

Heterogeneous Impacts of a Policy to Slow Deforestation in Paraguay

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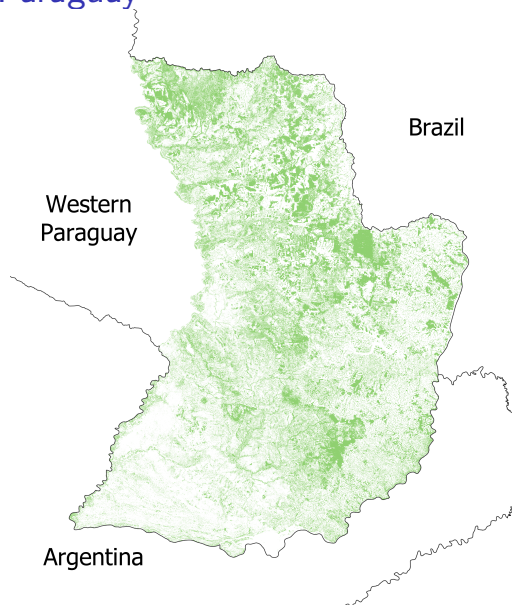
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Deforestation in Eastern Paraguay

Deforestation in Eastern Paraguay has been high for decades

Between 1973 and the 2000, forest cover in Eastern Paraguay's Atlantic Forest fell from three quarters to one quarter of surface area

(Huang et al. 2007)



Deforestation Policy

In December 2004,
Paraguay implemented the
Zero Deforestation Law

On paper, this law made
deforestation in Eastern
Paraguay illegal

In practice, many people
continued deforesting
despite possible fines or
incarceration

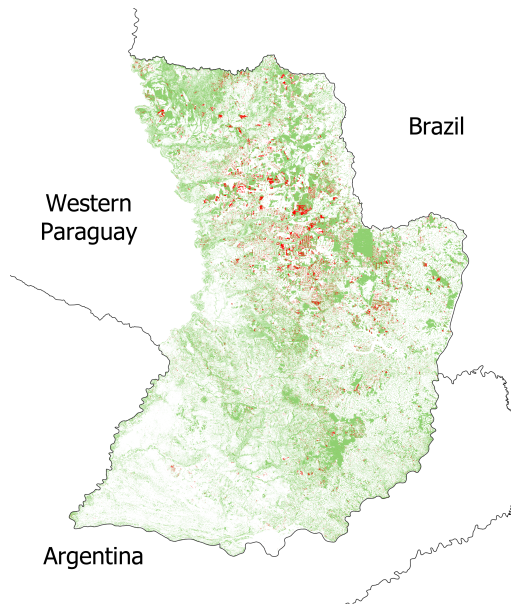


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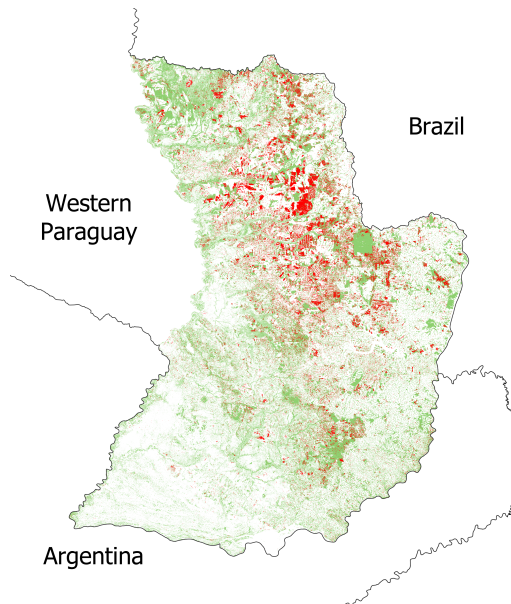


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Most deforestation in this region is for agriculture

Deforestation data suggest that the rate of deforestation fell after the Zero Deforestation Law

How did the Zero Deforestation Law impact farmer groups heterogeneously?

Overview

This is difficult to answer because spatial land use data does not exist

My process provides a generalizable way to estimate this

- 1 Generate data on agricultural land use after deforestation
- 2 Predict post-deforestation agricultural land use for all pixels deforested in Eastern Paraguay around the time of the Zero Deforestation Law
- 3 Analyze patterns in the predicted land uses

Preview of Results

- Large-scale farmers decreased clearing after the Zero Deforestation Law was implemented
- Deforestation for small-scale or rangeland uses were relatively less impacted

(1)

Post-Deforestation Agricultural Land Use Data Generation

Data Sampling Process

- Deforestation data comes from Global Forest Watch (Hansen et al. 2013)
 - 2001 onwards, annual
 - 30m resolution
- Take a random sample of pixels
 - deforested between 2001 and 2010
 - with initial tree cover of at least 30%

sampling is proportional to the loss in each year
- Categorize the agricultural land use after deforestation
 - using Google Earth Pro imagery
 - small-scale agriculture
 - large-scale agriculture
 - rangeland

Small-Scale Agricultural Land Use



Categorization: Deforestation is in a clearing of less than five hectares, and located within settlement patterns

Subsistence oriented

Non-mechanized

Produce mandioca, beans, maize, peanuts, and, until the 1990s, cotton
Small numbers of livestock

Large-Scale Agricultural Land Use



Categorization: Deforestation is in a clearing larger than five hectares that displays patterns of mechanized agriculture, and that is not located within a settlement pattern

Mechanized, commercial production
Main products include soy, maize, wheat and sugarcane

In 2010, soy was cultivated on over 2.5 million hectares in Eastern Paraguay

Rangeland Agricultural Land Use



Categorization: Deforestation is in a clearing greater than five hectares, does not show evidence of mechanized agriculture, and is not located within a settlement pattern

In 2010 over half of Paraguay's 12 million head of cattle were produced in Eastern Paraguay

(2)

Random Forest Prediction Model for Post-Deforestation Land Use

Random Forest Model

The generated post-deforestation land use data are used to train random forest machine learning models to predict land use

Separate models are trained using deforestation that occurred before the ban (*pre*) and deforestation that occurred after the ban (*post*)

- Outcome:
 - Post-deforestation agricultural land use
- Explanatory variables:
 - Physical land characteristics
 - Anthropological land characteristics

Explanatory Variables

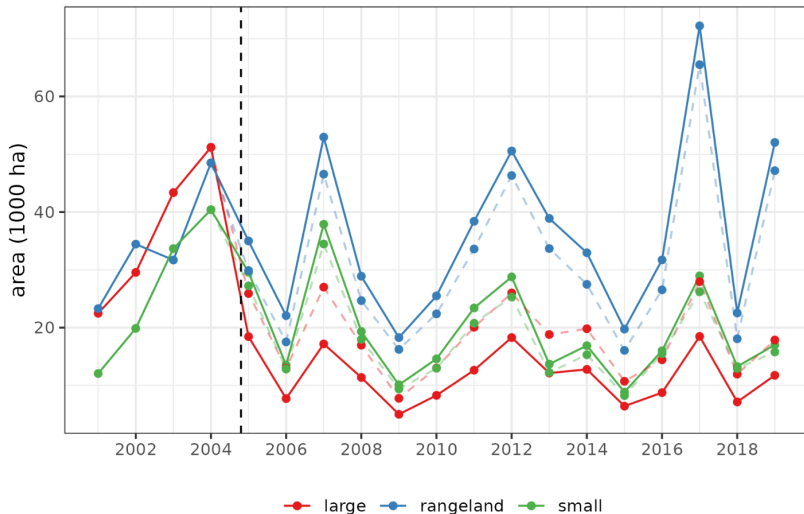
Variable	Unit	Mean	St. Dev.	Min	Max
Elevation	meters	235.0	74.9	41.0	757.0
Slope	degrees	3.1	2.1	0.0	52.1
Soil group	categorical	.	.	.	.
Ecoregion	categorical	.	.	.	.
Tree cover in 2000	percent	87.8	17.0	30.0	100.0
Mean tree cover within 100m	percent	69.7	23.0	0.6	95.0
St. dev. of tree cover within 100m	value	30.5	6.5	4.3	50.5
Mean tree cover within 1km	percent	45.2	18.1	0.0	77.5
St. dev. of tree cover within 1km	value	40.5	5.7	0.6	49.7
NTL value	NTL value	1.0	10.2	0.0	1649.8
Maximum NTL within 1km	NTL value	3.8	19.7	0.0	1986.0
Maximum NTL within 10km	NTL value	67.8	124.4	0.0	2142.0
Distance from a town	5 km bins	31.4	14.3	0.0	100*
Distance from a main road	5 km bins	15.1	10.0	0.0	60.0
Protected area when cleared	categorical	.	.	.	.

* All locations over 95km from a town are included in '100'. This category contains less than 1% of observations

(3)

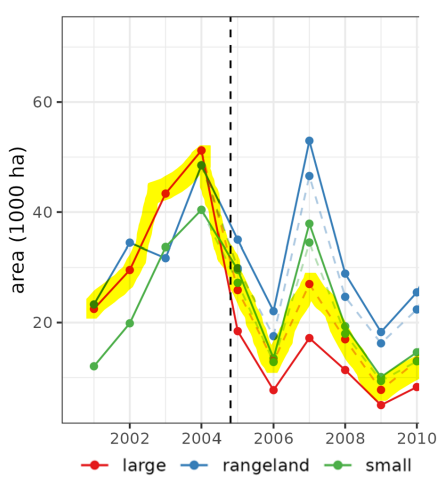
Land Use Predictions

Predicted Post-Deforestation Land Use



Deforestation fell for large-scale use. This can be broken down into two effects

Predicted Post-Deforestation Land Use

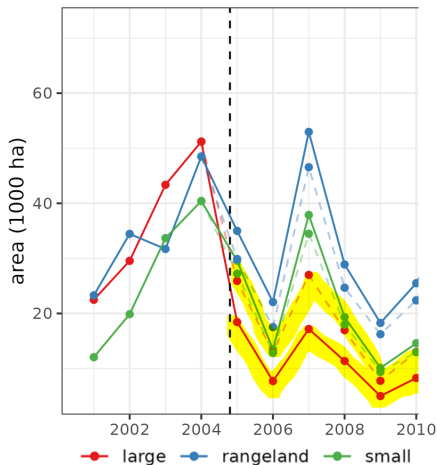


Composition Effect

Locations that are deforested change. Areas that would not have been deforested without the policy are now deforested, and vice versa

- Less land is deforested for large-scale agriculture after, even when predicting use with the *pre* model

Predicted Post-Deforestation Land Use



Land Use Effect

the agricultural use that deforested land is put to changes before and after the law is implemented

- Some land that would have gone to large-scale agriculture and is cleared post-policy now goes to small-scale agriculture or rangeland

Discussion

This decrease in deforestation for large-scale agricultural use may imply:

- Biodiversity benefits
 - Small-scale and rangeland systems have more plant diversity both within fields and due to increased boundaries
- Improved equity
 - The decrease in deforestation was not gained at the expense of economically-vulnerable small-scale farmers
- Decreased economic outcomes
 - Commodity production can be highly profitable

Further research can address potential spillovers

Thank you!

Questions?

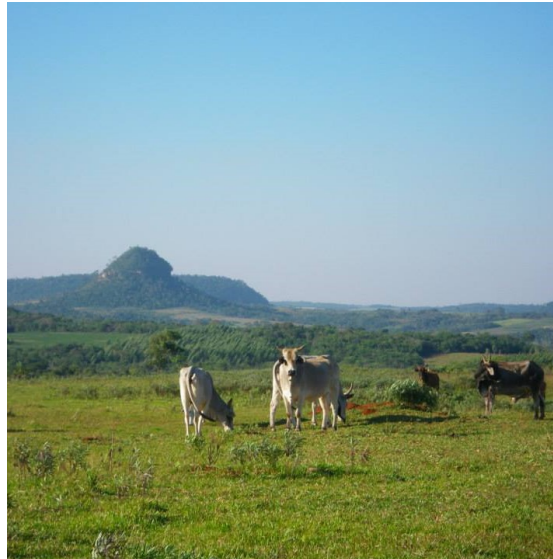
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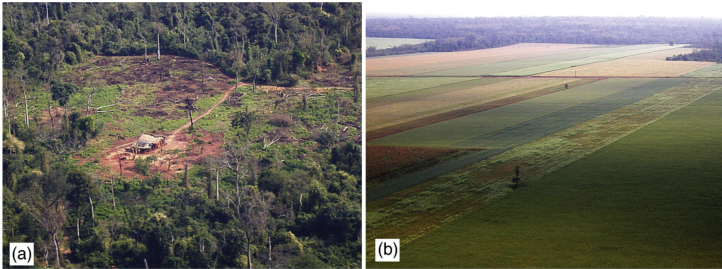
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APPENDIX

Agricultural Expansion in Eastern Paraguay



(Image: Huang et al. 2009)

- **1957: Ciudad del Este** established
- **1963:** The Agrarian Statute grants land titles for **settlements**
- **1967:** The Agrarian Statute is amended to **allow foreigners to purchase land** within 150km of the border
- **1975 to 1982:** Itaipu **hydroelectric project**
- **1996: Genetically modified soy** illegally introduced

Punishment for Deforestation

- 3 to 8 years incarceration
 - As of 2015, no one had gone to jail due to deforestation
- Fine of 500 - 2,000 daily wages
- Fine schedule updated in Decree 2598/2014
 - Severity based on size, intent, harm, and other factors

Severity	Daily Wages	USD (2020)
Lightest	1 - 500	13 - 6,500
Light	501 - 3,000	6,513 - 39,000
Severe	3,001 - 10,000	39,013 - 130,000
Most severe	10,001 - 20,000	130,013 - 260,000

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