Roads and Deforestation in the Amazon Basin

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NASA LBA project

A Basin-Scale Econometric Model for Projecting Future Amazonian Landscapes

Michigan State University
IPEA (Institute for Applied Economics Research)
Columbia University
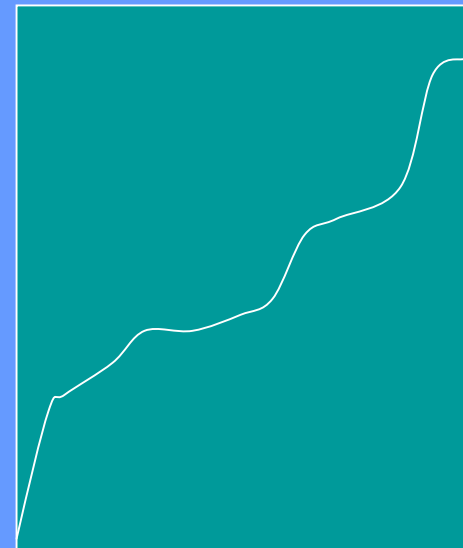Federal University Fluminense
IMAZON

ROADS CAUSE DEFORESTATION (?)

Roads

1965   1980   1995

Cleared Land

1965   1980   1995

An important Policy Issue

Governments want to build roads for economic development
but roads have environmental impacts

The question is, then, what kind of impacts, and how much?

Today, like to begin a discussion about this

➡ Start with a description of the road system itself

➡ Move on to a description of road-deforestation relationships,
both hypothetical and observed

We know a lot about deforestation....but what do know about roads??

Goals of talk:

Provide initial cut at a description of the road system in the Amazon Basin

Provide some evidence on complexity of the relationship between roads and deforestation

Tend to talk about roads as homogenous, undifferentiated

Federal, State, Municipal Government   *Official Roads*

loggers, colonists, fazendeiros   *Unofficial Roads*

Big differences between official – esp Fed – and unofficial roads

   in both characteristics and "road-deforestation relationship"

The Fed system, built in advance of deforestation….*exogenous, causal*

The unofficial system, not so obvious…….

         often built in the "process" of deforestation

Data for Legal Amazonia, Federal and State System: *Official Roads*

Jurisdiction	Year			
	1968	**1975**	**1985**	**1993**
Federal	12,555	15,495	18,890	18,974
State	484	12,914	33,606	36,688
No Info	-	448	21	-
Total	13,039	28,857	52,517	55,663

Somewhat deceptive, in that parts were relatively developed in the 1960s
esp to the east and south, *cerrado* lands (tropical savanna)

The ~7000 km increment, in Fed system (1968-93): forested Amazonia

Data sources: The data originate from two sources. The first source is a digital map produced by IBGE in 1997 created by updating the RADAM products with 1991 LandSat Images. The second source of data comprises paper maps from Republica Federativa Do Brazil, Ministerio Dos Transportes, Department Nacional De Estradas De Rodagem (DNER); these are paper maps for actual road networks existing in 1968, 1975, and 1985.   They were put in digital form by visually comparing 1968, 1975, and 1985 to the 1997 digital map from IBGE (for the year, 1991) in ArcMap GIS. The road system for each earlier year was constructed by extracting segments from the 1991 map existing in that early year. The attributes for the earlier years were changed as necessary from the 1991 map to make them consistent with the earlier state of the road (e.g., from paved to unpaved).

http://www.lbaeco.org/lbaeco/data/data_lba.htm

Brazil: http://lba.cptec.inpe.br/beija-flor/
US: http://beija-flor.ornl.gov/lba/
Beija-flor User's Guide: english [790K], portuguese
[240K] pdf

welcome to

Beija-flor

Search Engine for the LBA Project

- Search under "roads"

- Data sets 8, 9, 10, 11, 12, 13, 14, 15, 16

- Acre, Amapá, Amazonas, Maranhão, Mato Gross, Pará, Rondônia, Roraima, Tocantins

FOR EXAMPLE:

- **13. Data Set Title:** Historical Roads of the Amazon - Pará <u>Access data and documentation...</u>   **Abstract:** This PDF displays federal or state road locations for various years. Please refer to the dataset title for more information.

Road Infrastructure
Legal Amazon
1999
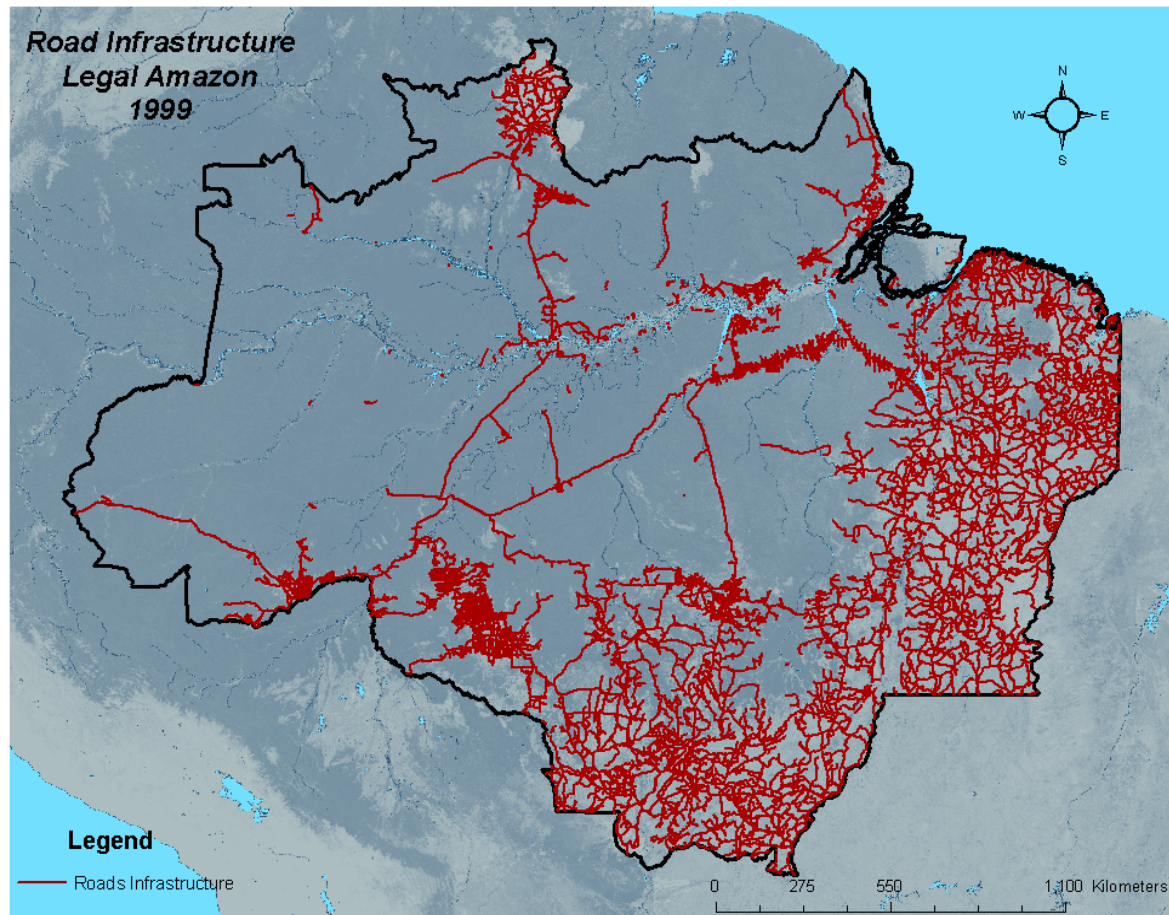
Recall TOTAL from 1993:

55,663 km

TOTAL 2003:

143,997 Km

Legend
—— Roads Infrastructure

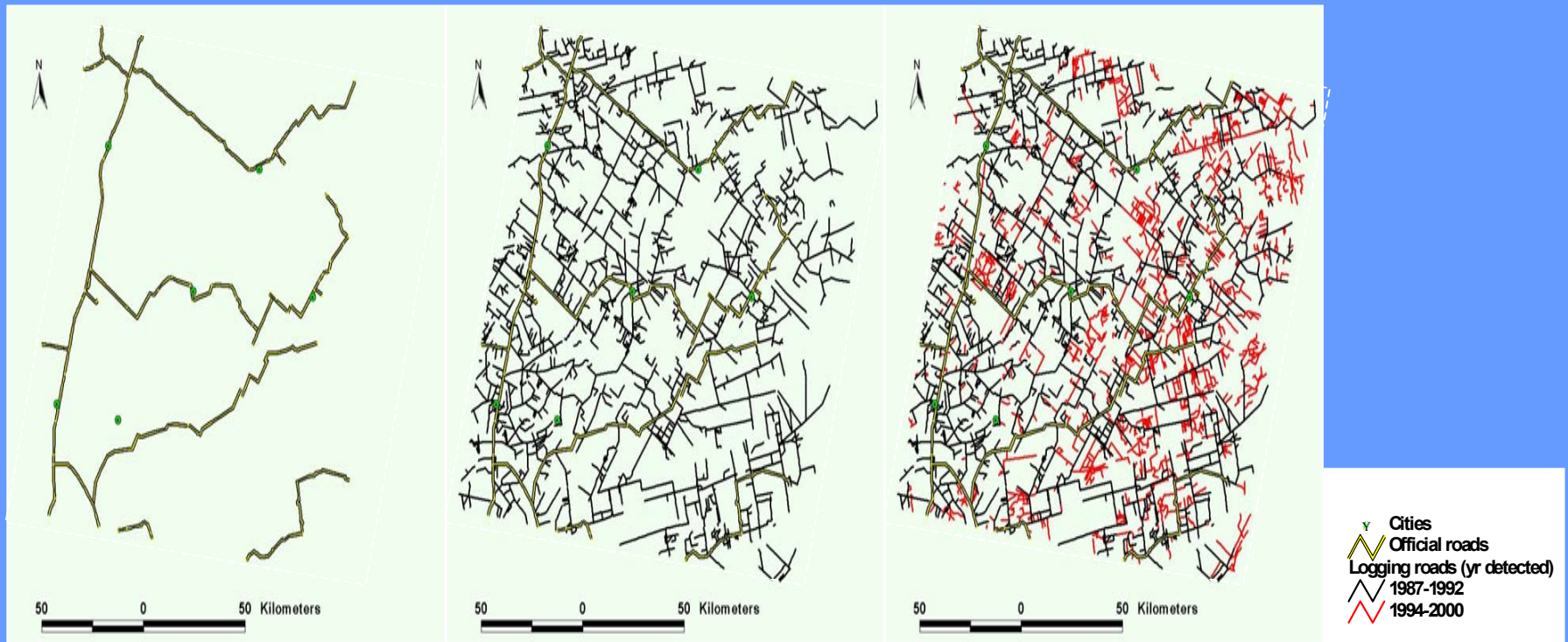0   275   550   1,100 Kilometers

Official + Unofficial Roads

Base Cartográfica Integrada Digital do Brasil ao Milonésimo
2003
Ministério do Planejamento, Orçamento e Gestão, **IBGE**

Northern Mato Grosso, expansion of private road system
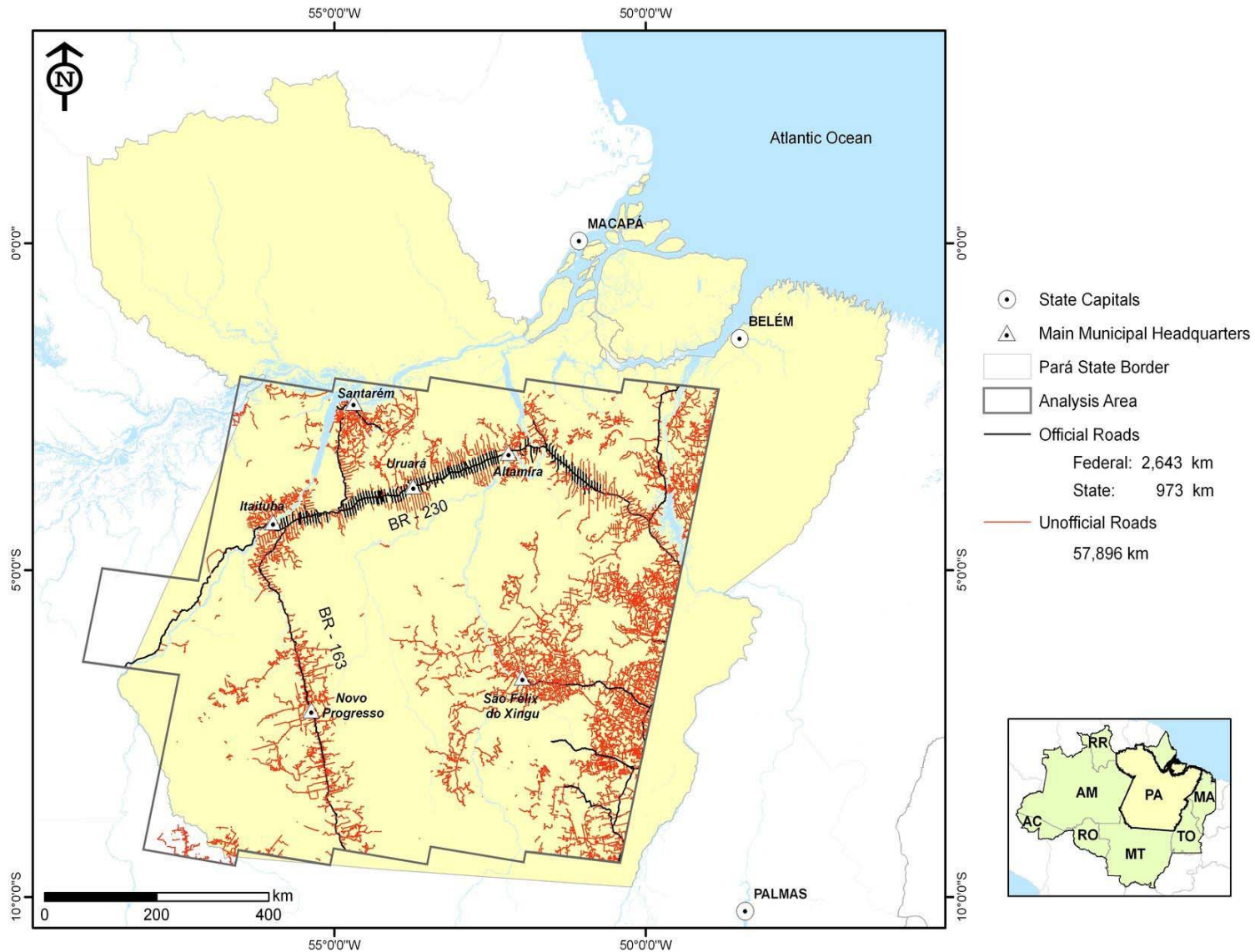
Unofficial Roads

Legend:
- Cities
- Official roads
- Logging roads (yr detected)
  - 1987-1992
  - 1994-2000

Visual interpretation based on TM and ETM+ Images, from the following years: 87,88,89,90,91,92,94,96,97,98,99, and 2000.

Central and Southern Pará

Unofficial Roads: *loggers* & Unofficial extensions of Official Roads: *colonists*

Legend:
- ⊙ State Capitals
- △ Main Municipal Headquarters
- Pará State Border
- Analysis Area
- Official Roads
  - Federal: 2,643 km
  - State: 973 km
- Unofficial Roads
  - 57,896 km

Labels on map: Atlantic Ocean, MACAPÁ, BELÉM, Santarém, Uruará, Altamira, Itaituba, BR - 230, BR - 163, Novo Progresso, São Félix do Xingu, PALMAS

Inset map labels: RR, AM, PA, MA, AC, RO, MT, TO

From Landsat mosaics comprised of 31 scenes, over period from 1985-2001. Road identification from Bands 3 & 5, at a scale of 1:50,000

Road building "agents" in Uruará Municipio, BR-230

Road Building Agent	Total (km)
Logging Company	153
Municipal Government	184
Fazendeiros	17
Colonists	61
Colonists + Federal Government	11.5
Loggers + Municipal Government	157
Municipal + Federal Government	35

As for Road-Deforestation Relationships.....

Road construction...may be influenced by agricultural development considerations. If roads are routed through agriculturally suitable areas and if some aspects of suitability are not observed, then the model may overestimate the effect of ...the road.

Chomitz and Gray (1996; 493)

In highly cleared areas we would not expect new paved roads to have much of an impact on clearing rates while the impact could be quite dramatic in relatively uncleared areas.....

Andersen et al. (2002; 126)

Is it national demand for land...that lead(s) to decisions to expand the road network?....Or is it the expansion of local...activities in some forest area that then justifies the construction of new roads?

Lambin, Geist, and Lepers (2003; 226)

In addition…….

Agricultural intensification…..could be promoted by roads

Long term landscape dynamics linked to economic development,
e.g. *The Forest Transition*

Consider the Interstate System in the US, constructed in the postwar years, when forest was rapidly recovering in many sites in the US

The focus here, on the short to mid-run,
in a land abundant environment

Deforestation and road extension are positively correlated:

The issue is causality

Roads x_r

$$y_d = \beta_0 + \beta_r x_r$$

Deforestation y_d

Roads x_r

$$y_d = \beta_0 + \beta_r x_r + \gamma q$$
$$x_r = f(q)$$

Deforestation y_d

(a)

Omitted variable q

Roads y_r

$$y_d = \gamma_d y_r + \delta_d x$$
$$y_r = \gamma_r y_d$$

Deforestation y_d

(b)

If cases (a) or (b) in evidence, then you have to be careful,

You can produce "biased" results…..ENDOGENEITY

you can overestimate or underestimate the impact of roads

An important issue in the Amazon,

given government interest in transportation infrastructure

Omitted Variable Endogeneity

y_d Deforestation x_r Roads q Third Factor

v, w Error terms

$$y_d = \beta_r^0 + \beta_r x_r + \gamma q + v \qquad \text{ACTUAL RELATION}$$

$$y_d = \gamma_0 + \gamma_r x_r + w \qquad \text{ESTIMATED RELATION}$$

$$\text{IF} \quad q = \delta x_r + r \qquad \text{THEN} \quad \gamma_r = \beta_r + \gamma \delta$$

$$\delta = \frac{\text{cov}(q, x_r)}{\text{var}(x_r)}$$

Reverse Causality Endogeneity

y_d deforestation

y_r roads

$u_r, \ u_d$ error terms

$y_r = \gamma_r y_d + u_r$

$y_d = \gamma_d y_r + \delta_d x + u_d$

ACTUAL RELATIONSHIPS

$y_d = (\gamma_d + \rho_d) y_r + (\delta_d - \rho_r \pi_r) x$ ESTIMATED RELATIONSHIP

$$\rho_d = \frac{\text{cov}(v, u_d)}{\text{var}(v)} \qquad v = \theta_r u_r + \theta_d u_d \qquad \pi_r = \frac{\gamma_r \delta_d}{1 - \gamma_r \gamma_d}$$

Working hypothesis:
　　　This road-deforestation relationship is linked to scale

There's a hierarchy, federal, state, municipal, private roads....

…..the Federal system represents an exogenous imprint

i.e. conforms to the causal model

State roads, and those built by private citizens and local
　　government…..

possible endogeneity

Makes sense behaviorally, if you think about the agents….

Federal bureaucrats, far removed, concerned about overall costs of construction, build in
　　straight lines connecting pre-existing points

Other roads: local residents, aware of local resources…..

The beginnings of an empirical argument

Consider the tiers of the hierarchy, starting with the federal system

When it was built, no extensive deforestation, so Case (b) unlikely

Had case (a) been strongly in evidence, we'd expect to see a pattern reflecting the factors (e.g., soils)

Key informants:
government didn't pay attention to resource quality simply had a vague idea about a network, and set about connecting pre-existing settlement….. Or "pontos de ajuda"
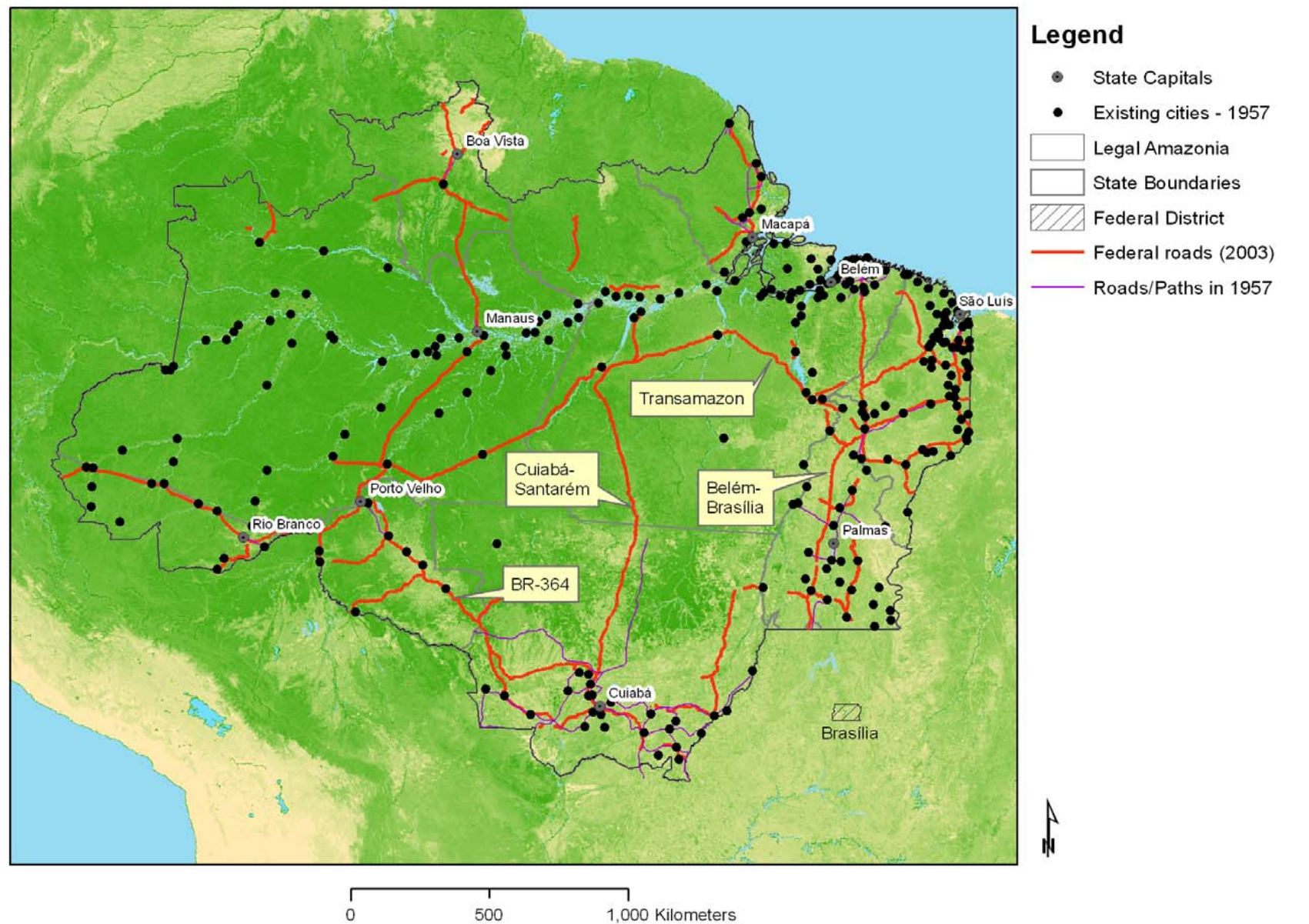
1957 settlements from: Instituto Brasileiro de Geografia e Estatística (IBGE). 1957. Grande Região Norte. Edited by J. P. Ferreira. Vol. XIV, Enciclopédia dos Municípios Brasileiros. Rio de Janeiro: IBGE.
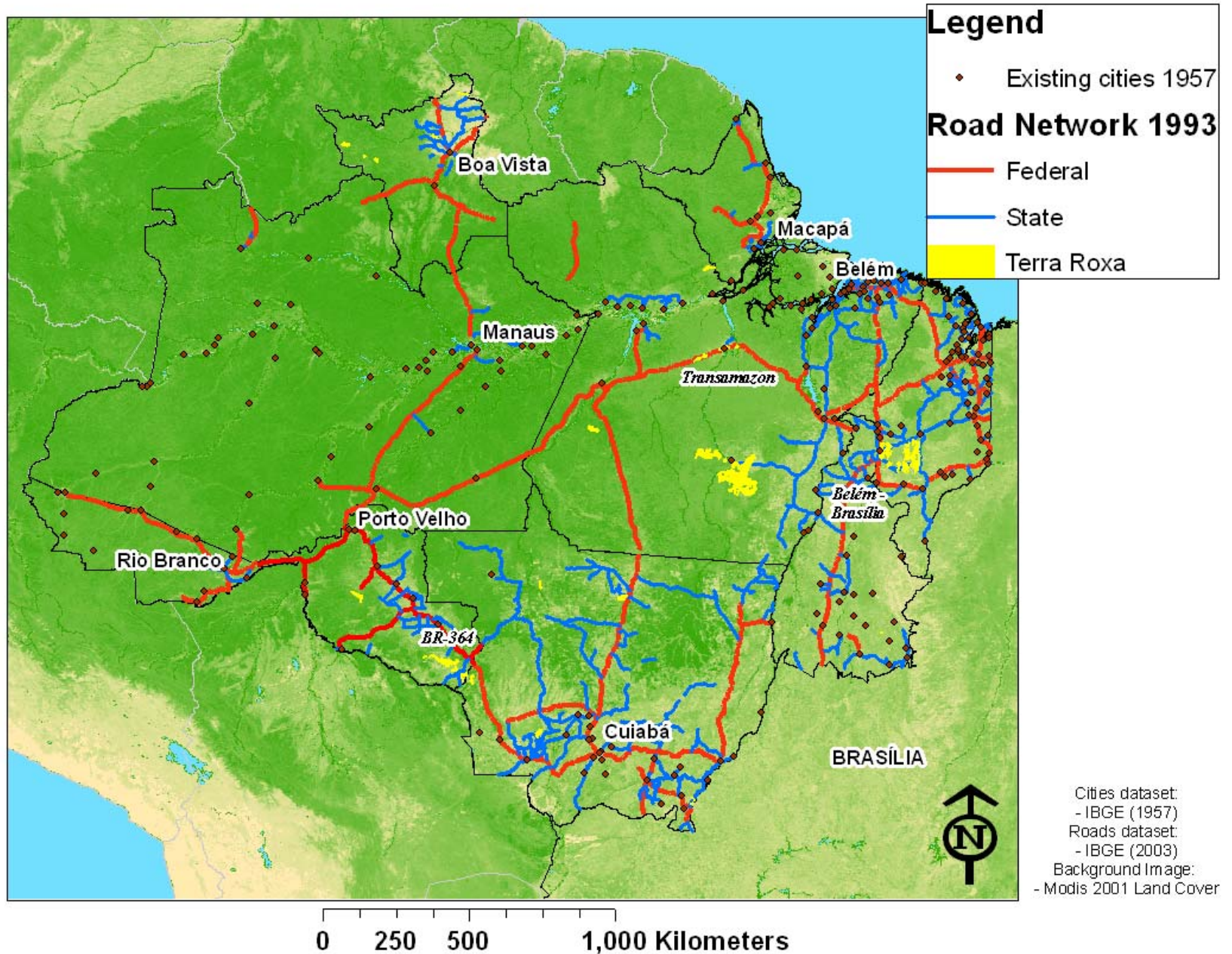
Regional **FEDERAL** system:

        mostly linear connections between pre-existing

  settlements

Some exceptions, all explained by topographic considerations

Well, what about other parts of the system ??

State and Federal Roads, and soil quality

Legend

- ◆ Existing cities 1957

Road Network 1993

- —— Federal
- —— State
- ▨ Terra Roxa

Boa Vista

Macapá

Belém

Manaus

Transamazon

Belém - Brasília

Porto Velho

Rio Branco

BR-364

Cuiabá

BRASÍLIA

Cities dataset:
- IBGE (1957)
Roads dataset:
- IBGE (2003)
Background Image:
- Modis 2001 Land Cover

N

0   250   500   1,000 Kilometers

State Road Connecting Pre-existing Deforestation
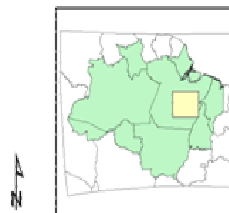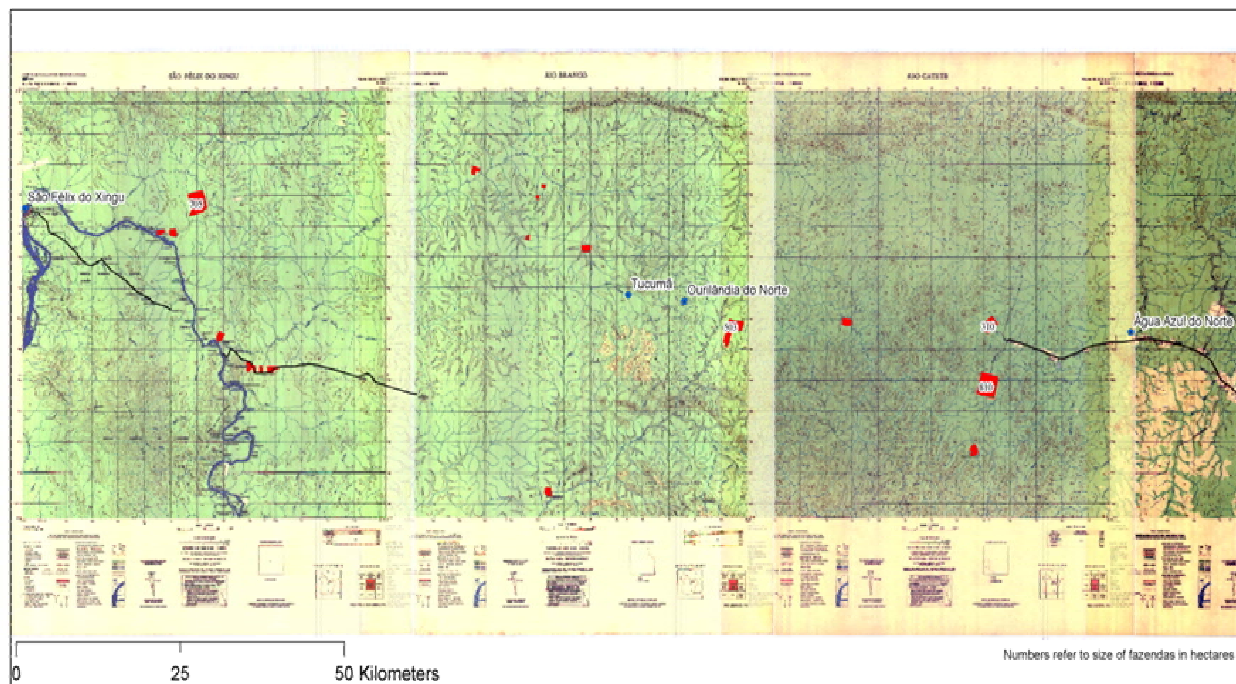
Figure from four IBGE 1:100,000 quad sheets (1981)

Numbers refer to size of fazendas in hectares

Legend

- Urban areas - not existing in 1979
- Existing paths (1979)
- Fazendas (1979)

Federal vs. State Road Changes 1975-1981

```
----------------------------------------------------------
  FEDERAL        |  Coeff.   Std.Error      z       P>|z|
-----------------+----------------------------------------
 mountainous    |  -0.52      0.30       -1.72     0.09
 gentle roll    |   0.15      0.13        1.16     0.25
 soil quality   |  -0.06      0.05       -1.28     0.20
 city distance  |   0.001     0.000       7.50     0.00


----------------------------------------------------------
  STATE          |  Coeff.   Std.Error      z       P>|z|
-----------------+----------------------------------------
 mountainous    |  -0.31      0.14       -2.17     0.03
 gentle roll    |   0.34      0.08        4.36     0.00
 soil quality   |   0.14      0.03        5.14     0.00
 city distance  |  -0.001     0.000      -8.26     0.00
```
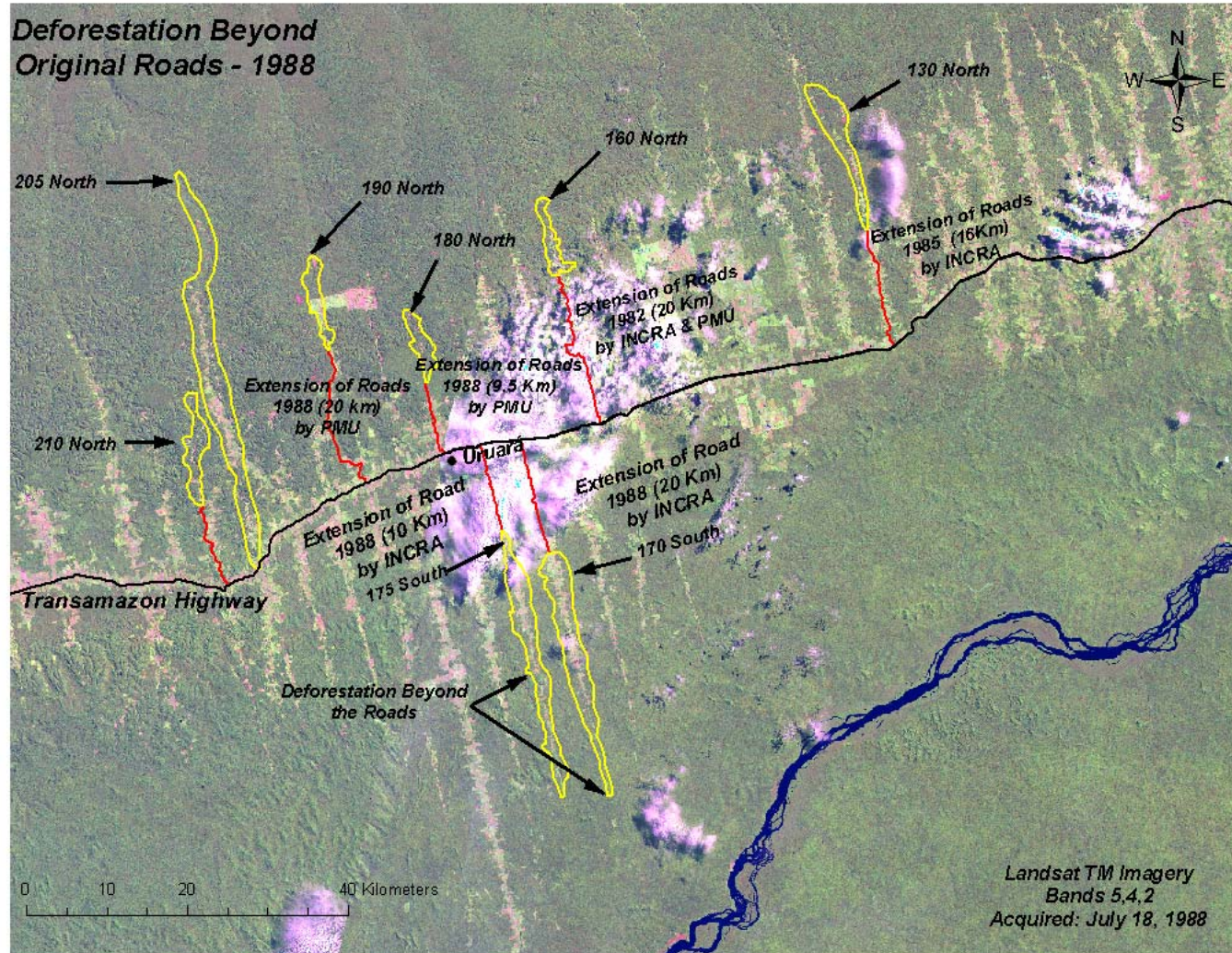
N = 5432 for both, and Pseudo R2 = 9% for both.

Reverse Causality
Deforestation before Roads
(Unofficial Roads: colonist extensions)

Some early conclusions:

- We do have evidence of endogeneity, and "omitted variables"
- Reverse causality relatively common in colonization areas
- Should keep in mind that the lower tiers of the hierarchy are set in motion by the upper tiers…..
- The road-deforestation relationship appears scale dependent

Note:
- you don't get the colonist extensions until the federal roads provide access overall

Implications:
- We are adapting our econometric models accordingly, in order to reduce bias in our estimates.

What does the Future Hold?

The Transamazon Highway
~2050   (?)