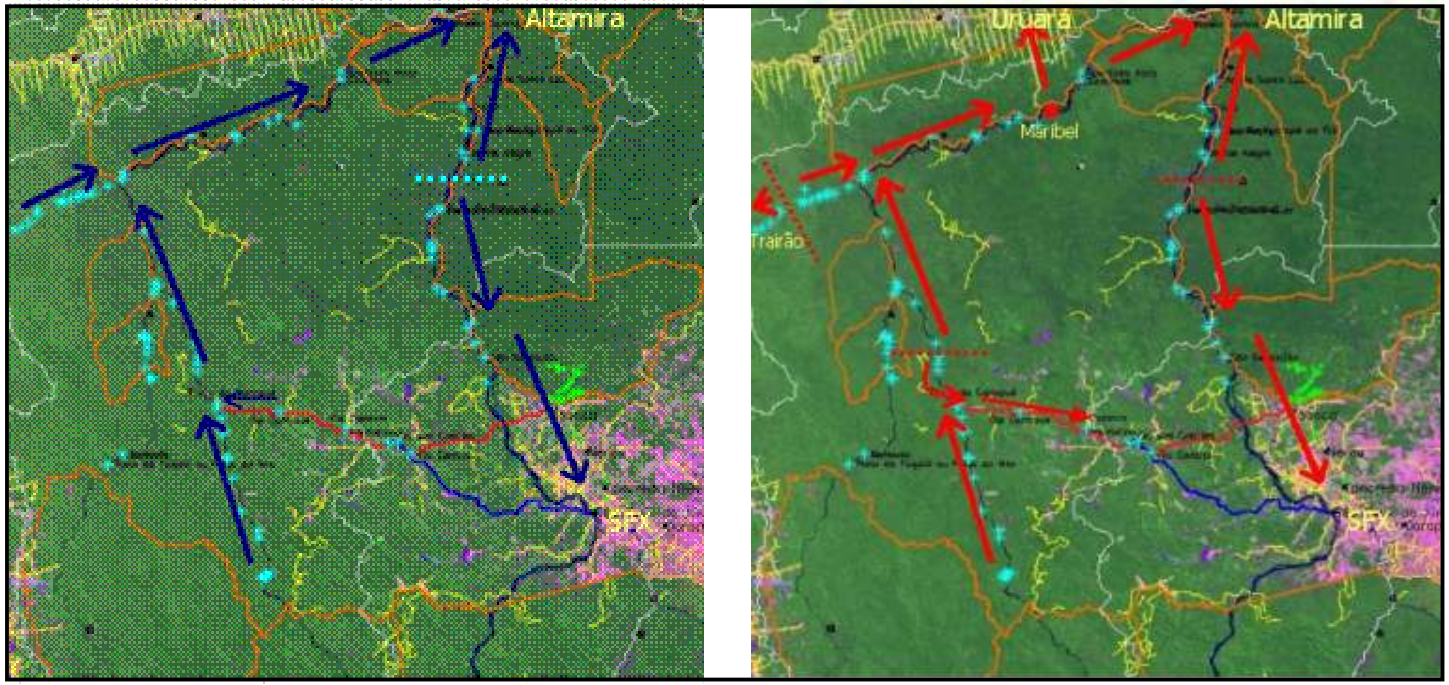
- **Population nucleus and settlements shaping the territory**
- **Hybrids networks: Roads + Rivers Streams**
- **Probably soil and relief have some influence in the farms spatial configuration**
- **Only roads can't explain deforestation pattern!!!!**



Prodes 2003 + Deter 02-04

* Câmara et al. 2005
Kampel (to be submited)

Population Flux: seasonality

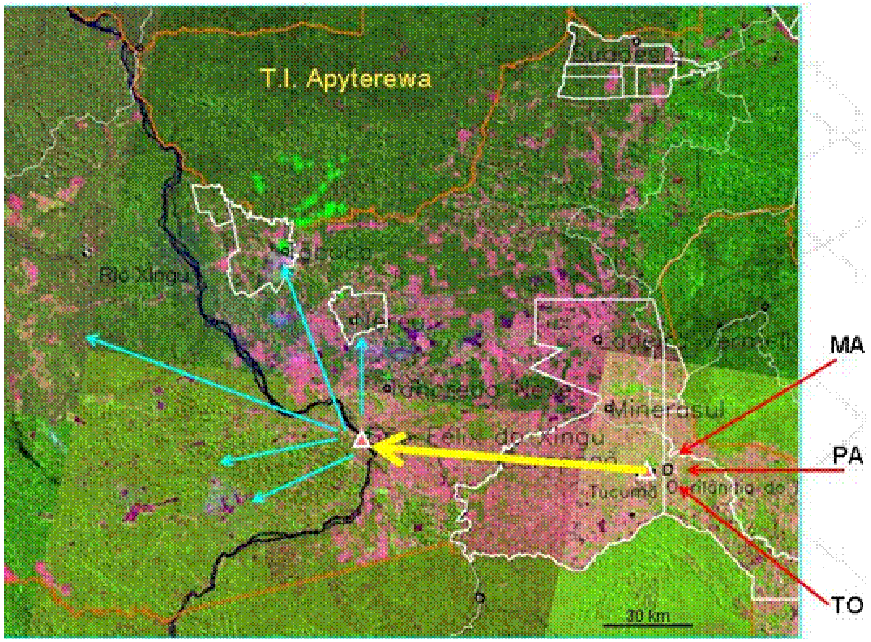


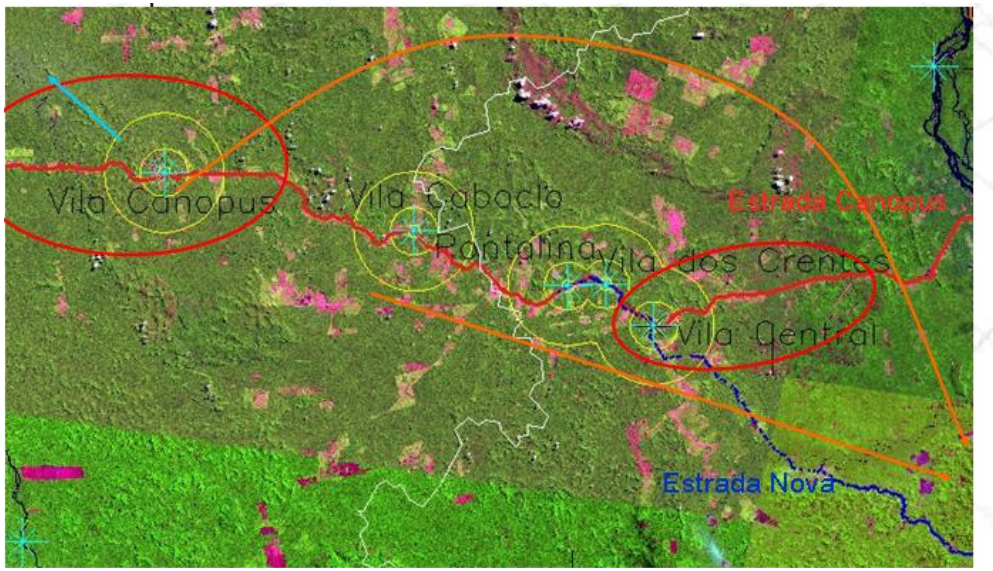
Rain season flux **Dry season flux**

Kampel (to be submited)

Population network

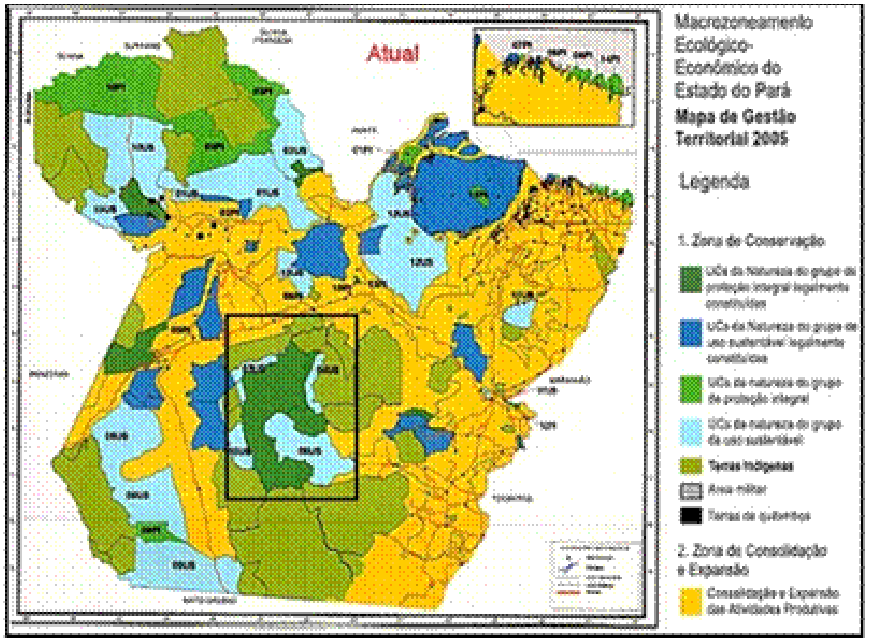
- **The human settlement and center of dispersion of population: The frontier movement.**





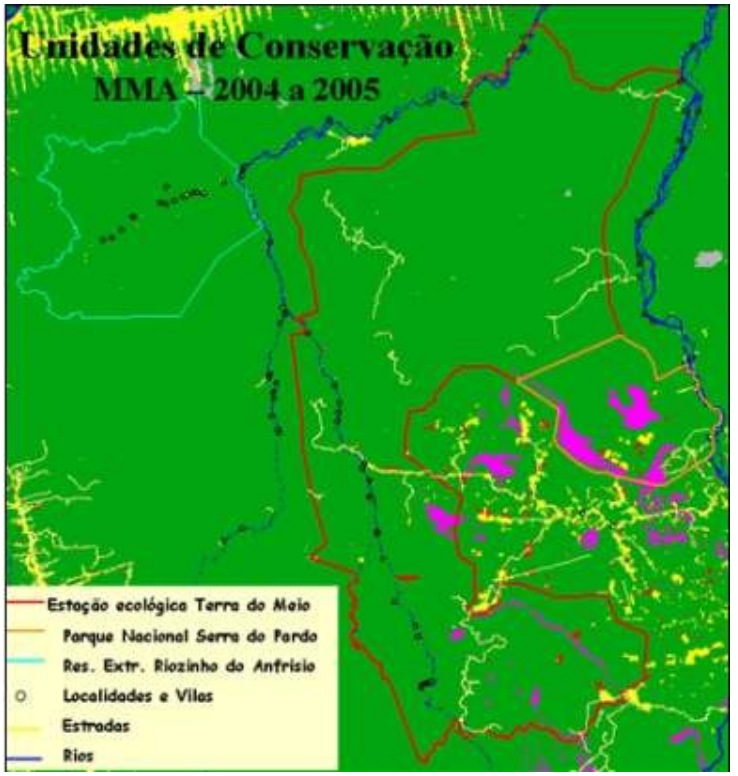
Kampel (to be submited)

Public Policies Analysis



Pará Zoning

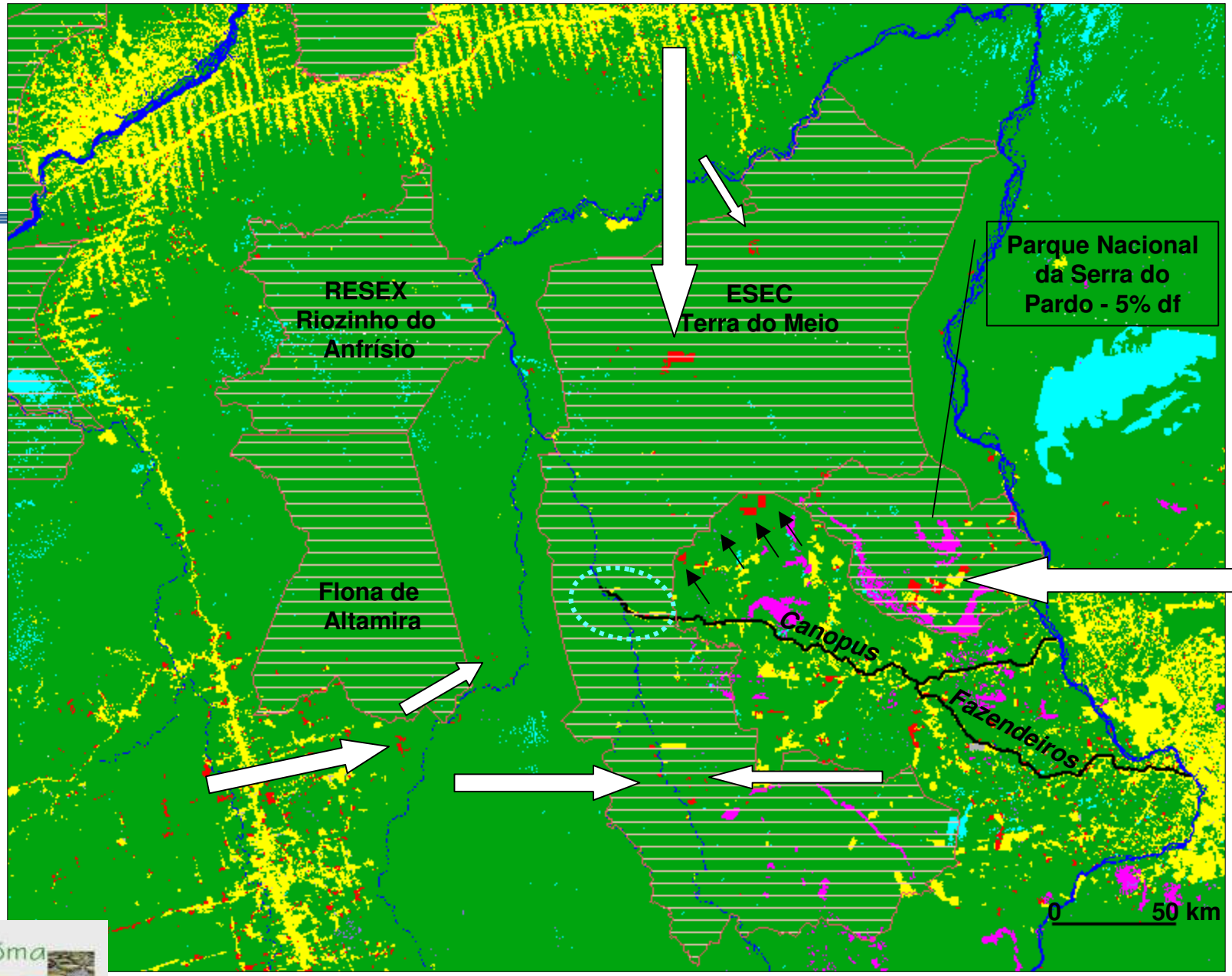
Macrozoneamento Ecológico Econômico do Estado do Pará.



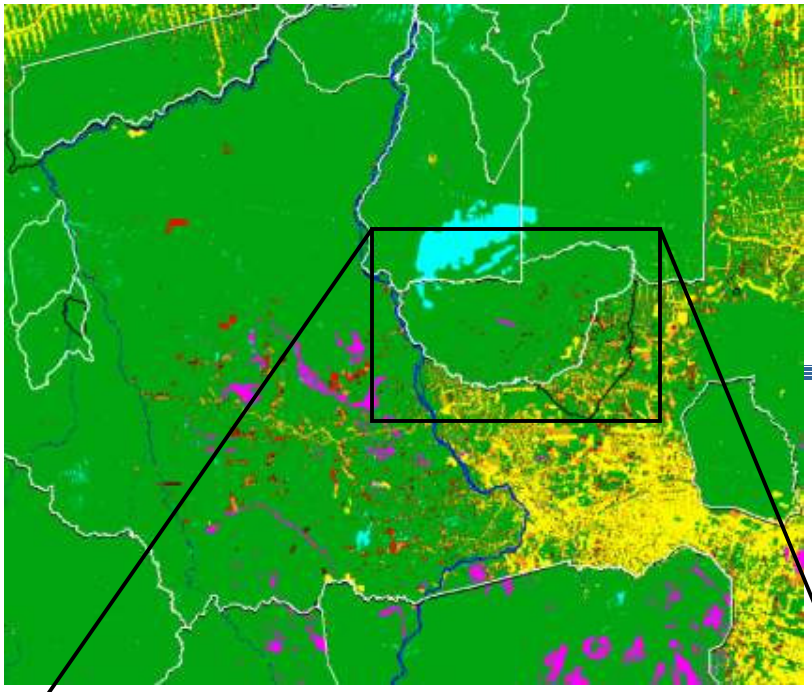
MMA – Conservation Unities

Escada et al, 2005

Unidades de Conservação e o avanço do desmatamento na "Terra do Meio"

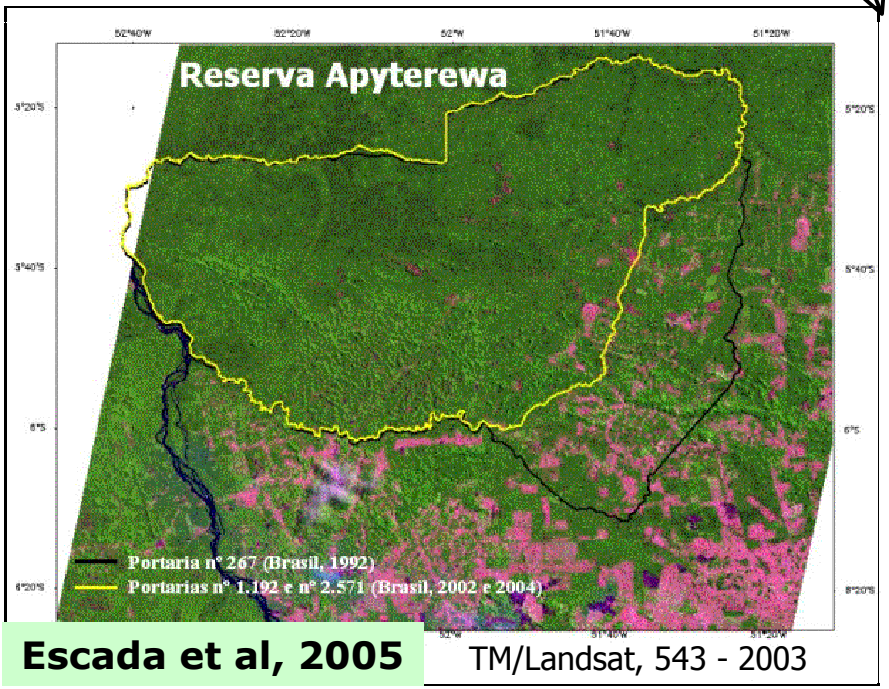


Escada et al, 2005 Prodes 2004 *(INPE, 2005)*



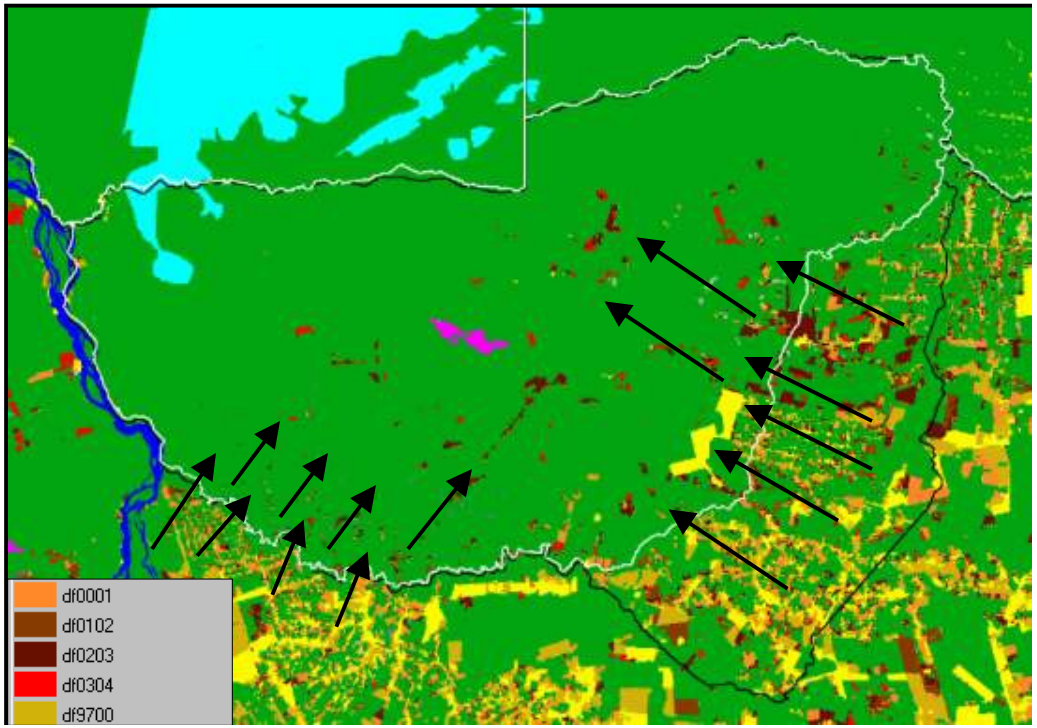
Indian Land Apyterewa

Prodes 1997- 2004



Escada et al, 2005

TM/Landsat, 543 - 2003



Next steps

- To improve analysis related to land use and land cover change, milk and beef chain, human settlements, population fluxes, social and infra-structure and transport networks, connectivity and land appropriation model, etc..
- To develop and integrate LUCC and network models
- To develop modeling tools in Terra-ME
- To build methodologies to develop scenarios

Conclusion

- **DPI/INPE team is involved with activities that aims to measure, model and understand the Amazonian human-environmental system;**
- **Models have been used to explore scenarios and to understand better how the several factors are structuring the territory, their interdependency and interactions in order to subsidize public policies for the region;**
- **The knowledge generated by this approach can help in the formulation of the global models helping to simulate and test feedback mechanisms and the resilience hypotheses.**

Scientific Papers

- Aguiar, A. P; Kok, K.; Escada, M. I. S.; Câmara, G. Exploration of patterns of land-use change in the Brazilian Amazon using the CLUE framework. IHDP Open Meeting. Bonn, October, 2005.
- 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.
- Alves, D. S.; An analysis of the geographical patterns of deforestation in Brazilian Amazon in the 1991-1996 period. In:Process of land Use and Forest Change in the Amazon. : University of Florida Press, 2002, Cap. 3, p. 95-106.
- Araújo, R.; Expansion des Fronts Pionniers Structures Funcières et Populations Traditionelles; Seminário ATI Aires PROTEGEES do IRD New Orlean,13 a 15 de Dezembro de 2004.
- Becker, B. Amazônia: Geopolitica na virada do III Milenio. Ed. Garamond. São Paulo. 2004.168 p. (in Portuguese)
- Becker, B. Geopolítica da Amazônia. Revista Estudos Avançados. USP, São Paulo. vol.19 (53). 2005. p 71-86. (in Portuguese)

Scientific Papers

- Câmara, G. Aguiar, A. P. D. ; Escada, M.I.S.; Amaral, S.;Carneiro, T.; Monteiro, A. M. V.;Araújo, R.; Vieira, I.; Becker, B. Amazonian Deforestation Model. Science V. 307. Science. 2005. 1043-1044 p.
- Carneiro, G. T.; Aguiar, A. P.; Escada, M. I. ; Câmara, G.; Monteiro, A. M. V. TerraME - A modeling Environment for non-isotropic and non-homogeneous spatial dynamic models development. LUCC Workshop. Amsterdam, October 2004.
- Coy, M. Rondônia: Frente pioneira e programa POLONOROESTE: O processo de diferenciação sócio-econômica na perifieria e os limites do planejamento público. Tubinguen Geographhische Studien, n. 95 p. 253-270, 1987.
- Dale, V. H; O'Neill R V.; Southworth, F; Pedlowski, M. Modeling Effects of Land Management in the Brazilian Amazonian Settlement of Rondonia, Conservation Biology, v. 8 n. 1, p. 196-206, 1994
- Escada, M.I. S; Monteiro A. M. V.; Aguiar A. P. D.;Carneiro T. S; Câmara, G. Análise de padrões e processos de ocupação para a construção de modelos na Amazônia: Experimentos em Rondônia. Anais. IN: Simpósio Brasileiro de Sensoriamento Remoto, XII. Goiânia - GO, 16-21 Abril, 2005.

Scientific Papers

- Escada, M.I. S.; Vieira I. C. G.; Amaral. S.; Araújo R.; Veiga J. B. da; Aguiar A. P. D.; Veiga I.; Oliveira, M.; Gavina J.; Carneiro Filho, A.; Fearnside P. M.; Venturieri A.; Carrielo F.; Thales M.; Carneiro T. S.; Monteiro A. M. V.; Câmara G. Padrões e Processos de Ocupação nas Novas Fronteiras da Amazônia: Apropriação Fundiária e Uso da Terra no Xingu/Iriri. Revista de Estudos Avançados, IEA-USP, Dossiê Amazônia, Agosto, vol.19 (54). 2005. p 09-23.
- 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)
- Escada, M. I.S. E
- Kampel, S., Araújo, R., Escada, M.I.S., Vieira, I.C.G., et al. Redes e conectividades na estruturação da frente de ocupação do Xingu-Iriri. Geografia,2006 – no prelo.
- Kitamura, P. C. A Amazônia e o Desenvolvimento Sustentável. Ed. EMBRAPA – SPI, 1a ed., 1994, p 182.
- Machado, L. A fronteira agrícola na Amazônia. IN: Becker, B. K.; Christofoletti, A.; Davidoch, F. R.; Geiger, R. P. P. **Geografia e Meio Ambiente no Brasil**, p. 181-217. 1998.

Scientific Papers

- Vieira, I. C. G.; Escada, M.I. S.; Amaral, S.; Araújo, R.; Veiga; J. B. da; Aguiar, A. P. D.; Veiga I.; Oliveira, M.; Gavina, J.; Carneiro Filho, A.; Fearnside P. M.; Venturieri A.; Carrielo F.; Thales M.; Carneiro, . S.; Monteiro A. M. V.; Câmara, G. Novas Fronteiras na Amazônia: Padrões e Processos na Estruturação do Território na Frente de Ocupação de São Félix do Xingu-Iriri. 2005.63 p.