

Deforestation, Development, and Transition within an Amazonian Frontier Settlement

Methods for Maintaining Quality Panel Data

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Tropical Deforestation in Brazil



- ❑ Tropical deforestation is a striking form of land cover transformation that has attracted research across multiple disciplines seeking to describe, explain, and predict the progression of the deforestation frontier
 - ❑ Brazil has the largest area of dense tropical forest of any country
 - ❑ 17% of the Amazon is now deforested.
 - ❑ Of the 408 municipalities in the Brazilian Amazon whose native forest cover was at least 50% forest, more than half are now in the deforested zone, with an average total deforestation of 65%
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Outline



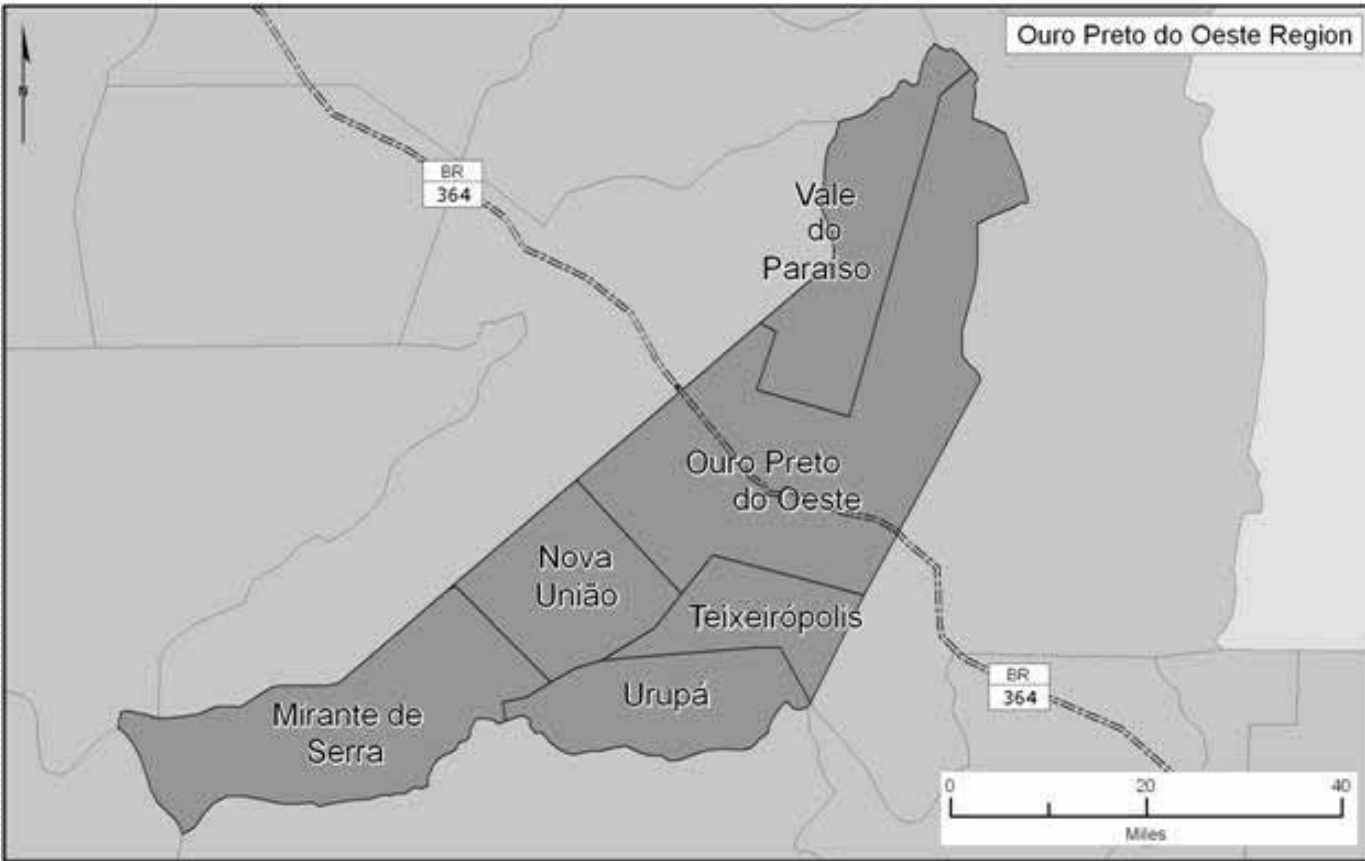
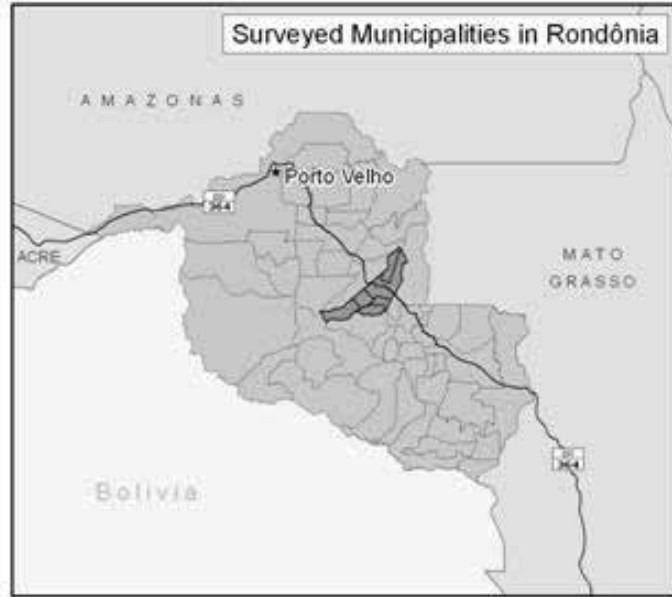
- ❑ Land Cover / Land Use Literature
 - ❑ Study area (6 municipalities)
 - ❑ Data collection (3 time periods: 1996, 2000, 2005)
 - ❑ Land use trends
 - ❑ Methods for Improving Data Quality (pre-survey)
 - ❑ Methods for Testing Data Quality (post-survey)
 - ❑ Estimations of Deforestation
 - ❑ Conclusions
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Land Cover/ Land Use Change

- ❑ Researchers typically work with macro scale data
 - ❑ micro data is often unavailable and costly to obtain
 - ❑ results of studies conducted at the local level have suggested that greater wealth is closely linked to higher levels of deforestation
 - ❑ proximate cause often identified at the macro level are road creation and paving
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Purpose of Paper

- This paper advances this literature on LULC through several avenues.
 - First, using robust data from a spatially referenced three-period household panel survey matched with classified remote sensing data, we estimate land use and land cover change over a nine-year period, correcting for spatial error
 - Second, we tackle the issue of panel sampling in multiple ways to determine its overall impact on our estimates of land use change.
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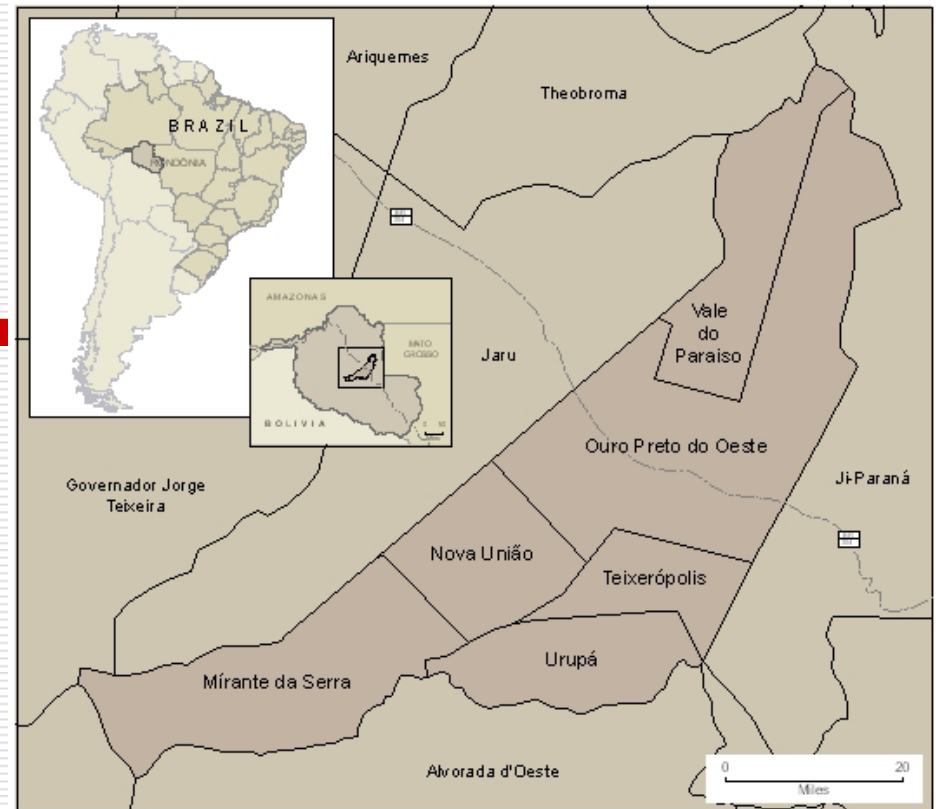


Study Area – Ouro Preto do Oeste, Rondonia

- ❑ survey region serves as an ideal laboratory for the analysis of land cover/ land use change
 - ❑ it is representative of the 'arc of deforestation'
 - ❑ falls in a priority area for monitoring and managing development pressures
 - ❑ is within a government sponsored settlement located within a typical 'old frontier'.
 - ❑ located within the state of Rondônia – the state that has experienced the most extensive and rapid land transformation within the last 20 years
 - ❑ large average lots sizes (approximately 71 hectares) enable matching of survey and satellite data at the household level
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Study Area

Ouro Preto do Oeste Rondônia



Municipality	KM ²	Population Density	Percent Deforested	GDP/Capita	Cattle Density	IDH
Mirante da Serra	1206	12.2	44.2%	R\$ 3,134	46.0	0.691
Nova União	815	7.9	76.8%	R\$ 2,518	103.3	0.680
Ouro Preto do Oeste	1991	20.5	84.3%	R\$ 3,813	130.4	0.727
Teixeirópolis	467	11.2	90.3%	R\$ 2,635	130.0	0.685
Urupá	840	19.6	75.1%	R\$ 2,388	94.9	0.671
Vale do Paraíso	973	9.7	82.6%	R\$ 2,524	98.2	0.704
State of Rondônia	237,576	5.55	26%	R\$ 3,888	44.9	0.735

Area and percent deforested are from INPE (2007);

Number of people, cattle per square kilometer, and GDP per capita are from IBGE (2000);

IDH (index of human development) is from the Atlas do Desenvolvimento Humano no Brasil (UNDP 2003).



Data collection

N = 171 in 1996

- Household survey
- Remote sensing
- GIS of market and social infrastructure

Three waves

- 1996
- 2000
- 2005

Panel tracking:

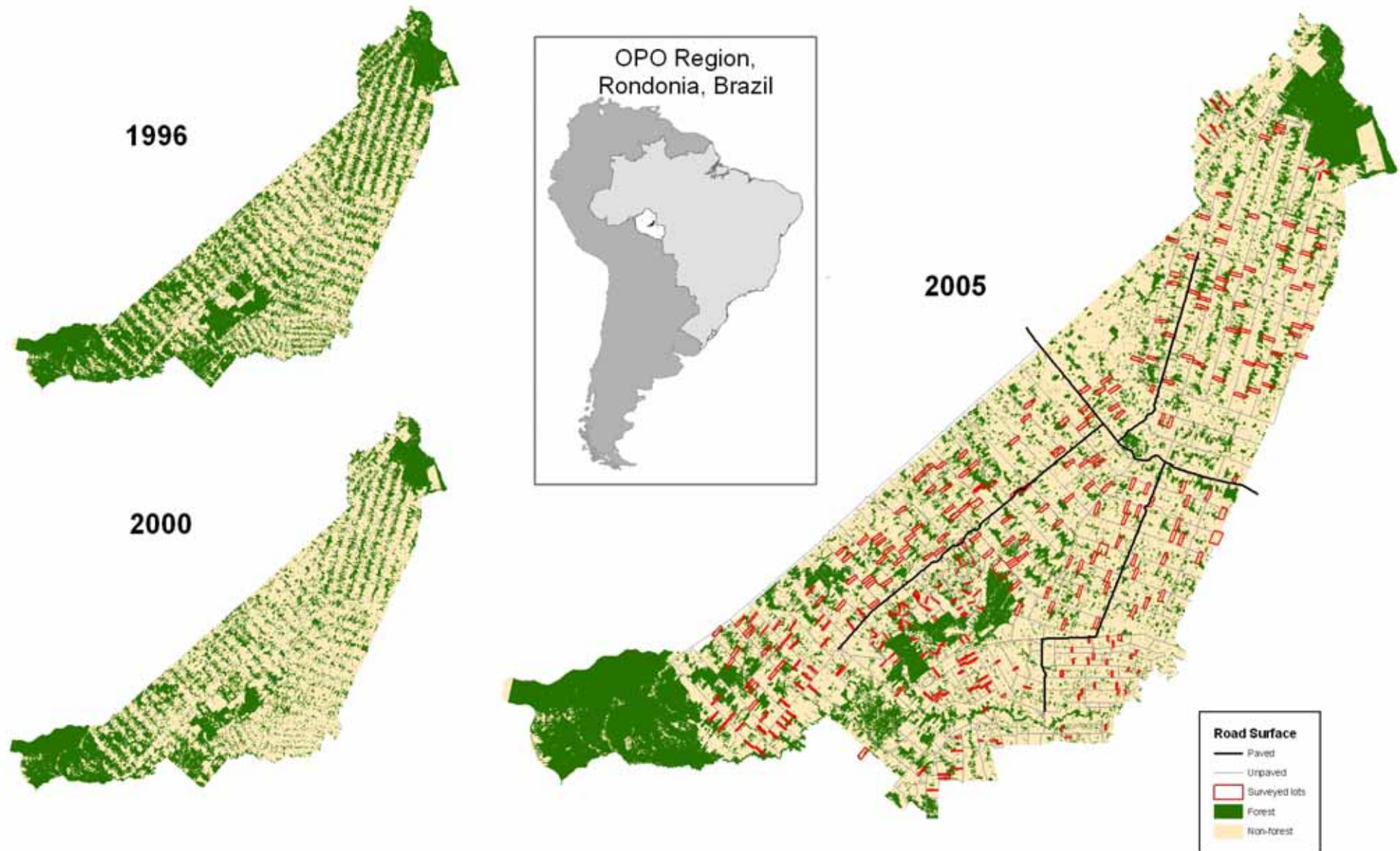
- Original lots
 - Household members to move from the original lots
 - Supplemented with lots added to original sample
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Land cover/use

Mean percent in forest (remote sensing)				
		1996	2000	2005
Mirante da Serra	1	46.34%	32.16%	17.63%
Nova Uniao	2	28.53%	16.94%	16.24%
Teixeropolis	3	17.07%	8.78%	9.57%
Urupa	4	25.00%	13.63%	10.75%
Vale do Paraiso	5	31.81%	16.93%	20.23%
OPO	6	19.99%	12.62%	16.05%
Total Region		28.53%	16.82%	12.39%

Mean percent in pasture (self-reported)				
		1996	2000	2005
Mirante da Serra	1	44.7%	47.0%	63.9%
Nova Uniao	2	61.8%	71.0%	74.2%
Teixeropolis	3	79.3%	80.9%	74.6%
Urupa	4	51.9%	61.1%	71.1%
Vale do Paraiso	5	60.6%	74.1%	79.5%
OPO	6	83.4%	77.7%	81.3%
Total Region		61.5%	68.3%	73.7%

Figure 1 – Land Cover for Ouro Preto do Oeste, Rondonia for Survey Years

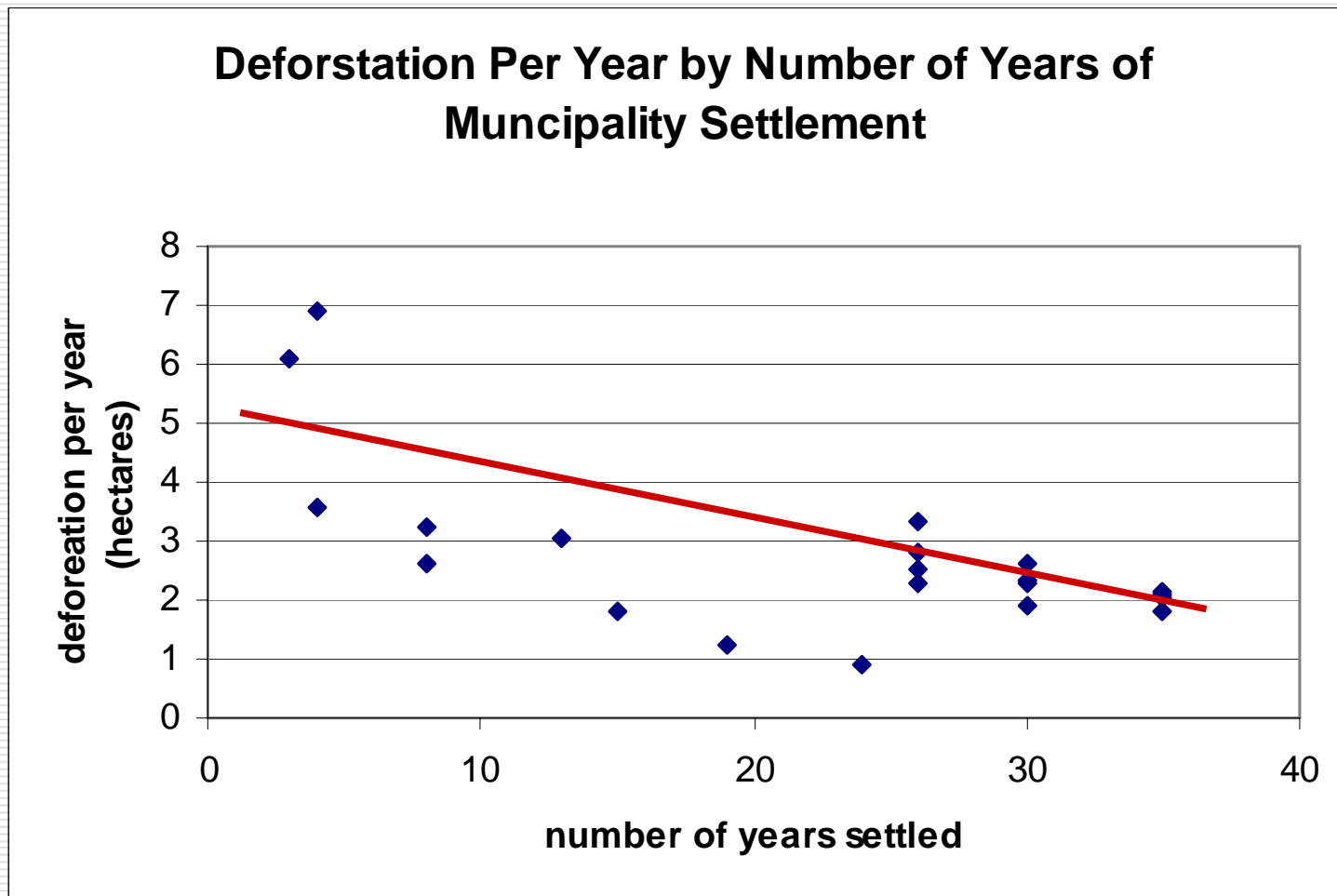


Deforestation Rates

Deforestation Estimations for Municipalities in Ouro Preto do Oeste, Rondônia

Municipality	Year of Settlement	1996		2000		2005	
		Deforestation Per Year (hectares)	% of Lot Deforested Per Year	Deforestation Per Year (hectares)	% of Lot Deforested Per Year	Deforestation Per Year (hectares)	% of Lot Deforested Per Year
Mirante da Serra	1992	6.90	0.16	3.25	0.08	3.04	0.05
Nova União	1970	2.30	0.03	1.89	0.03	1.81	0.02
Ouro Preto do Oeste	1970	3.34	0.03	2.61	0.03	2.16	0.03
Teixeirópolis	1970	2.82	0.03	2.31	0.03	2.05	0.02
Urupá	1981	1.79	0.05	1.23	0.04	0.89	0.03
Vale do Paraíso	1970	2.52	0.03	2.32	0.03	2.11	0.02
Settlement							
Palmares	1997					2.61	0.11
Martim Pescador	2002					6.08	0.24
Padre Ezekiel	2001					3.55	0.23

Deforestation Levels



Draw from several approaches

- Survey Administration
 - Survey bias
 - Agricultural household models
(microeconomics approach)
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Survey Administration

- The precision of the estimates for the survey region and municipalities for 1996 and 2000 were determined for a sampling of key variables and used to guide the sampling approach undertaken for the expanded 2005 survey.
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Precision Estimates

Table 1: Estimation of Minimal Required Sample Size For Different Land Use and Welfare Indicators

Variable	Definition	Mean	Std.Dev.	Estimated Sample Size
1996				
CattleLot	Number of cattle owned on the lot	71.44	83.73	7010
Vehicles	Number of vehicles (including motorcycles, cars, trucks and tractors) owned by the household	0.43	0.67	0
Lotsize	Lot size, in hectares as reported by household	70.64	46.12	2127
Agri	Number of hectares in agriculture reported by household	7.42	6.54	43
Pasture	Number of hectares in pasture, secondary forest, fallow reported by household	46.45	37.69	1420
Forest	Number of hectares in primary forest reported by household	16.67	18.88	356
Agrofor	Number of hectares in agroforestry reported by household	0.11	0.46	0
2000				
CattleLot	Number of cattle owned on the lot	96.64	94.59	8946
Vehicles	Number of vehicles (including motorcycles, cars, trucks and tractors) owned by the household	0.80	0.91	1
Lotsize	Lot size, in hectares as reported by household	63.49	34.97	1223
Agri	Number of hectares in agriculture reported by household	6.16	7.06	50
Pasture	Number of hectares in pasture, secondary forest, fallow reported by household	45.27	31.36	984
Forest	Number of hectares in primary forest reported by household	11.86	14.20	202
Agrofor	Number of hectares in agroforestry reported by household	0.19	1.33	2

Interviewed Household Lots

Table 2: Percentage of Households Interviewed by Municipality in Each Survey Year

	1996			2000			2005		
	Number of Lots	Number Interviewed	Percent Interviewed	Number of Lots	Number Interviewed	Percent Interviewed	Number of Lots	Number Interviewed	Percent Interviewed
Ouro Preto do Oeste	2007	45	2.24	2087	44	2.11	2085	80	3.84
Vale do Paraíso	935	20	2.14	937	20	2.13	937	36	3.84
Nova União	592	28	4.73	1217	28	2.30	1212	79	6.52
Teixeirópolis	387	11	2.84	387	11	2.84	387	16	4.13
Urupá	1561	35	2.24	1782	35	1.96	2717	75	2.76
Mirante da Serra	1140	32	2.81	1141	32	2.80	1376	72	5.23
Total	6622	171	2.58	7551	170	2.25	8714	361	4.14

Table 3: Descriptive Statistics for Random Sample of Household Lots in the Original Survey Region

Variable	Definition	1996 Mean	Std.Dev.	2000 Mean	Std.Dev.	2005 Mean	Std.Dev.
<i>Household Characteristics</i>							
Family	Number of household members living on the lot	8.42	6.02	7.40	5.76	5.90	4.01
Age Household	average age of the household heads, years	46.36	12.94	49.08	12.45	48.33	13.88
Edu Household	average education level of the household heads, years	2.50	2.47	2.49	1.62	3.14	2.22
Year Migration	Year the household head or family migrated to Rondonia =1 if the origin of the household head is one of the states in the south or southeast region of Brazil; 0 otherwise	1978.82	5.87	1979.58	6.77	1980.11	6.31
South	number of unions, farming associations or co-ops household members participate in	0.82	0.38	0.85	0.36	0.75	0.43
Unions		0.71	0.82	1.02	0.85	1.26	1.02
<i>Inputs for Agriculture</i>							
Chemical Inputs	total cost of fertilizer, herbicides, and pesticides used by the household within the survey year, 2000 reais	140.82	192.11	575.78	1963.76	255.61	918.54
Labor							
Payments	labor paid for by household, 2000 reais	172.84	818.56	103.92	231.28	622.01	1706.64
<i>Income and Assets</i>							
Cattle	number of cattle owned on the lot	71.44	83.73	96.64	94.59	106.08	111.10
Total Income	Income from annuals, perennials, milk, off farm labor, honey and fish, beef and calves 2000 reais	7957.34	9418.57	15689.00	16394.30	15133.70	20267.40
Vehicle Value	Value of all vehicles owned by household, 2000 reais	5152.16	13420.10	5298.91	8892.69	7621.30	17334.50
Vehicles	Number of vehicles (including motorcycles, cars, trucks and tractors) owned by the household	0.55	0.92	0.86	1.04	1.20	1.20
<i>Lot Characteristics</i>							
Lot Size	Lot size, in hectares as reported by household	70.64	46.12	63.49	34.97	63.27	56.80
Forest	Number of hectares in primary forest reported by household	16.67	18.88	11.86	14.20	7.55	19.14
Non-forest	Number of hectares in agroforestry, pasture, agriculture, and fallow as reported by household	53.97	37.76	51.62	31.17	55.63	50.17
Distance City							
Center	distance to the city center, meters	37730.40	19347.80	37649.90	19222.40	39242.60	18910.00
Distance Market	distance to the closet market, meters	11371.70	4729.07	11298.00	4746.10	11587.80	5168.68
Soil	dominant soil type on lot, characterized by initial ability to support agriculture (1-good, 2-moderate, 3-restricted, 4-unsuitable), data collected from soil maps (Radam Brazil 1978a, 1978b).	2.27	0.74	2.28	0.74	2.33	0.74
Average Slope	Average slope gradient on the lot	5.48	3.36	5.47	3.37	5.51	3.39

Table 5: Descriptive Statistics for Different Household Samples Collected In 2005

Variable	Original Sample		Extended Sample		Extended and Tracked	
	Households in the Original Random Sample N=170		Households in the Original Random Sample Plus those Added Randomly from Original and New Settlements N=284		Households in the Extended Plus Sample Plus those Household Members and Entire Households that were Tracked N=361	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
<i>Household Characteristics</i>						
Family	6.30	4.41	5.90	4.01	5.56	4.04
Age Household	51.09	13.44	48.33	13.88	46.34	14.62
Age Household	2.89	2.17	3.14	2.22	3.21	2.18
Year Migration	1979.69	6.02	1980.11	6.31	1980.29	6.34
South	0.78	0.42	0.75	0.43	0.74	0.44
Unions	1.18	0.96	1.26	1.02	1.12	1.01
<i>Inputs for Agriculture</i>						
Chemical Inputs	575.78	1963.76	255.61	918.54	244.499	975.467
Labor Payments	103.92	231.28	622.01	1706.64	528.713	1547.9
<i>Income and Assets</i>						
Cattle	124.48	128.23	106.08	111.10	93.03	107.96
Total Income	17111.80	23982.80	15133.70	20267.40	14125.70	22572.40
Vehicle Value	8623.10	16084.60	7621.30	17334.50	6547.95	15646.10
Vehicles	1.28	1.18	1.20	1.20	1.09	1.15
<i>Lot Characteristics</i>						
Lot Size	75.45	65.63	63.27	56.80	63.64	60.70
Forest	9.66	23.63	7.55	19.14	7.72	19.18
Non-forest	66.12	57.76	55.63	50.17	55.83	52.90
Distance City Center	37630.40	19566.60	39242.60	18910.00	39526.50	18755.70
Distance Market	11595.00	4748.07	11587.80	5168.68	11264.10	5073.08
Soil	2.28	0.75	2.33	0.74	2.33	0.74
Average Slope	5.51	3.37	5.51	3.39	5.49	3.28

	1996	2000	2005
Non-Forest	83.3		
Forest	52.5		

* 70 percent cutoff suggested to identify problem variables (Marquis et al. 1986, Bound and Krueger 1991).

Table 8: Estimations of Cattle Per Household Lot from Census Data

	1996			2000			2005		
	Number of Lots	Cattle	Cattle Per Lot	Number of Lots	Cattle	Cattle Per Lot	Number of Lots	Cattle	Cattle Per Lot
Mirante da Serra	1140	35590	31.22	1141	55466	48.61	1376	103407	75.15
Nova União	NA	NA	NA	1217	84159	69.15	1212	127248	104.99
Ouro Preto do Oeste	2986	316175	105.89	2087	259615	124.40	2085	359948	172.64
Teixeirópolis	NA	NA	NA	387	60696	156.84	387	90519	233.90
Urupá	1561	55166	35.34	1782	79722	44.74	2717	153665	56.56
Vale do Paraíso	935	66147	70.75	937	95591	102.02	937	160569	171.36
Region	6622	473078	71.44	7551	635249	84.13	8714	995356	114.22

Source: IBGE (2007) IBGE - Pesquisa Pecuária Municipal,

<http://www.ibge.gov.br/home/estatistica/pesquisas/default.shtm>, accessed August, 2007.

Table 9: Confidence Tests for Cattle Estimations Per Lot

	Census Estimate	Survey Estimate	Standard Deviation	N	80% Confidence Interval		Within Confidence
1996 n=171							
Ouro Preto do Oeste	105.89	98.95	84.15	84	87.09	110.81	?
Vale do Paraíso	70.75	85.30	57.55	20	68.21	102.39	?
Nova União	NA	NA	NA	NA	NA	NA	
Teixeirópolis	NA	NA	NA	NA	NA	NA	
Urupá	35.34	42.03	100.07	35	19.92	64.14	?
Mirante da Serra	31.22	22.75	29.47	32	15.93	29.57	X
2000 n=170							
Ouro Preto do Oeste	124.40	159.91	107.06	44	138.90	180.92	
Vale do Paraíso	102.02	109.50	61.96	20	91.10	127.90	?
Nova União	69.15	119.75	93.66	28	96.50	143.00	X
Teixeirópolis	156.84	136.36	133.11	11	81.29	191.43	?
Urupá	44.74	38.49	31.82	35	31.46	45.51	?
Mirante da Serra	48.61	34.38	37.29	32	25.74	43.01	X
2005 – Original Sample (n=170)							
Ouro Preto do Oeste	172.64	182.86	162.29	43	151.14	214.58	?
Vale do Paraíso	171.36	173.50	95.96	20	14.56	201.00	?
Nova União	104.99	147.10	119.77	29	112.50	181.71	X
Teixeirópolis	233.90	200.91	180.24	11	150.38	251.44	?
Urupá	56.56	56.27	37.48	29	42.17	63.83	?
Mirante da Serra	75.15	58.55	47.13	34	44.92	72.18	X
2005 – Extended Sample (n=276)							
Ouro Preto do Oeste	172.64	163.86	142.70	65	141.18	186.55	?
Vale do Paraíso	171.36	141.87	94.84	31	120.04	163.70	X
Nova União	104.99	105.13	102.71	64	88.67	121.58	?
Teixeirópolis	233.90	190.87	154.57	15	139.72	242.01	?
Urupá	56.56	49.43	33.45	51	43.43	55.43	X
Mirante da Serra	75.15	51.69	58.18	50	49.72	68.92	X
2005 Extended and Tracked (n=358)							
Ouro Preto do Oeste	172.64	107.26	112.64	81	91.09	123.43	X
Vale do Paraíso	171.36	110.97	83.76	35	92.47	129.48	X
Nova União	104.99	85.77	78.18	66	73.31	98.23	X
Teixeirópolis	233.90	115.53	114.88	17	78.28	152.78	X
Urupá	56.56	34.96	32.66	75	30.08	39.84	X
Mirante da Serra	75.15	47.18	53.71	84	39.61	54.75	X

Agricultural Household Model

- Max: $E_t \sum_{t=0}^{\infty} (1 + \delta)^{-t} U(X_A, X_M, L_L; H, S)$
- subject to:

$$P_M X_M = P_A (Q - X_A) - P_N X_N + W\bar{L} \quad W = \sum_{i=1}^I W_i$$

$$\bar{L} = L + L_H \quad L \geq L_A + L_W + L_L \quad L = \sum_{i=1}^I L_i$$

$$D = D_{NF} + D_F$$

- $X_i = X_i (W_i, P_A, P_M, P_N, Y, D, \theta, H, S)$
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Table 10 – Estimations of Deforestation

	Original Sample	Extended Sample	Extended and Tracked
	Households in the Original Random Sample N=161	Random Sample Plus Households Added Randomly from Original and New Settlements N=274	Households in the Extended Plus Sample Plus those Household Members and Entire Households that were Tracked N=309
<i>Household Characteristics</i>			
	0.10	0.04	0.09
Family	(0.26)	(0.20)	(0.17)
	0.04	0.04	0.03
Age Household	(0.08)	(0.05)	(0.05)
	0.21	-0.06	0.02
Age Household	(0.52)	(0.35)	(0.33)
	1.71	2.02	0.82
South	(2.63)	(1.78)	(1.67)
	-1.87	-1.05	-1.09
Unions	(1.20)	(0.76)	(0.72)
<i>Inputs for Agriculture</i>			
	0.00	0.00	0.00
Chemical Inputs	(0.00)	(0.00)	(0.00)
	0.00	0.00	0.00
Labor Payments	(0.00)	(0.00)	(0.00)
<i>Income and Assets</i>			
	0.00***	0.00	0.00
Vehicle Value	(0.00)	(0.00)	(0.00)
<i>Lot Characteristics</i>			
	0.81***	0.84***	0.83***
Lot Size	(0.02)	(0.02)	(0.01)
	0.00	0.00***	0.00***
Distance City Center	(0.00)	(0.00)	(0.00)
	0.31	1.77*	2.41**
Soil	(1.58)	(1.07)	(0.99)
	0.32	0.16	0.13
Average Slope	(0.39)	(0.24)	(0.22)
R- squared	0.95	0.94	0.95
Adjusted R-squared	0.95	0.94	0.95

*, **, *** represent significance at the 90, 95, and 99 confidence intervals, respectively

Conclusions

- Survey data are consistent with independent sources
 - There are significant differences between the extended samples collected in 2005
 - These differences impact the estimation of deforestation
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Next Steps

- Analyze differences between survey and census data for additional welfare and land use variables at the municipality level.
 - Estimate panel models of deforestation
 - Test for spatial autocorrelation in the estimations
 - Account for endogeneity of welfare and income in estimations of deforestation
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