Econometric Estimation of Deforestation Impacts from Roads and Other Drivers

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Basin-Scale Econometric Modeling

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Spatially Rich Data

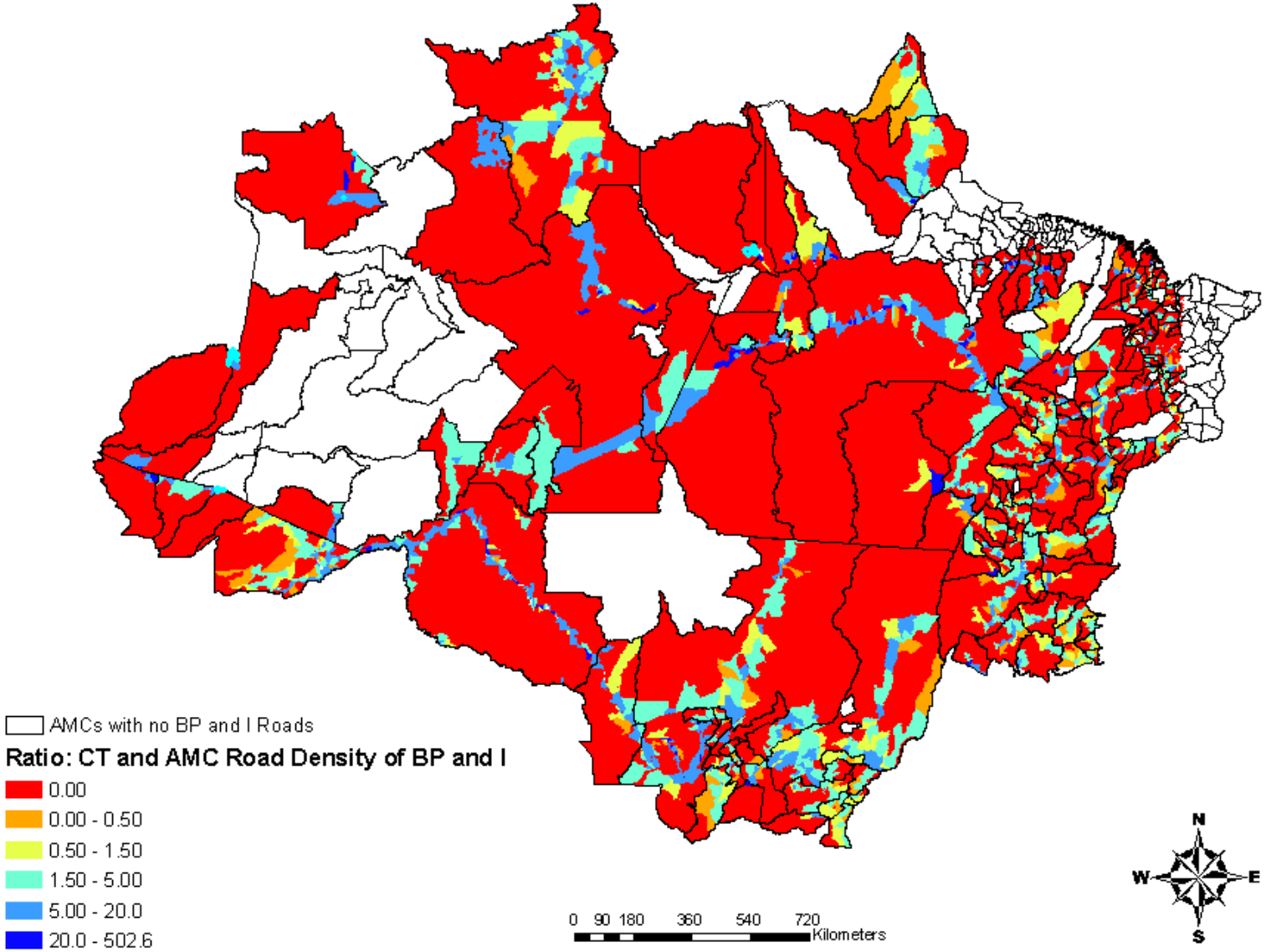
Census Tracts (1996 boundaries) – LOTS of them:

- allows better statistical controls for what we miss; census-tract results are relative to counties' trends
- avoids measurement errors seen in big aggregates

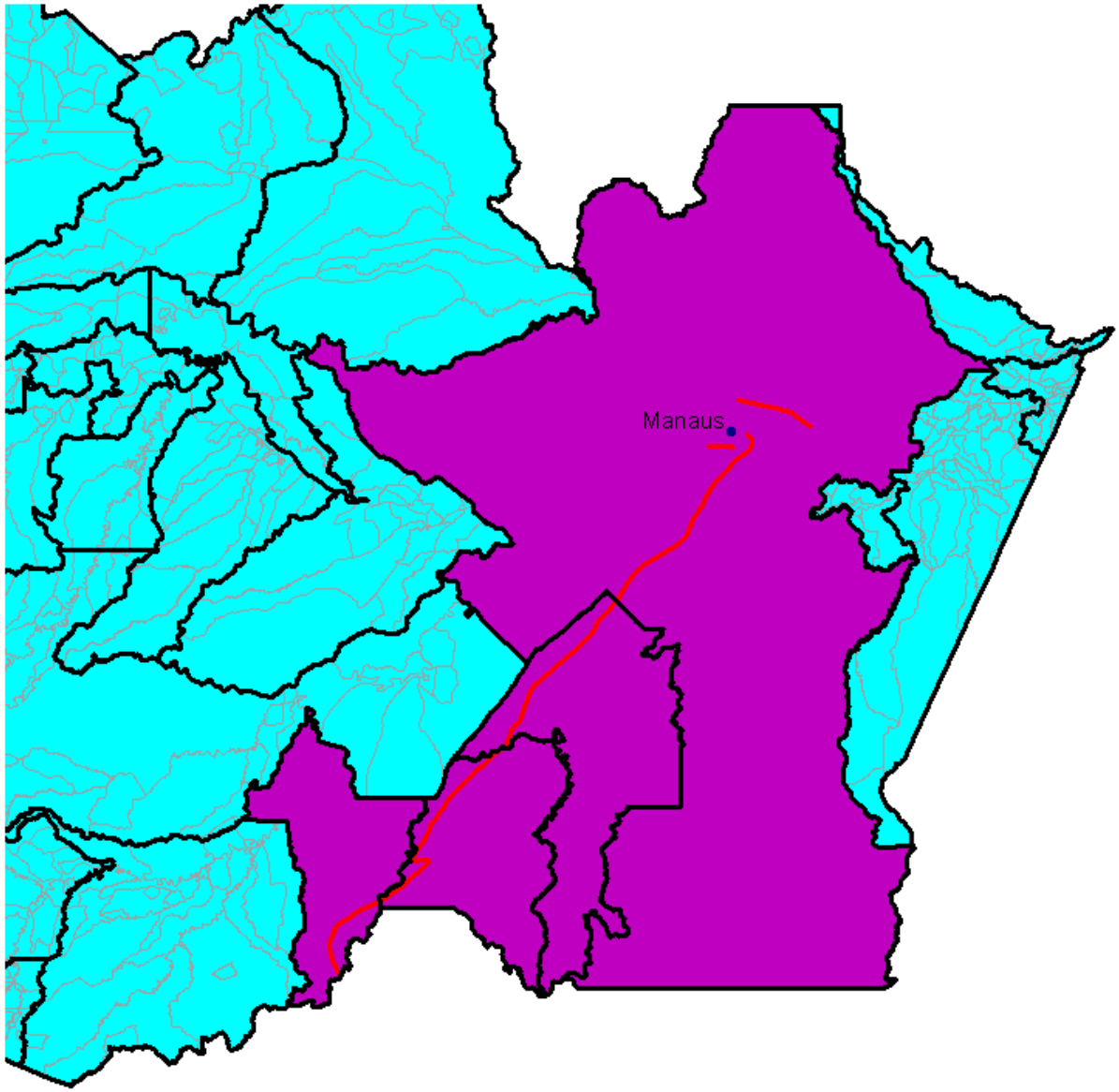
There are some questions of appropriate measurement:

- *treatment of the size of units within estimation*
- *appropriate normalization of clearing in a unit*

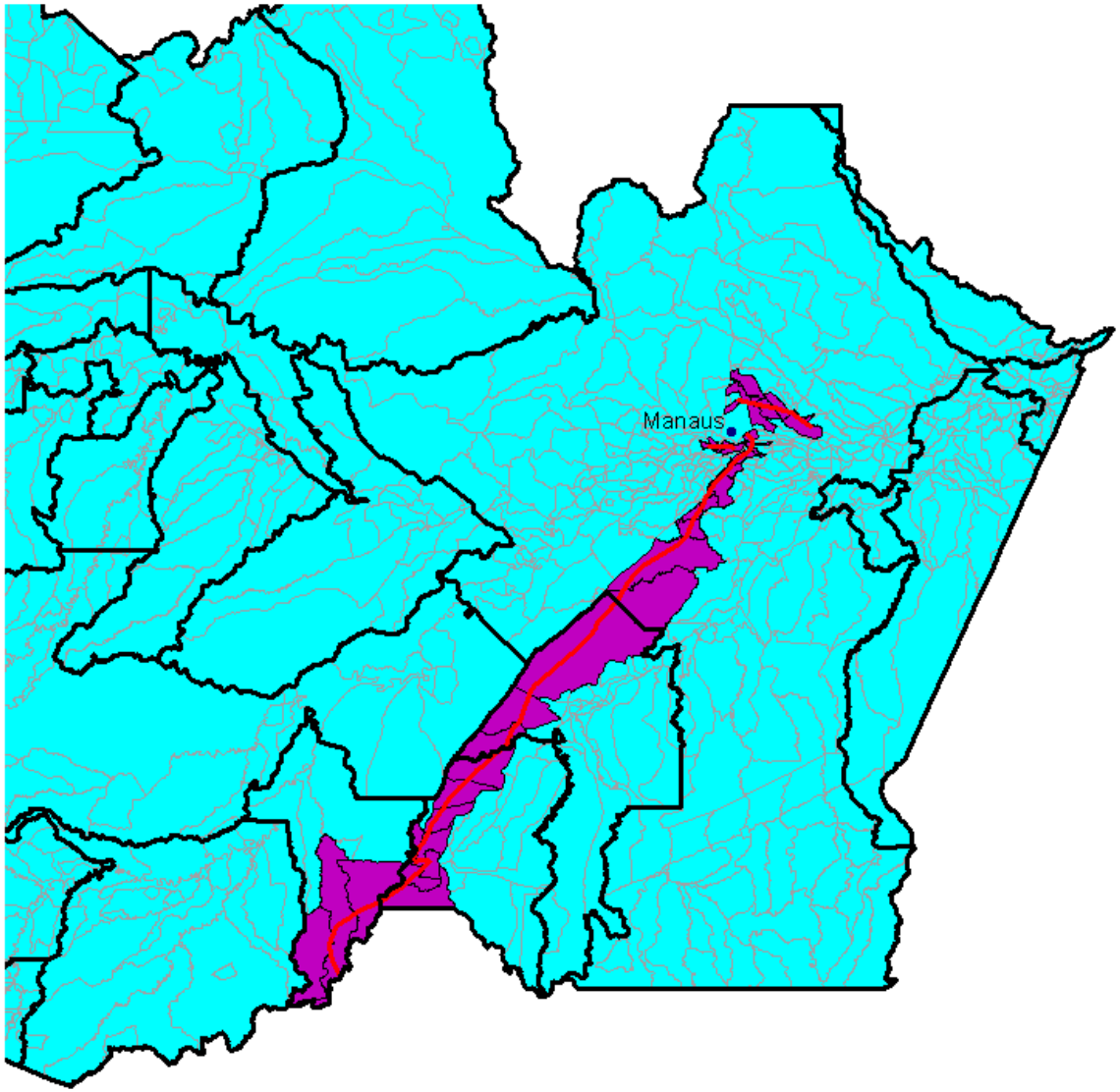
Disaggregation of Roads in AML: "Being Paved" and "Implanted" Roads 1975



Road Assigned to Entire Municipio



Road Assigned to Census Tracts



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- *avoids measurement errors seen in big aggregates*

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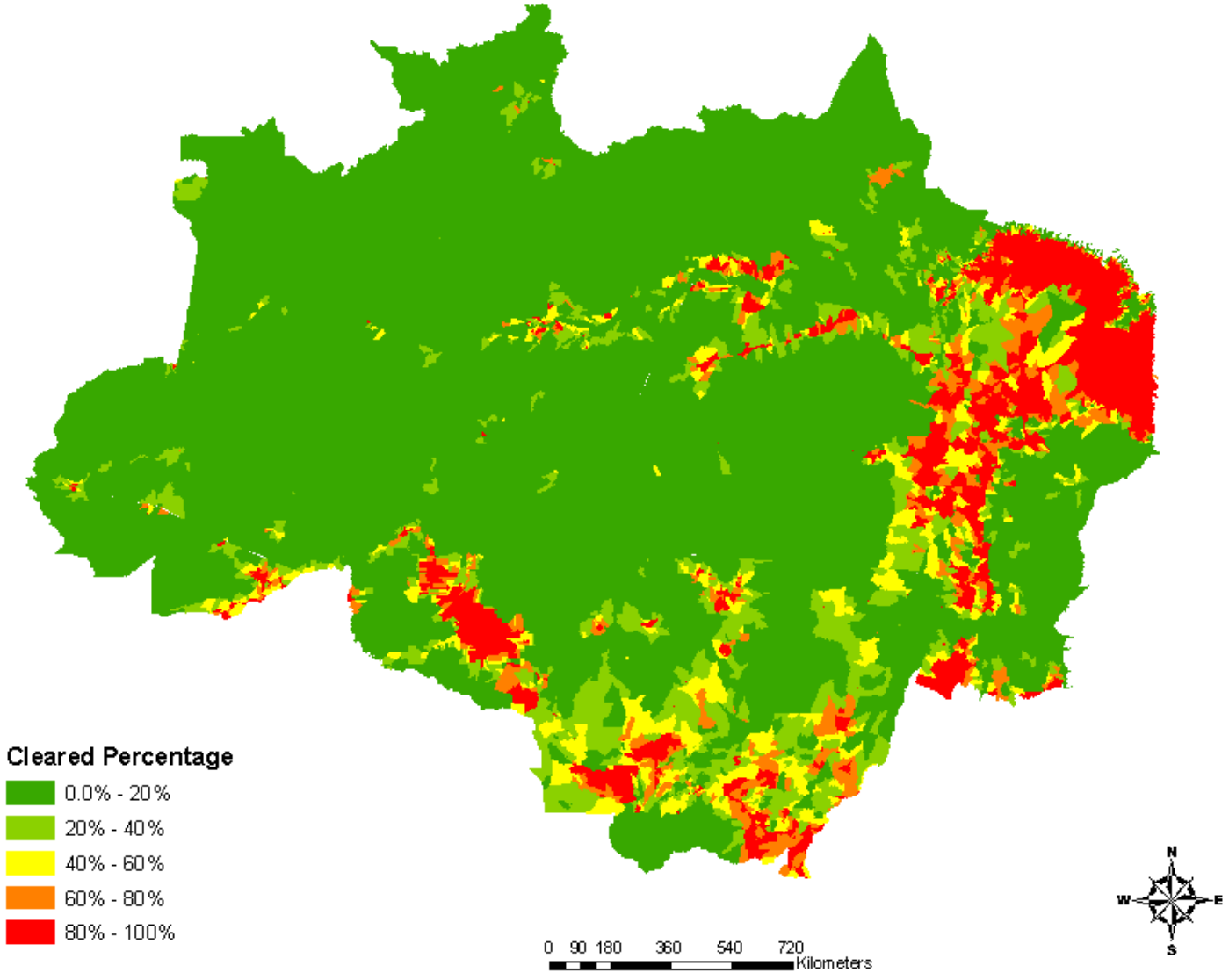
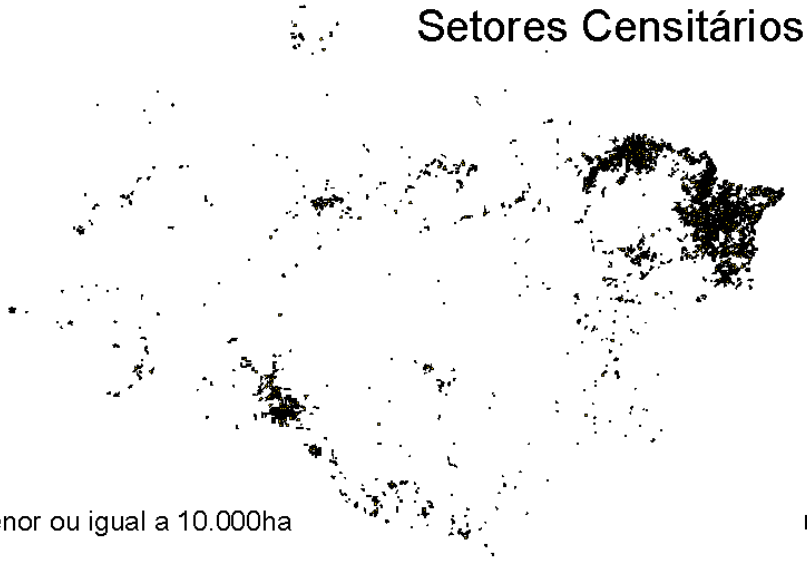
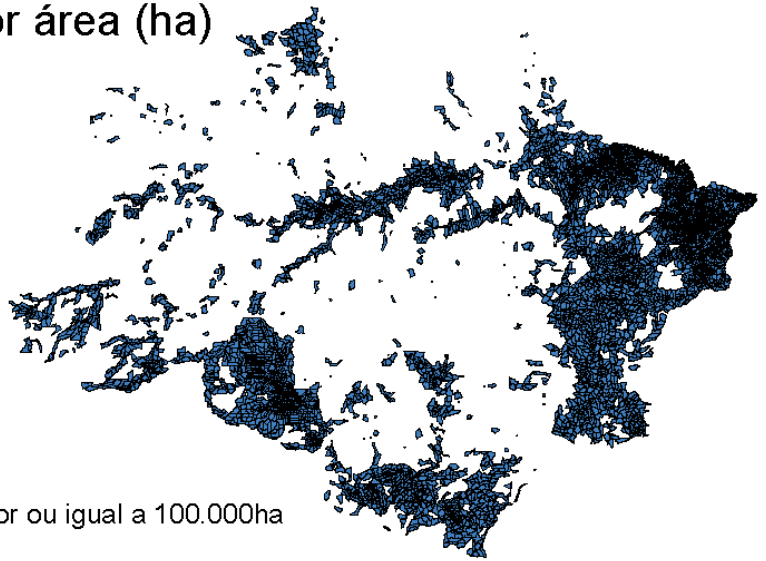
Cleared Percentage by Census Tracks
Diagnostico 1991



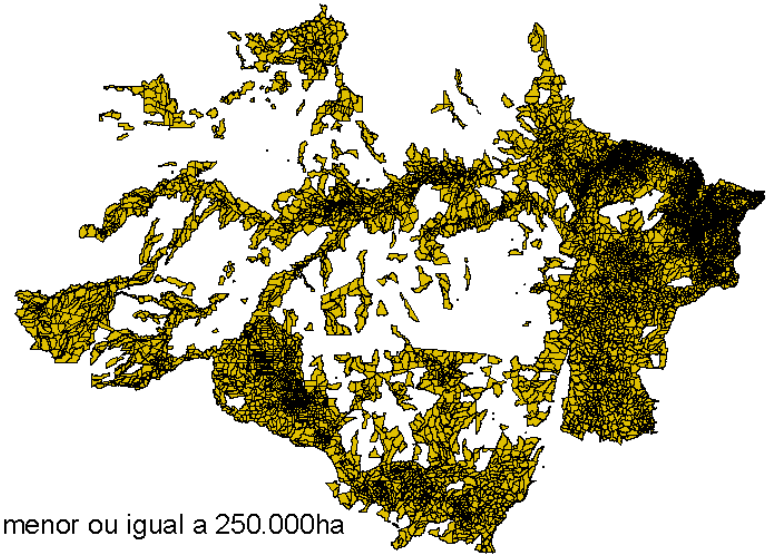
Setores Censitários por área (ha)



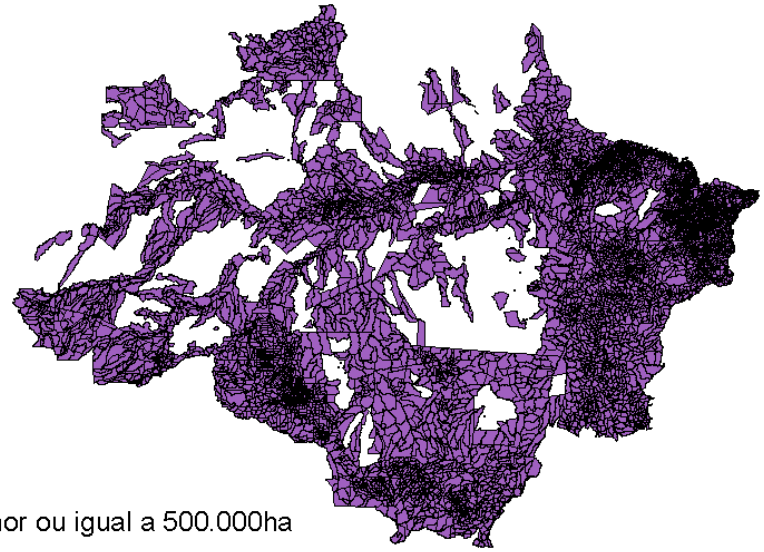
menor ou igual a 10.000ha



menor ou igual a 100.000ha



menor ou igual a 250.000ha



menor ou igual a 500.000ha

Temporally Rich Data

Forest Changes 1976 - 1987, 1986 - 1992, 1992 - 2000:

- remotely sensed; unlike census, can map to tracts
- blending pairs of Diagnostico and TRFIC/Prodes

Road Changes 1968 – 1975, 1975 – 1987, 1985 - 1993:

- from maps, so roads can be mapped to census tracts
- amazingly, separating Fed/State & Paved/Unpaved; important to consider what types may follow others

Other Variables

- distances to large and medium and small cities:
  - evolution determined by Perz demographic projections (though small city group only shrinks, not adding new)
  - clearing frontiers move away from big cities over time?

- biophysical constraints on production (for us, fixed):

  amount of rain, several categories of slope, and soil fertility

- prior clearing: represents all sorts of possible changes …

- census data (counties): changes in population & output

Regression Analyses

- explain fraction of forest lost in tract during period
  - to combine periods, annualize the loss and explain that
  - could use dummies per period, but are not significant

- for cleaner results, always use prior road investment; for development dynamics, also use 2nd and 3rd lags

- include dummy variable for each municipio (AMC), to strip out trends possibly due to unobserved factors

- drop tracts very close to big cities & all missing data

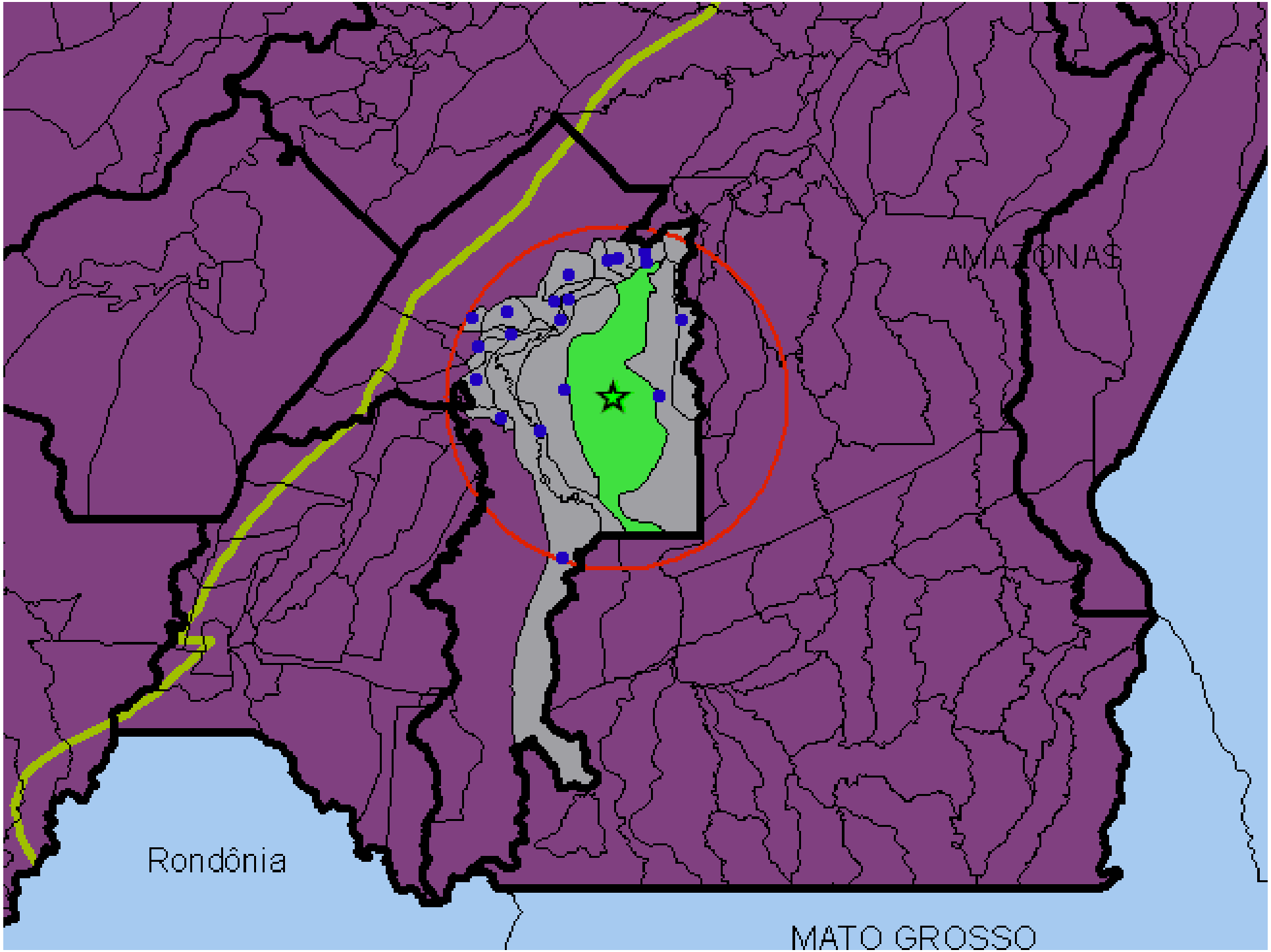
Basic Results (with a focus upon Roads)

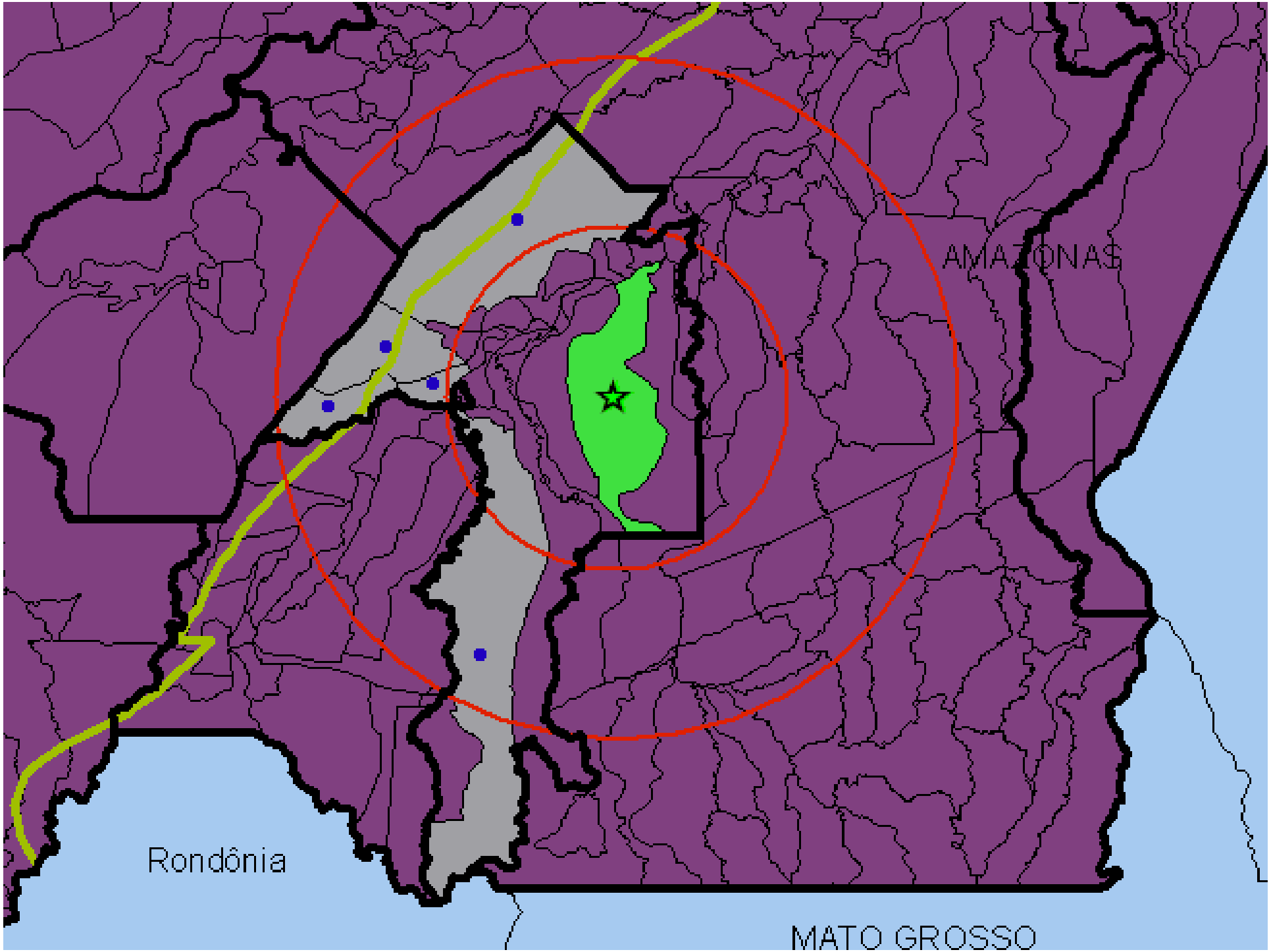
Observations: 15,971 (3 periods pooled) *Adjusted R-squared: 0.45*

Prior Paved Federal Change	3.9 (0.00)	Lag2	3.2 (0.00)	Lag3	1.6 (0.01)
Prior Paved State Change	1.0 (0.06)	Lag2	2.9 (0.00)	Lag3	1.7 (0.18)
Prior Unpaved Federal Change	4.1 (0.00)	Lag2	3.2 (0.00)	Lag3	1.0 (0.11)
Prior Unpaved State Change	2.2 (0.00)	Lag2	2.5 (0.00)	Lag3	5.3 (0.00)
Prior Forest Fraction Cleared	1.2 (0.00)				
Min. Distance to Small City *	-1.4 (0.00)	Med	-0.3 (0.00)	Large	0.1 (0.00)
Slope = "Rocky Outcropping"	-1.4 (0.00)	Soave Ondulado	0.3 (0.000)	…	
Soil Suitability for Agriculture	0.02 (0.01)				

Road Effects – complications for 'THE #'

- multiple road types: if each has a #, categorize (AB paving)
- effects over time with lags: okay if enough periods (AB?)
- effects change over time ? need to choose a 'base' period; for instance, earliest cross-section has distance to large city < 0
- effects over space -- not just own tract but neighbors':
  - at LBA 2005, showed 68-75 roads raised neighbor clearing
  - we have not yet done this using all periods (to apply to AB)


AMAZONAS
Rondônia
MATO GROSSO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More Complications for 'THE #' for Roads

- given a clearing rate, any forest impacts require forest:
  - important case: tract's vegetation is mostly cerrado
  - for projections, need to know this setting too (AB?)
- roads' impacts on clearing rates are also dependent:
  - not very sensitive to dropping higher cerrado areas
  - prior clearing affected 76-87 impacts…(AB goes?)

Basic Regression, prior clearing = 0%

Observations: 6,344 (3 periods pooled) *Adjusted R-squared: 0.46*

Prior Paved Federal Change	3.3 (0.02)	Lag2	4.1 (0.00)	Lag3	1.8 (0.31)
Prior Paved State Change	3.9 (0.03)	Lag2	3.0 (0.27)	Lag3	12 (0.32)
Prior Unpaved Federal Change	5.9 (0.00)	Lag2	3.5 (0.00)	Lag3	2.6 (0.20)
Prior Unpaved State Change	3.3 (0.00)	Lag2	-0.1 (0.93)	Lag3	6.4 (0.00)

First lag results are generally a bit higher than the pooled.

However, the additional lags are generally less significant.

Basic Regression, prior clearing 0 - 25%

Observations: 6,028 (3 periods pooled) *Adjusted R-squared: 0.49*

Prior Paved Federal Change	5.3 (0.00)	Lag2	4.9 (0.00)	Lag3	1.8 (0.06)
Prior Paved State Change	0.5 (0.53)	Lag2	2.9 (0.02)	Lag3	0.6 (0.71)
Prior Unpaved Federal Change	4.1 (0.00)	Lag2	5.1 (0.00)	Lag3	1.3 (0.19)
Prior Unpaved State Change	2.0 (0.00)	Lag2	2.6 (0.00)	Lag3	4.7 (0.00)

First lag results are again a little bit higher than the pooled.

Additional lags are like the pooled, higher than prior = 0 %.

Basic Regression, prior clearing > 25%

Observations: 3,599 (3 periods pooled) *Adjusted R-squared: 0.40*

Prior Paved Federal Change	1.7 (0.02)	Lag2	0.4 (0.47)	Lag3	0.2 (0.75)
Prior Paved State Change	-0.2 (0.71)	Lag2	0.9 (0.01)	Lag3	0.9 (0.44)
Prior Unpaved Federal Change	1.0 (0.11)	Lag2	0.5 (0.21)	Lag3	-0.8 (0.12)
Prior Unpaved State Change	0.4 (0.14)	Lag2	0.9 (0.00)	Lag3	0.9 (0.08)

Much weaker, in significance & in magnitude if significant.

Lagged Federal and earlier State (unpaved) hang on some.

A Final Complication for 'THE #' for Roads

- roads are unlikely to be located randomly across area:
  - decisions, with (fed/state) goals, are often involved
  - places getting roads may differ from those without
- accurate inference thus requires the right comparison:

  for example, if paved strongly follows prior unpaved,

  then compare with not paved that have prior unpaved

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.

Paved Roads often follow Prior Unpaved

- not highly correlated overall, as uni-directional
- tract-area-weighted density of paved building is 20 times higher if 1st or 2nd lagged unpaved > 0

Regression Explaining Investments in Paved Roads Using Prior Roads

Observations: 23,346 (3 periods pooled) Adjusted R-squared: 0.11

Lagged Paved Investment	-0.04 (0.00)	Second Paved Lag	-0.01 (0.24)
Lagged Unpaved Investment	0.07 (0.00)	Second Unpaved Lag	0.25 (0.00)

Paved Impacts differ where Prior Unpaved

Basic Regression for tracts with positive Prior Unpaved Investments

Observations: 2,894 (3 periods pooled) *Adjusted R-squared: 0.50*

Prior Paved Change	-0.2 (0.79)	Lag2	4.1 (0.00)	Lag3	3.0 (0.03)
Prior Unpaved Change	1.0 (0.11)	Lag2	3.3 (0.00)	Lag3	4.2 (0.00)

Basic Regression for tracts with zero Prior Unpaved Investments

Observations: 12,861 (3 periods pooled) *Adjusted R-squared: 0.45*

Prior Paved Change	1.6 (0.01)	Lag2	2.4 (0.00)	Lag3	0.8 (0.23)
Prior Unpaved Change	2.0 (0.00)	Lag2	----------	Lag3	----------

Road Effects: where does Avanca Brasil go ?

- prior clearing (seems to lower effects of road on rate):
  - where paving goes, weighted prior clearing is over 50 %, but in non-AB census tracts, prior clearing is under 20 %
  - for AB unpaved, the comparison is roughly 30% to 15 %
- prior roads investments (also seem to affect impacts):
  - for AB paved, prior paving is much higher than non-AB
  - for AB unpaved, recent paving and lagged unpaved higher
- cerrado (at any clearing rate, forest impact is lower):
  - for AB paved, more in cerrado than non-AB, 36% > 18 %
  - for AB unpaved, more in cerrado than non-AB, 31% > 17 %

Summarizing

- empirics using rich data, spatially & temporally, allow controls and the cleanest tests of roads' causal impacts

- paved & unpaved investments *(prior, 2nd and 3rd lags)* are found to <u>increase</u> deforestation in their own tracts {see early-period evidence of spillover increases too}

- however we are going further, to acknowledge setting & processes of fed/state paved/unpaved road location, in order that our projections use the right coefficients