



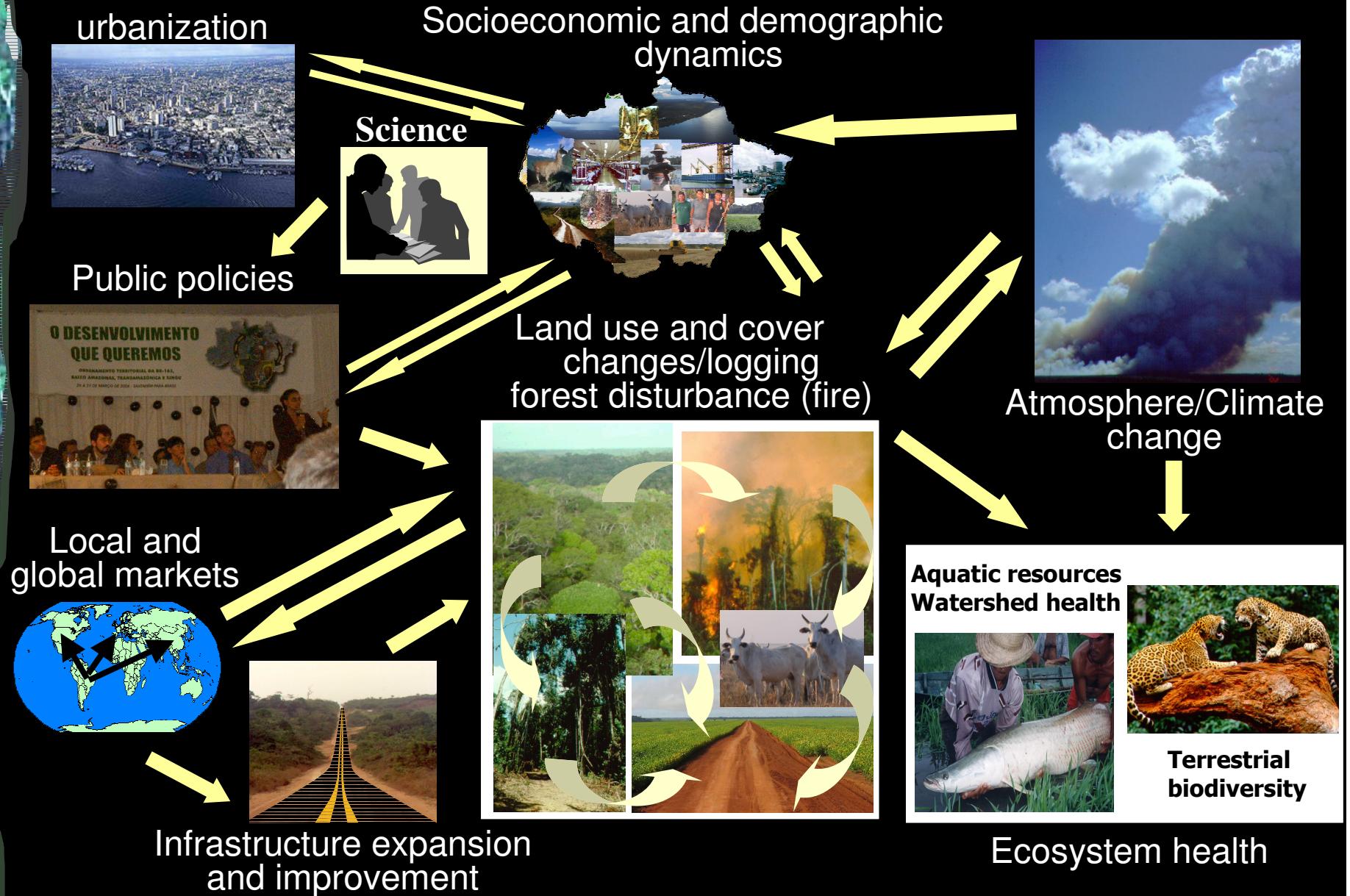
Coupling socioeconomic and demographic dimensions to a spatial simulation model of deforestation for the Brazilian Amazon

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Daniel Nepstad**



11th LBA-ECO Science Team Meeting in Salvador, Brazil, September 26-28, 2007

A scientific framework for basin wide conservation

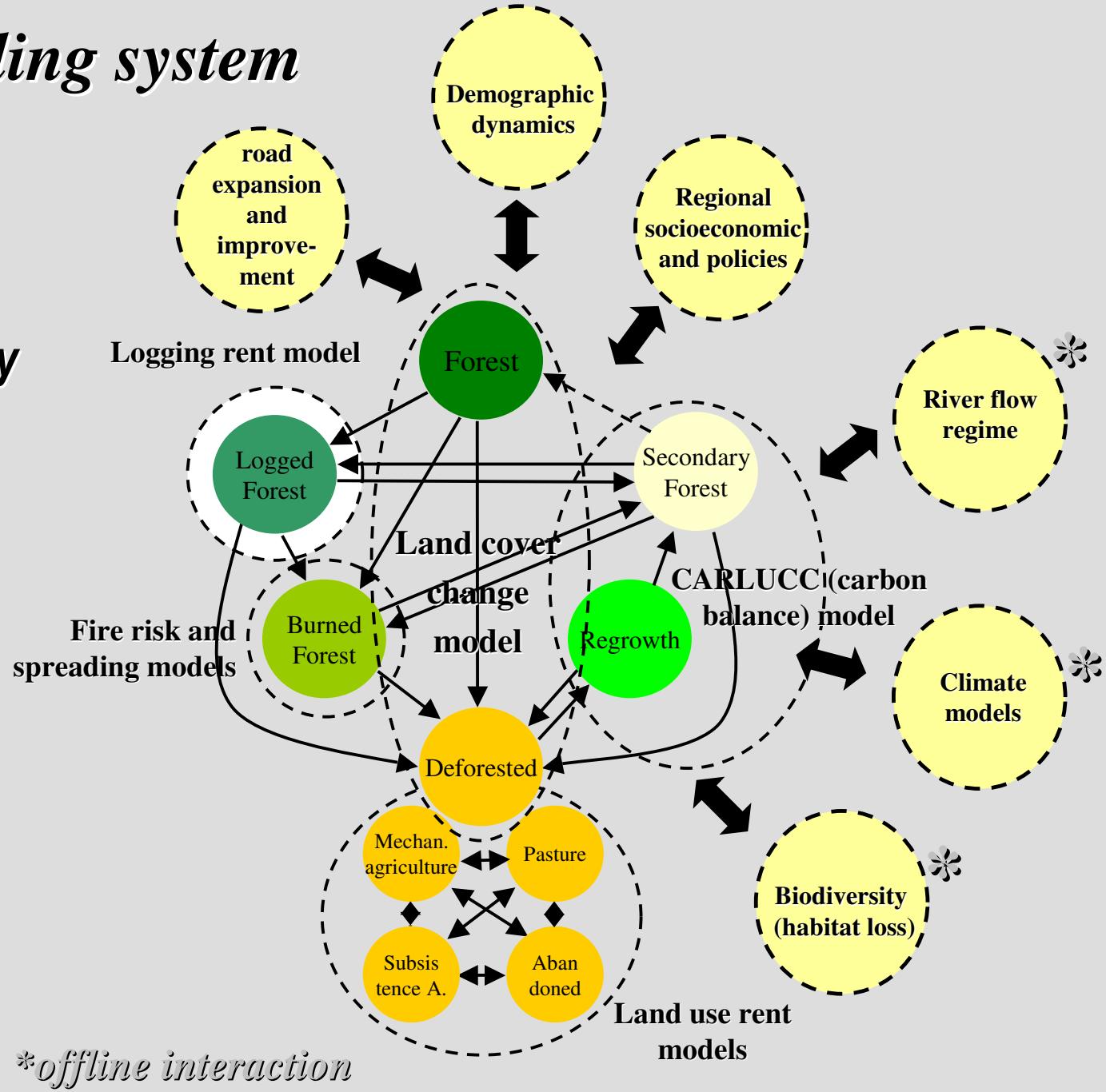


System dynamics: Analyze **feedback effects** among system elements

A modeling system

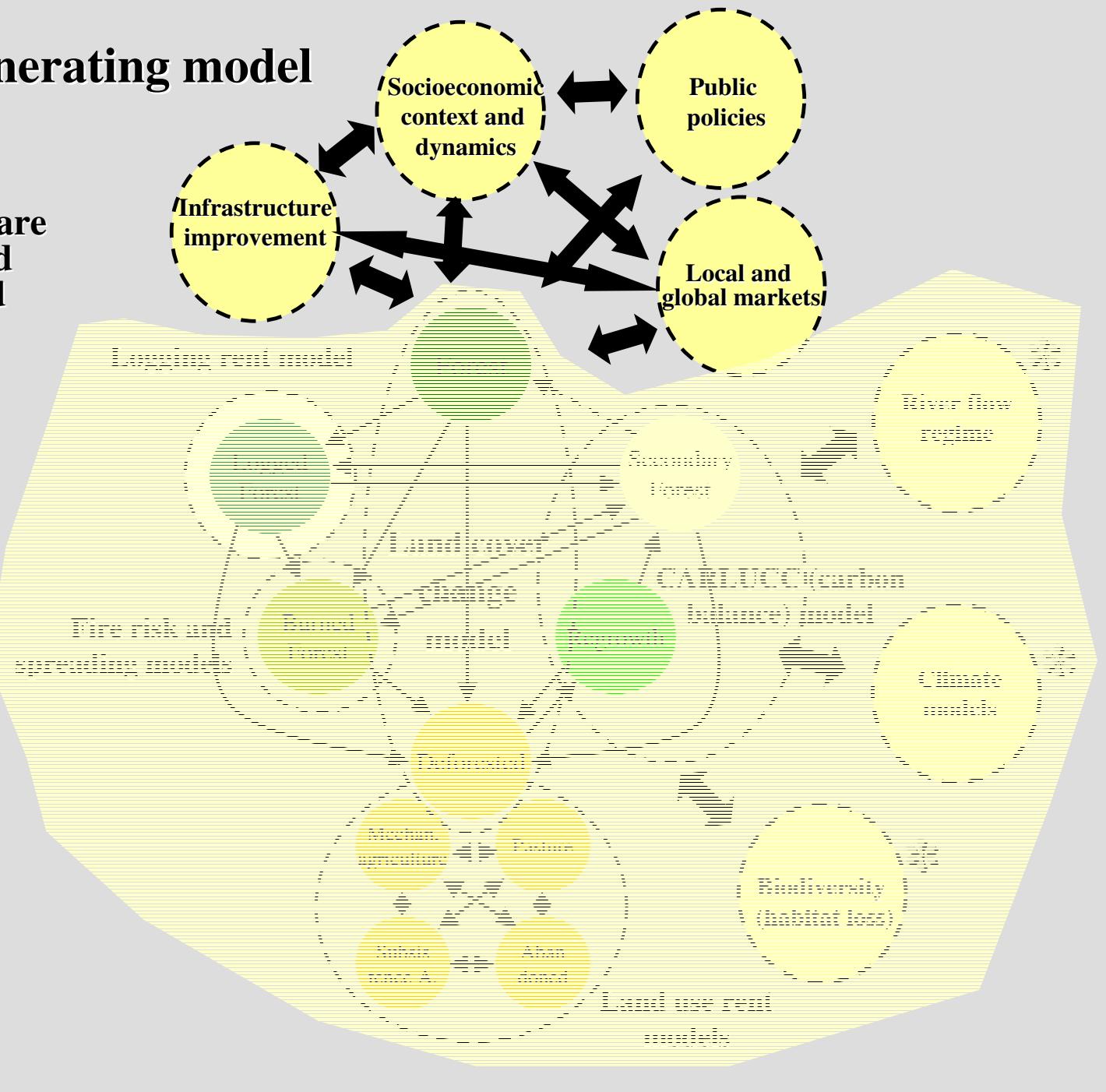
*A series of
models
developed by
various
research
teams*

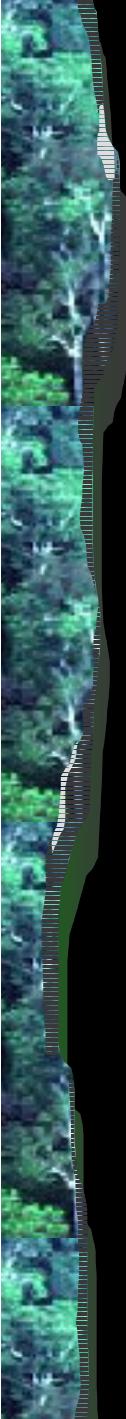
WHRC
UFMG
IPAM
INPE-CPTEC
USP
Boston U.
UFPa
Virginia Tech
Duke U.
Yale



Scenario generating model

Causes of deforestation are complex and interrelated



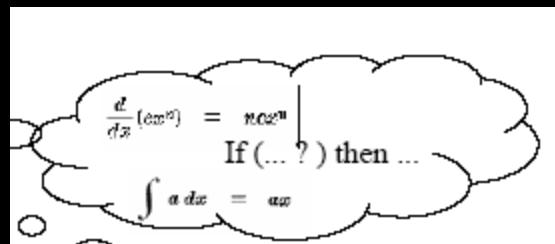


The incorporation of the human dimensions into models of deforestation still represents a great challenge.



Given the complex nature of interrelationships, it is difficult to distinguish effect from cause as well as to measure quantitatively the influence of socioeconomic drivers.

Mathematical model

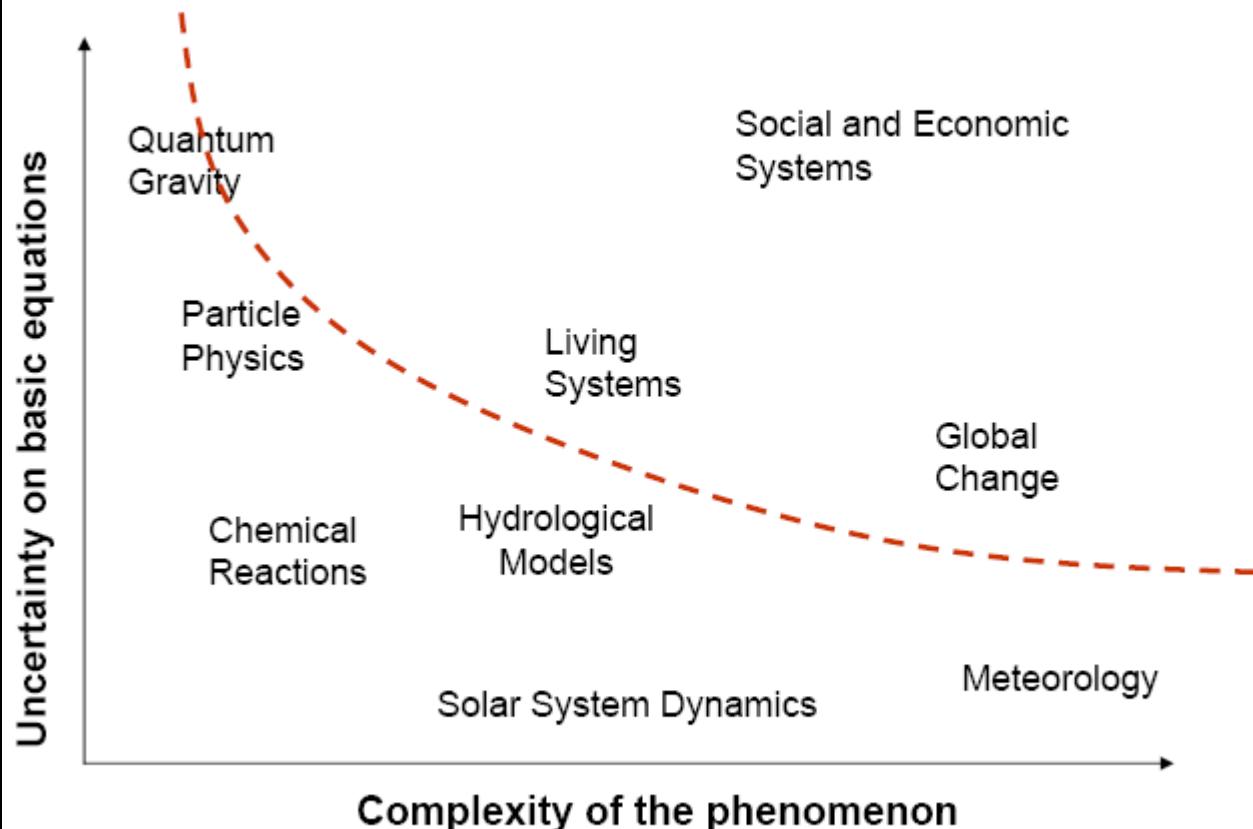

$$\frac{d}{dx}(\exp^x) = \exp^x$$

If (... ?) then ...

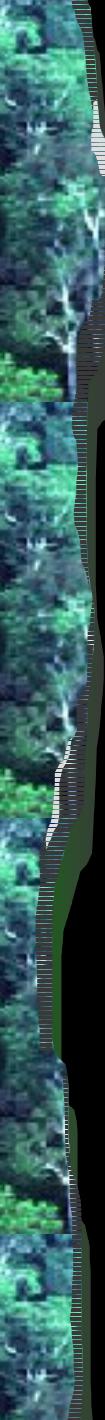
$$\int a dx = ax$$

$$A \Leftarrow C$$
$$B \Leftarrow C$$
$$A + B \Rightarrow C$$


Limits for Models



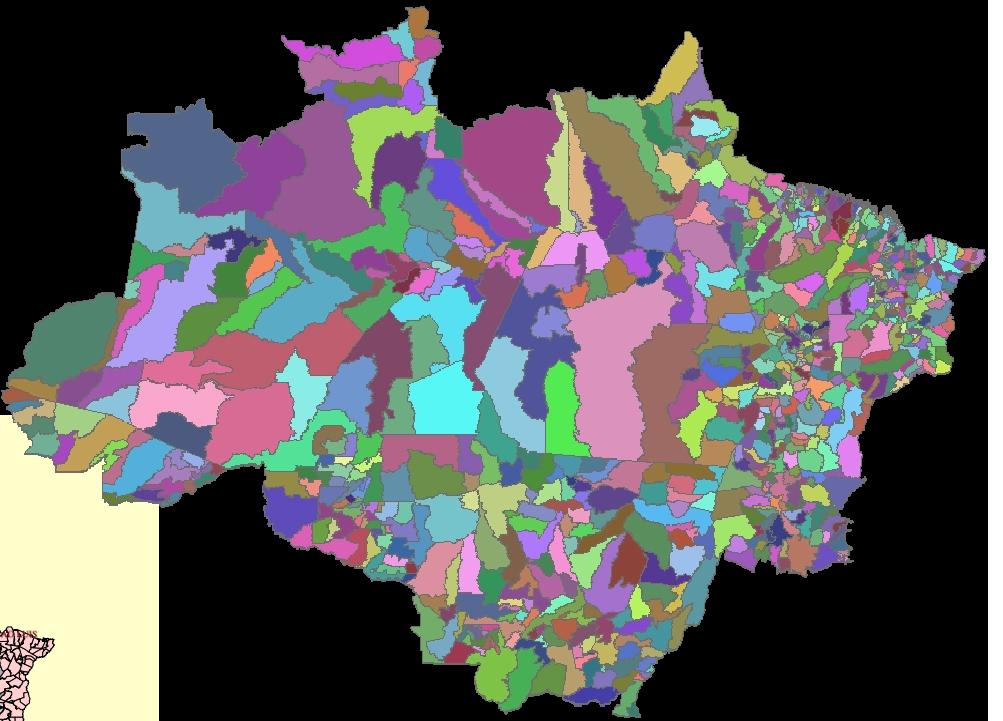
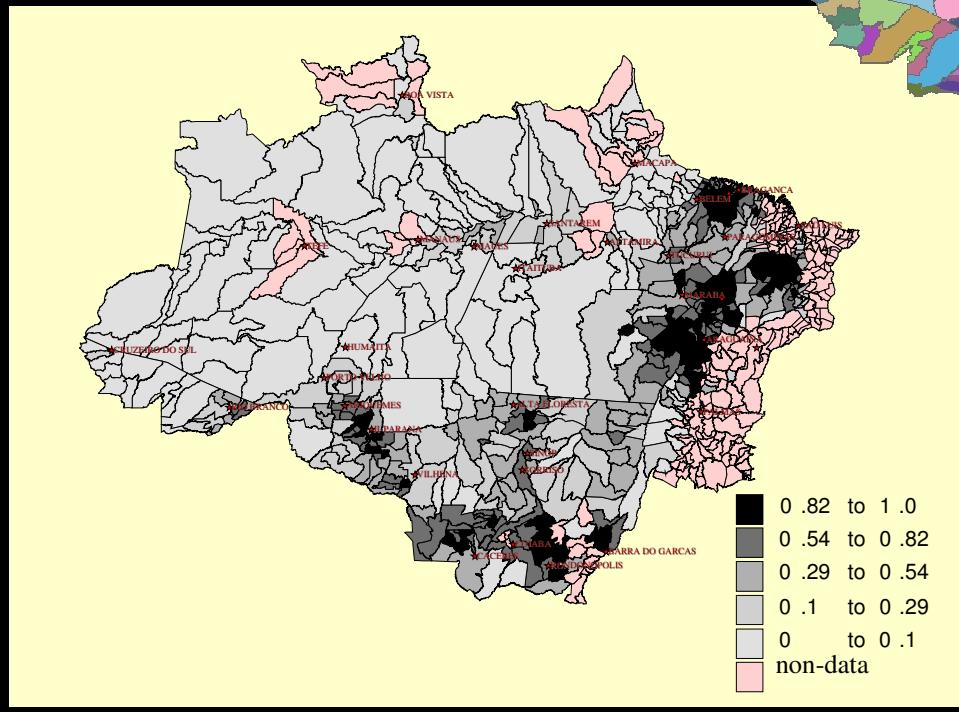
source: John Barrow
(after David Ruelle)



To develop a spatial model of deforestation for the Brazilian Amazon that incorporates the influence of a series of socioeconomic, demographic, and policy variables

*not an agent based model

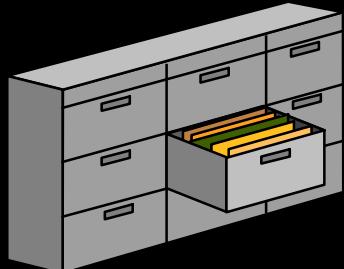
Inpe's Prodes data
1997-2001



IBGE 1996 population tally, 2000 census, as well as other economic and social surveys carried out within 1996-2001 period at municipal level.



Database



deforestation

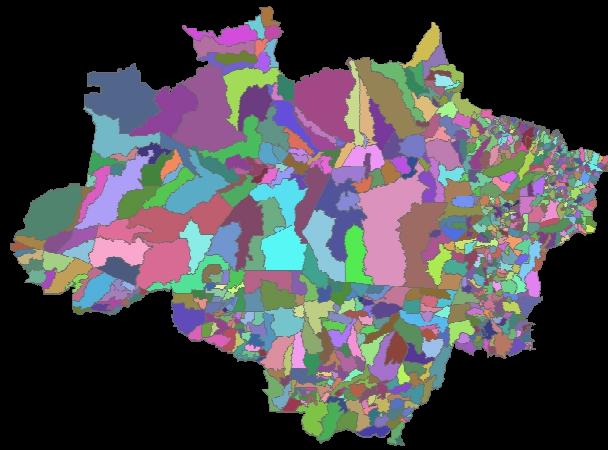
models

% deforested land by 1997

% deforested land by 2001

% deforestation 1997-2001

***All variables normalized by county's area**



Socioeconomic and demographic variables

Model	n.	Variable
all	1	Mean distance to paved roads
all	2	Mean proximity to urban centers
all	3	Number of cattle heads per Km2
all	4	Income from agriculture per km2
all	5	% of planted area
all	6	Total population density
all	7	Rural population density
all	8	Rural population density adjusted by agrarian concentration index
all	9	Urbanization level
all	10	Social development index
all	11	Economic development index
all	12	Infrastructure agrarian index
all	13	Timber and Agriculture production index
all	14	Primary sector domestic product
all	15	Secondary sector domestic product
all	16	Tertiary sector domestic product
all	17	Gross domestic product
all	18	% protected area
2001	19	Migration rate (1995/2000)
2001	20	Migration balance (1995/2000) /km2
2001	21	Migratory volume/ Km ²
2001	22	Income per capita from agriculture /km2
2001	23	Working population in rural activities /km2
2001	24	% of Working population in rural activities

Source: 3 - IBGE - PPM, 1997; 4 and 5, IBGE - PAM, 1997; 6 to 9 1996 IBGE Population tally and IBGE 2000 demographic census; 10-13 Garcia et al, 2004, 14 -17 Andrade and Serra, 1999. 20-24 IBGE 2000 demographic census.

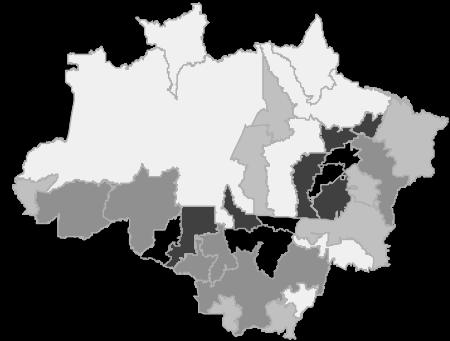
Methodological steps

- ORDINARY LEAST SQUARES (stepwise model)
- OLS model with outliers control (heteroskedasticity)
- DIAGNOSTICS FOR SPATIAL DEPENDENCE
- SPATIAL LAG MODEL

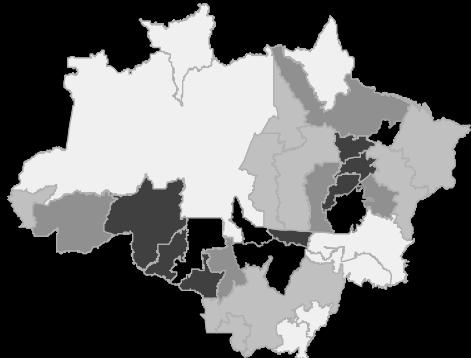
Socioeconomic drivers incorporated into the deforestation model

	VARIABLE	COEFF	S.D.	z-value	Prob
Mean Distance to Paved Roads	W_X1	0.476653	0.0572576	8.324710	0.000000
Growth rate of cattle herd	CONSTANT	0.0175743	0.00290395	6.051857	0.000000
Growth rate of the value agriculture production		-2.85729E-0051.20166E-005	0.000536177.41236E-005	-2.377786	0.017417
Net Migration rate		0.0970091	0.0466453	2.079719	0.037551
Percent of Protected area		0.0142441	0.00555849	2.562592	0.010389
		-0.0002045765.25166E-005		-3.895452	0.000098
P	P	0.0802619	0.00552175	14.535597	0.000000
N	N	-0.0478951	0.0155622	-3.077654	0.002086

1997-2001



Simulated 1997-2001

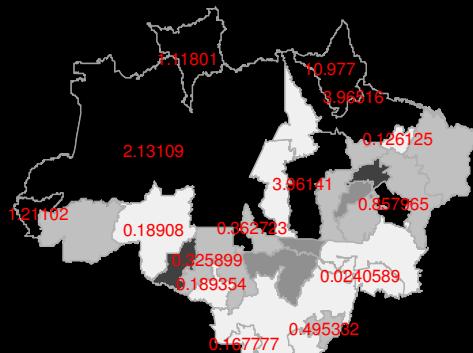


Model	heteroscedastic		R	R ²	Log Likelihood
	control	yes			
Spatial (Maximum Likelihood)		yes	0,802	0,643	969,68

Simulated = real

Total = 18 k km²/year-1

Errors



Rates aggregated by subregion

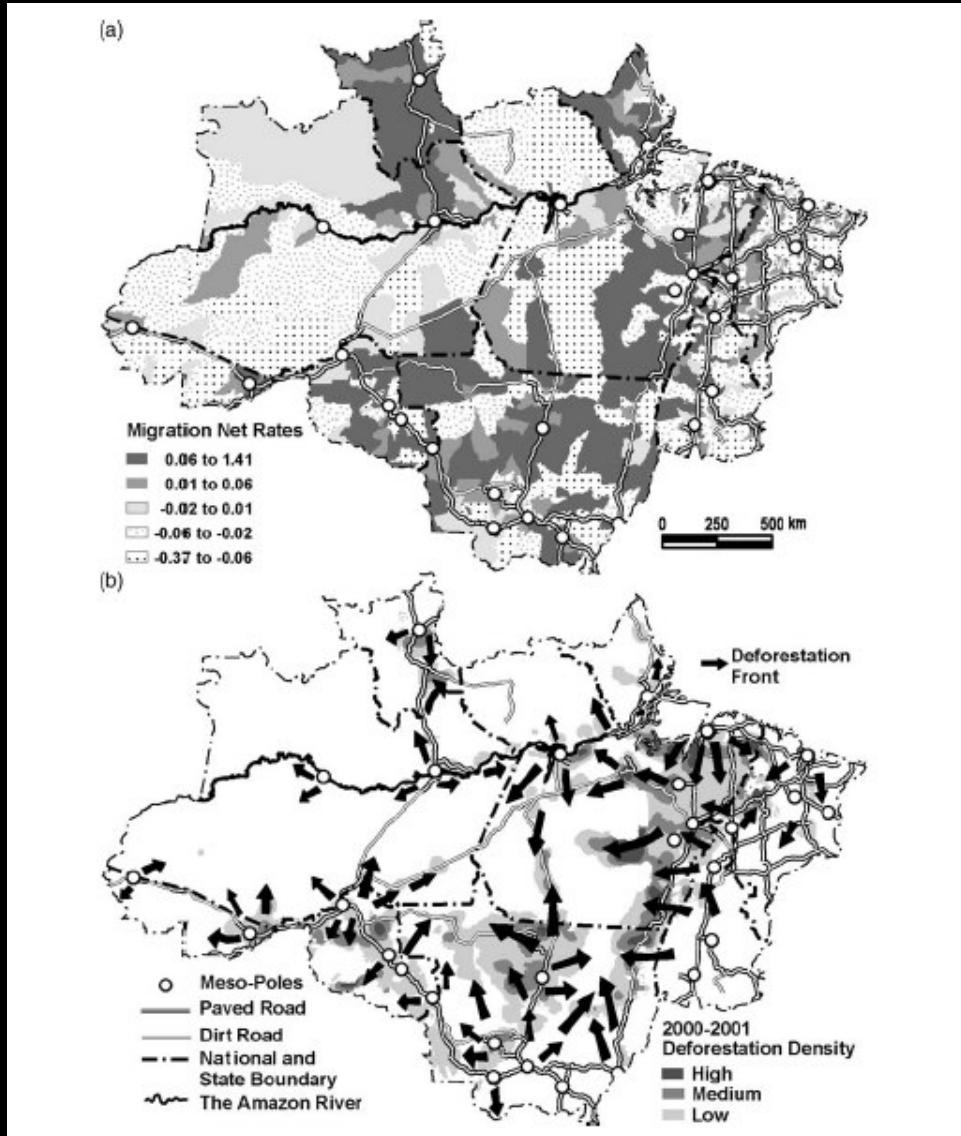


Forecasting deforestation under various scenarios of:

- 1. Infrastructure improvement**
- 2. law enforcement and PA expansion and implementation**
- 3. regional migration**
- 4. cattle herd expansion**
- 5. agriculture expansion**

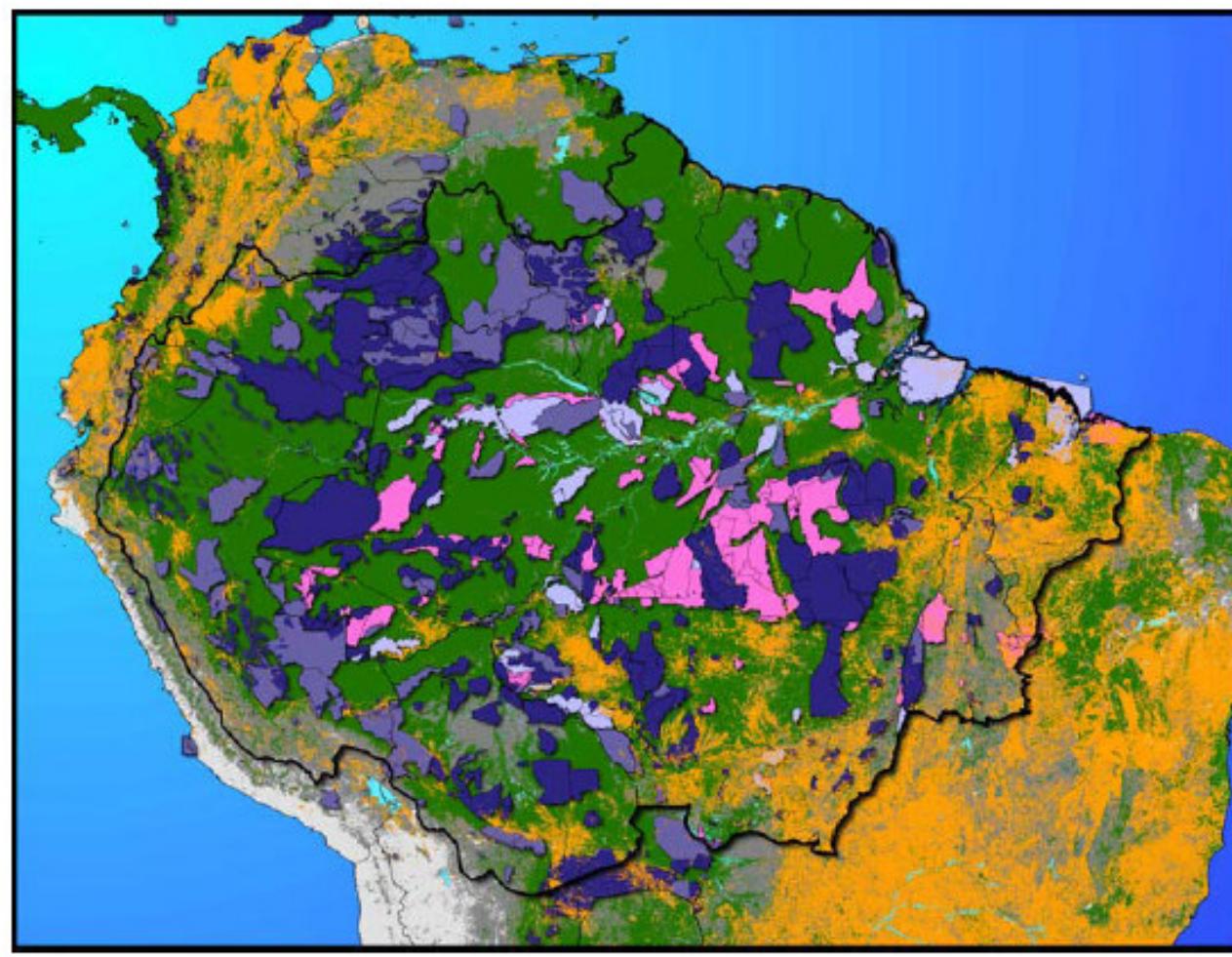
Stochastic model

Migratory movements and frontier mobility



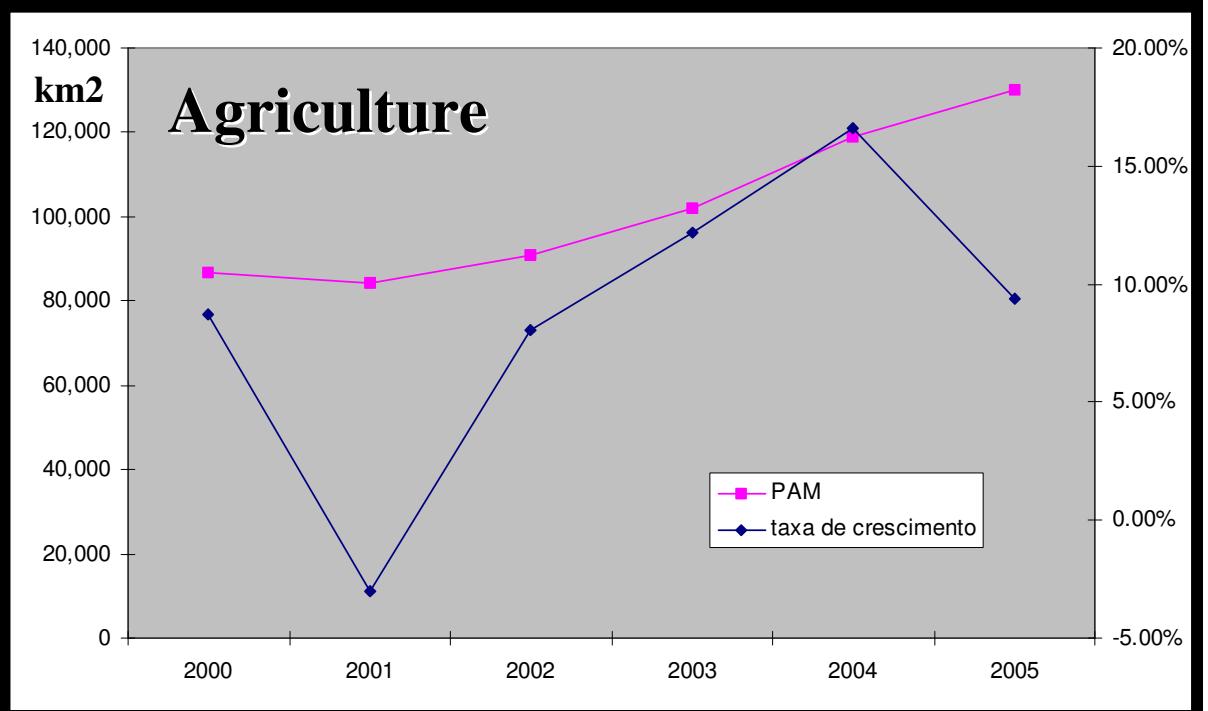
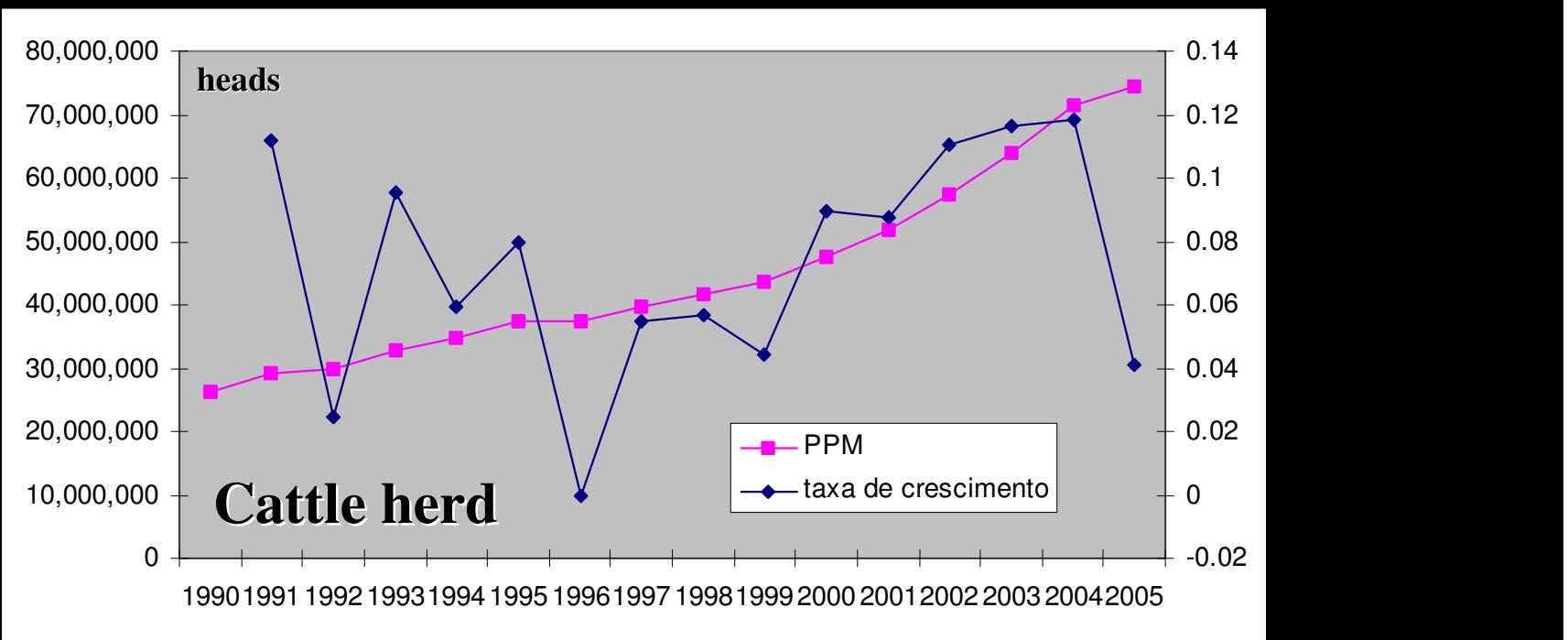
Incorporating planned infrastructure



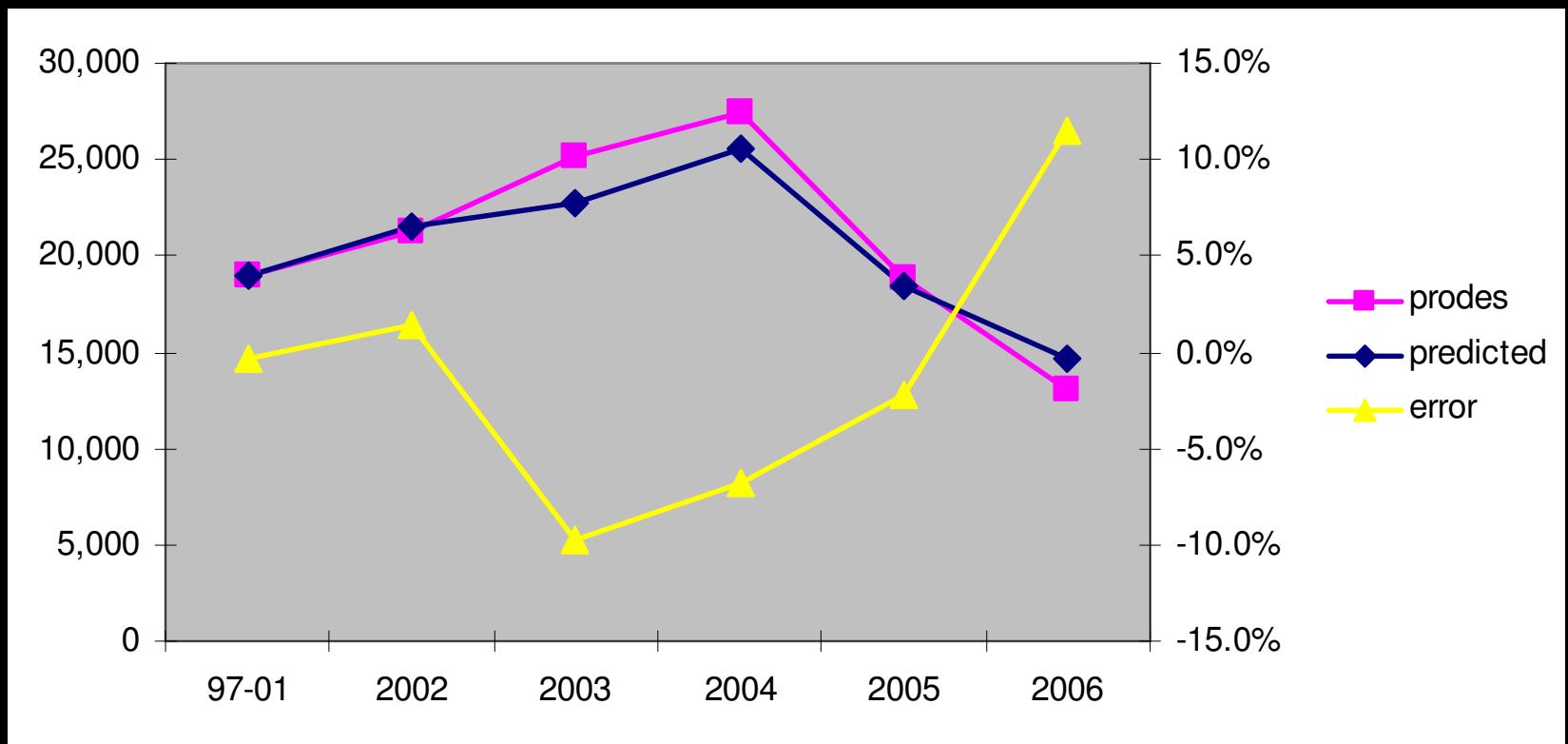


**More than
24 Mhec.**

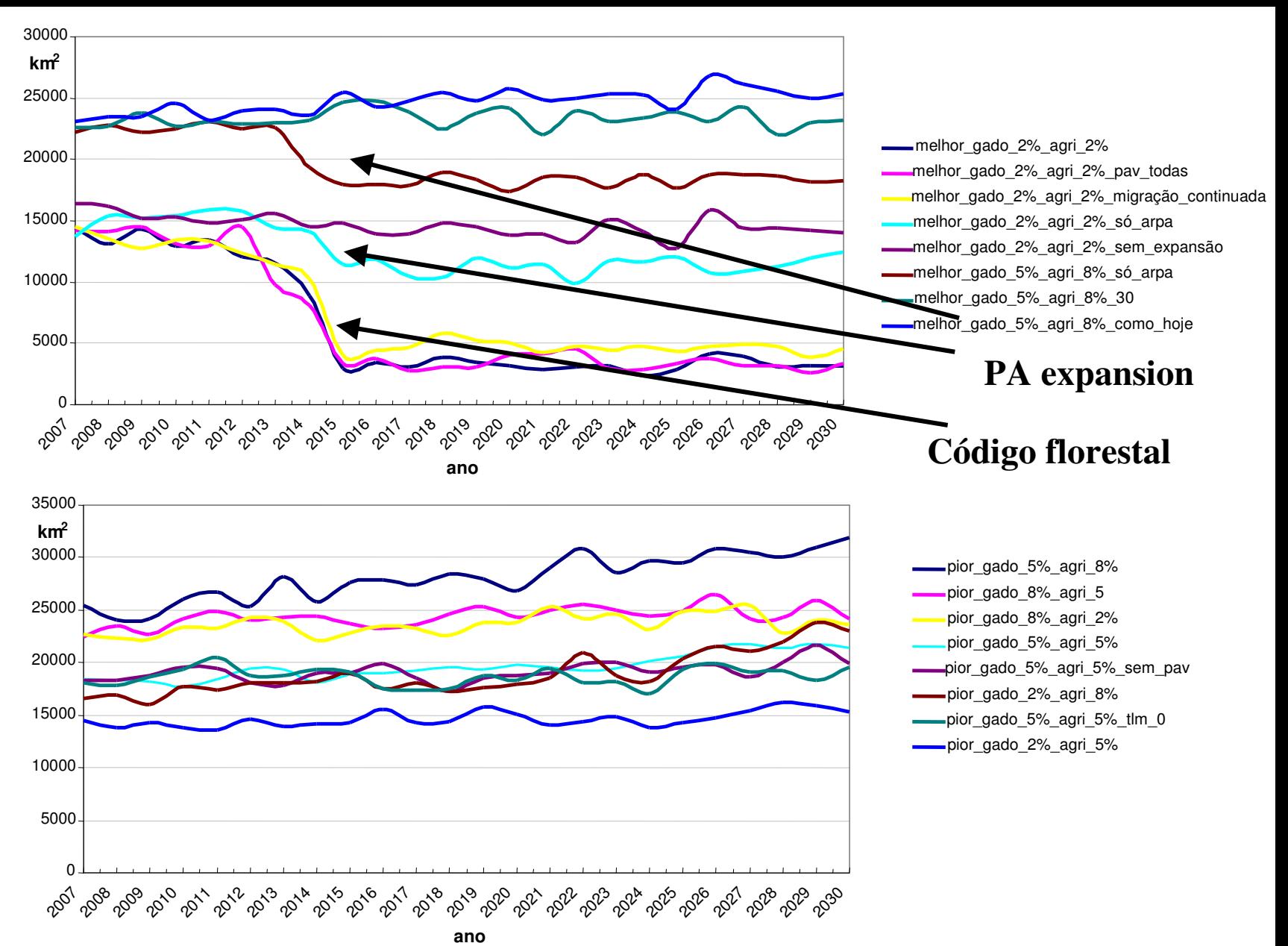
New protected areas created in the Amazon by the Brazilian government since early 2004 (pink) are a remarkable display of political will. Already existing protected areas and indigenous lands are indicated in shades of blue. Indigenous lands are dark blue.



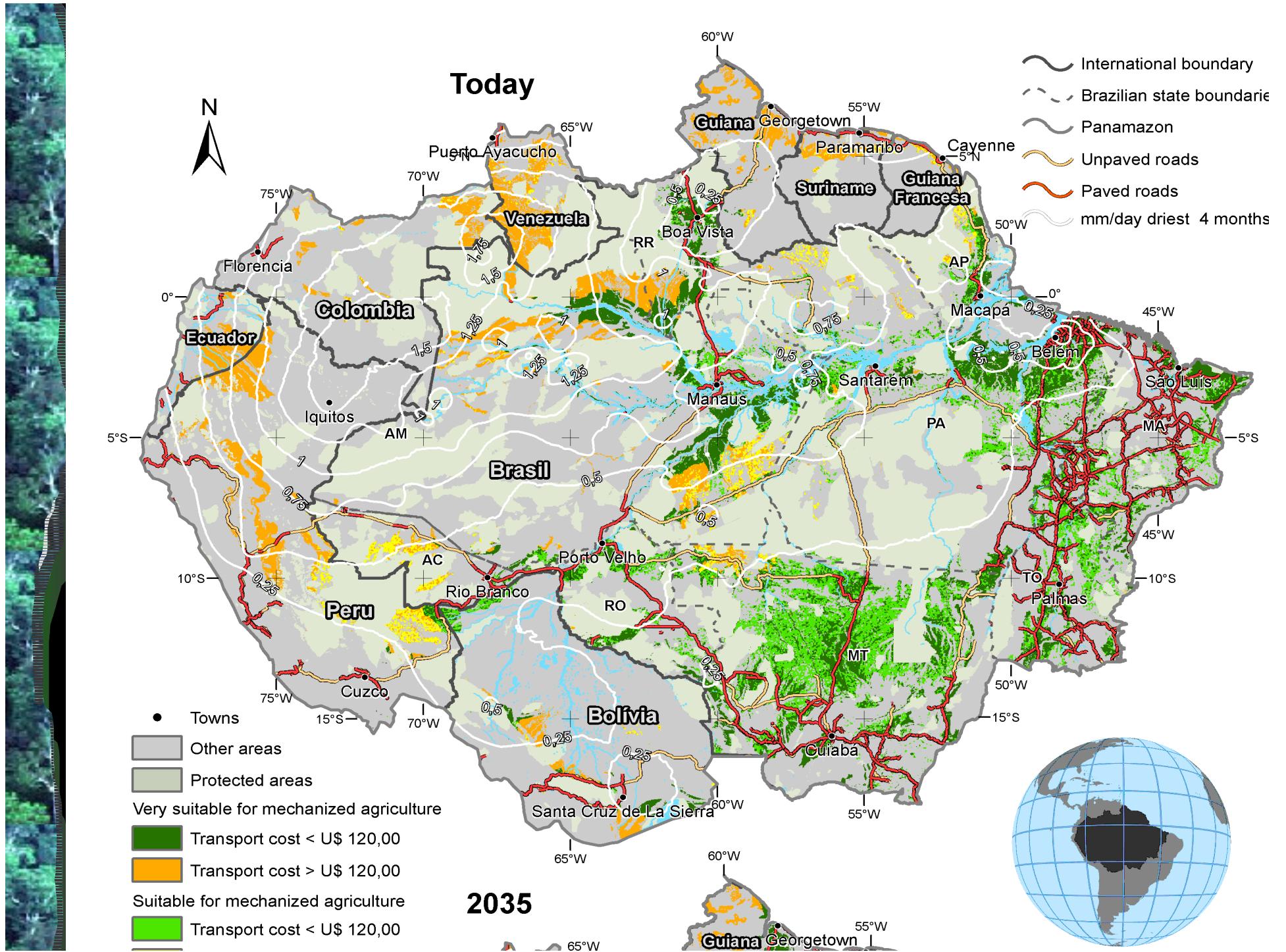
Annual deforestation in Brazilian Amazon



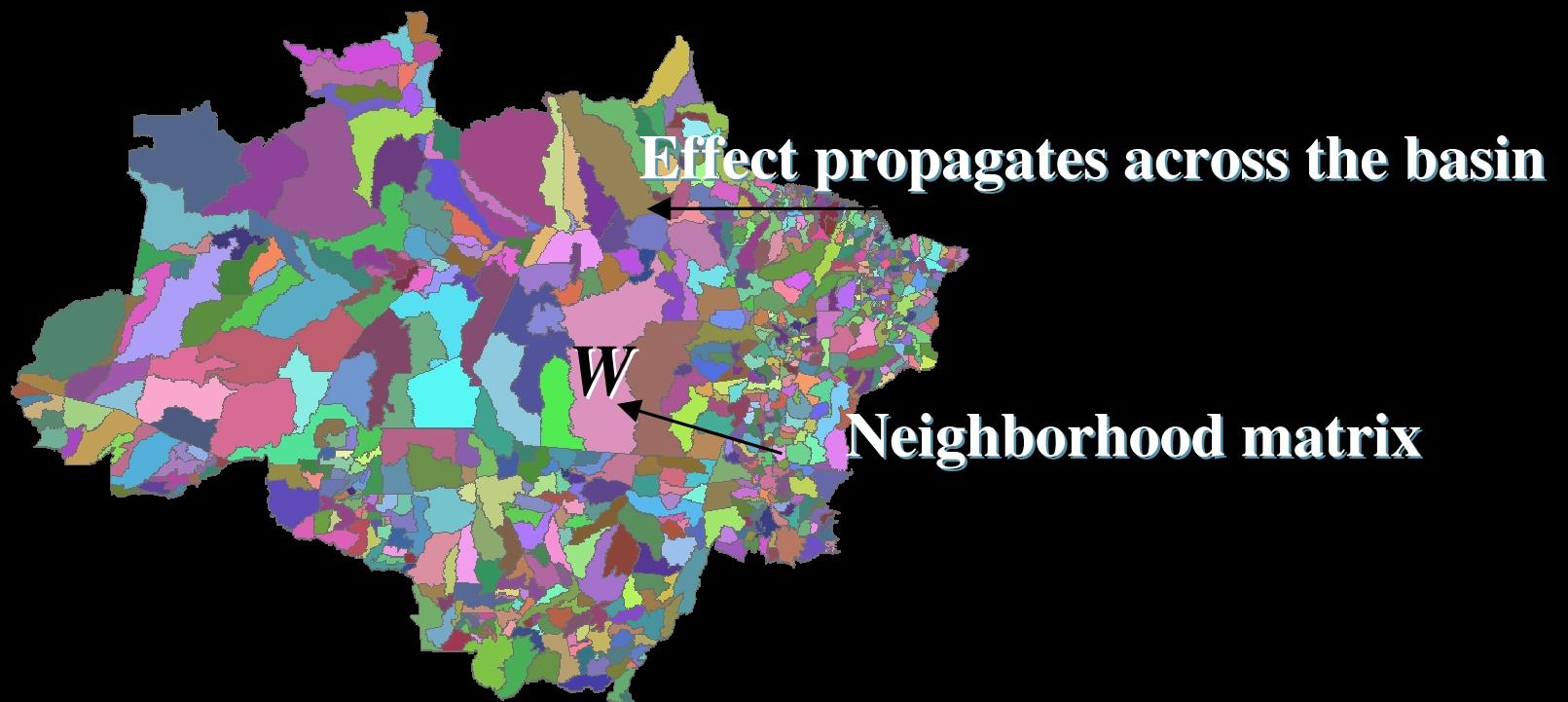
10% maximum deviance
lower variability

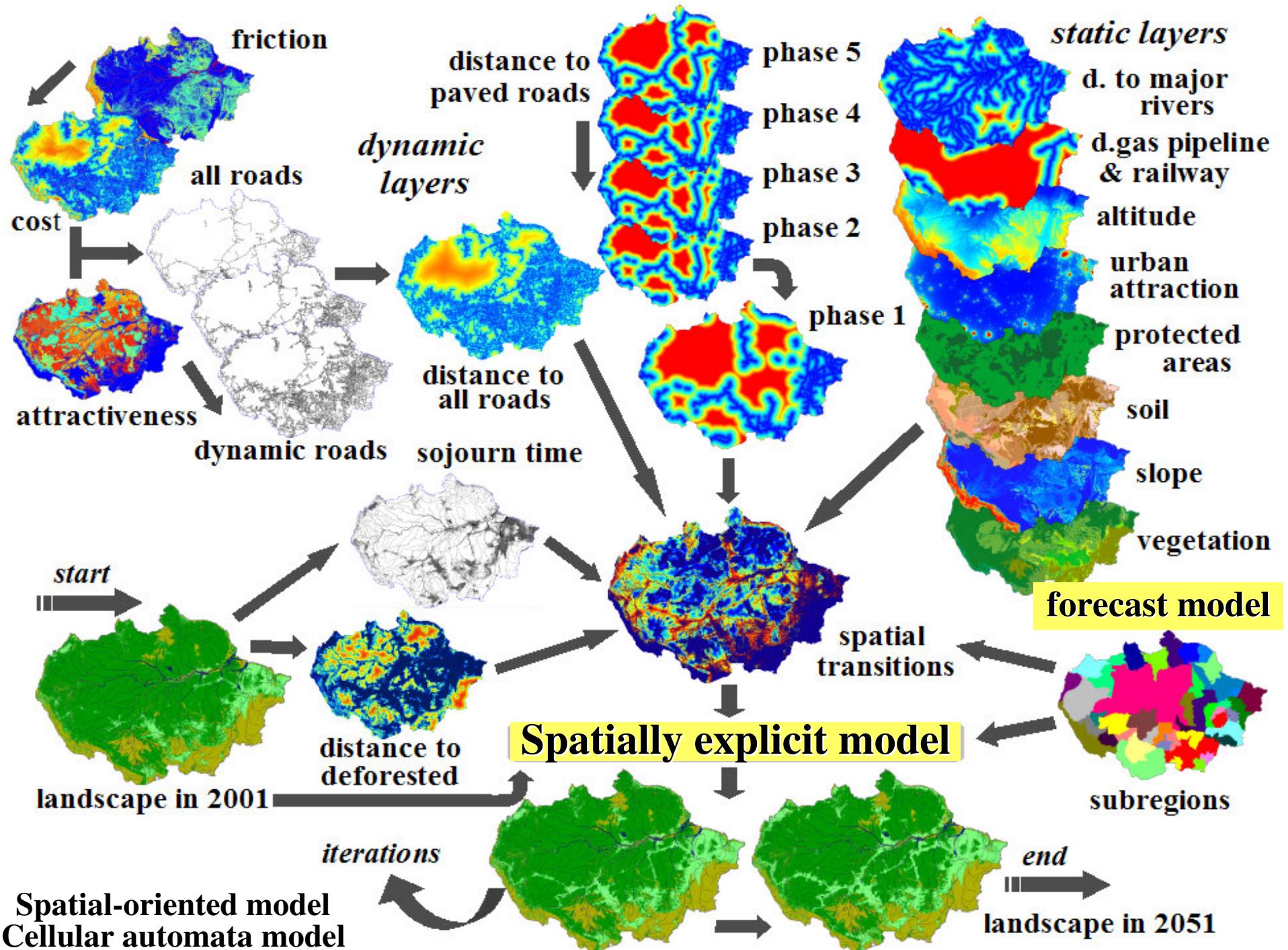


Set timing for target realization



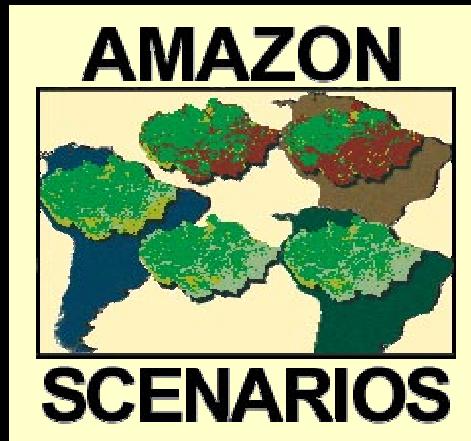
- The obtained model can be used to infer the potential for future deforestation from changes in the socioeconomic and demographic context, not only within a specific Amazon county, but also from its neighboring regions.







Thank you, Obrigado



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