Climate Change Effects on Brazilian Agricultural Land Use– Cross-Sectional Panel Model with Census Data

Kathryn G. Anderson, Eustáquio J. Reis

October 5, 2006

Outline

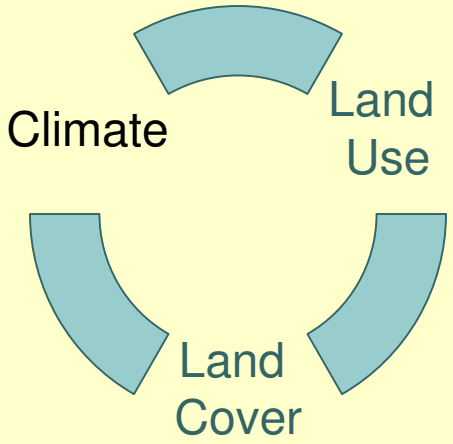
- Motivation
- Past results
- Model
  - Theory
  - Specification
- Data
- Results
  - Estimation
  - Simulation
- Conclusions
- Extensions

Motivation

- Quantify climate change effects on the agricultural economy.
  - Project impacts on farm profits.
    - www.ipea.gov.br
    - www.nemesis.org.br
    - www.ipeadata.gov.br
- Land use feedback linkage for models that project future climate change.

Motivation – Feedback Linkage

- Deforestation ➔ 2nd largest global source of CO_2
- Elsewhere:
  - Δ land use $\Rightarrow \Delta$ land cover
  - Δ land cover $\Rightarrow \Delta$ climate
- Current project:
  - Δ climate $\Rightarrow \Delta$ land use



Past Results

- Evenson and Alves (1998)
  - ⇑ 1 ℃; ⇑ 3% rainfall:
    - land values ⇓ 1.2%
    - natural forest ⇓ 2%
- Timmins (2003)
  - GCM spatially differentiated climate change
    - natural and planted forest ⇑

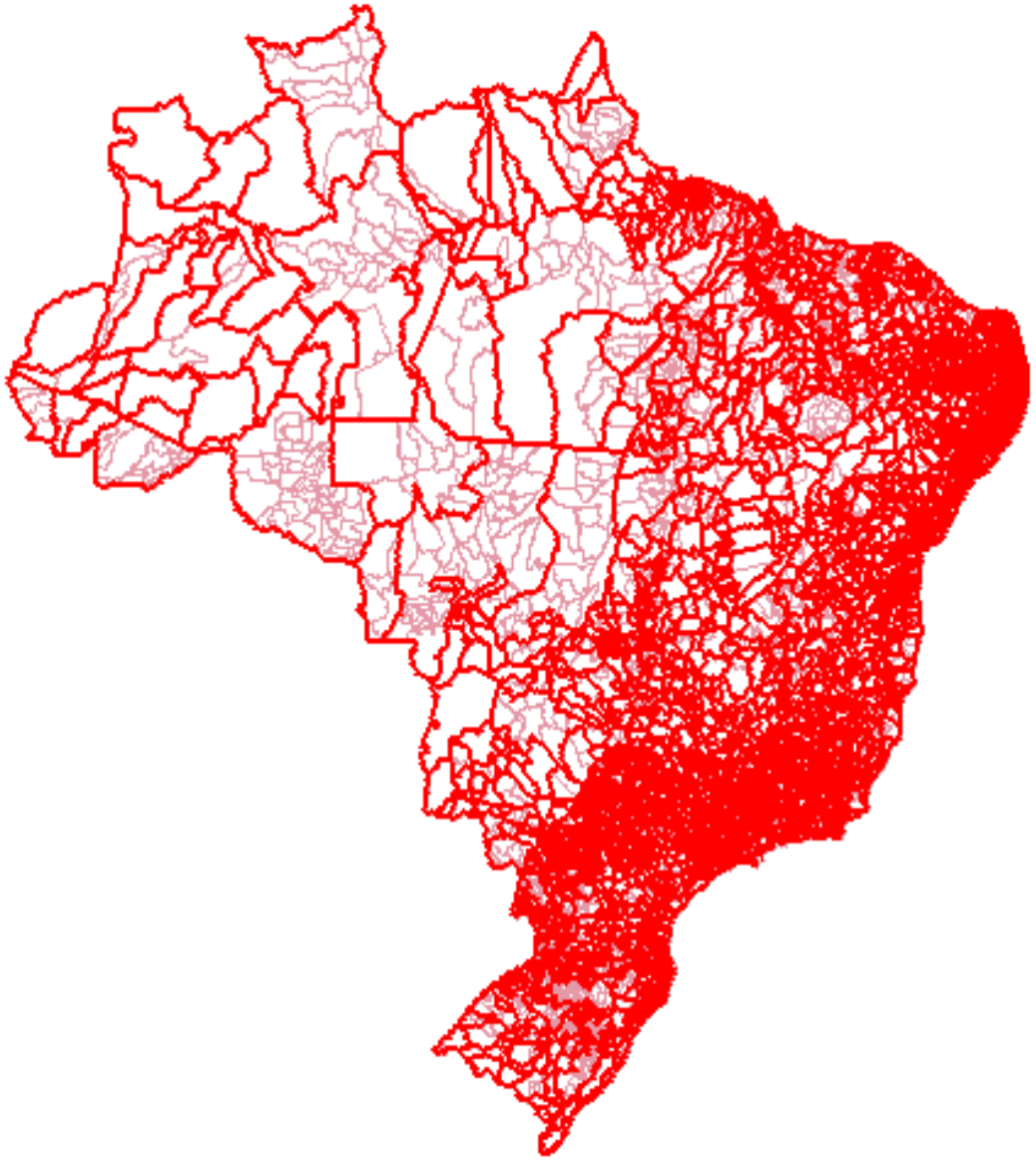
Model – Theory

- Climate → *(profits)* → land conversion
- Regression analysis
  - Depvar = ARALT: proportion of municipio area unsed in agropastoral activities
    - annual or perennial cropland
    - planted pasture
    - planted forest
    - short-term fallow
  - Assumption: Spatial variation in climate mimics temporal variation
  - Estimated with Agricultural Census data
  - MCA-level cross-sectional model
    - Excluded non-representative and metropolitan MCAs

BRASIL

Areas Minimas Comparaveis entre 1997 e 1970

Divisao Municipal 1997



MCAs

1970

1975

1980

1985

1995/96

Elaboracao: IPEA/DIMAC utilizando Malha Municipal Digital do Brasil 1997 (IBGE/DGC/DECAR)

Model Estimation – Logistic Specification

$$\log\left(\frac{ARALT_i}{1-ARALT_i}\right) = \alpha + \beta T_i + \delta T_i^2 + \gamma P_i + \phi P_i^2 + \eta T_i P_i$$

$$+ \tau T_i E_i + \varphi P_i E_i + \sum_c \lambda_c Z_{ic} + e_i$$

- $ARALT_i$ = altered area per hectare of establisment area;
- T_i = temperature (°C);
- P_i = precipitation (mm);
- E_i = Erosion limitation;
- Z_{ic}= edaphic, geographic, and socio-economic control variables;
- e_i = error term;
- α, β, δ, γ, ϕ,, η, t, φ, and λ_c = parameters to be estimated.

Model – Theory

- Climate enters the model in 3 different steps:
  1. to estimate the land use model.
  2. to predict the current amount of converted land.
  3. to project amount of converted land under climate change.

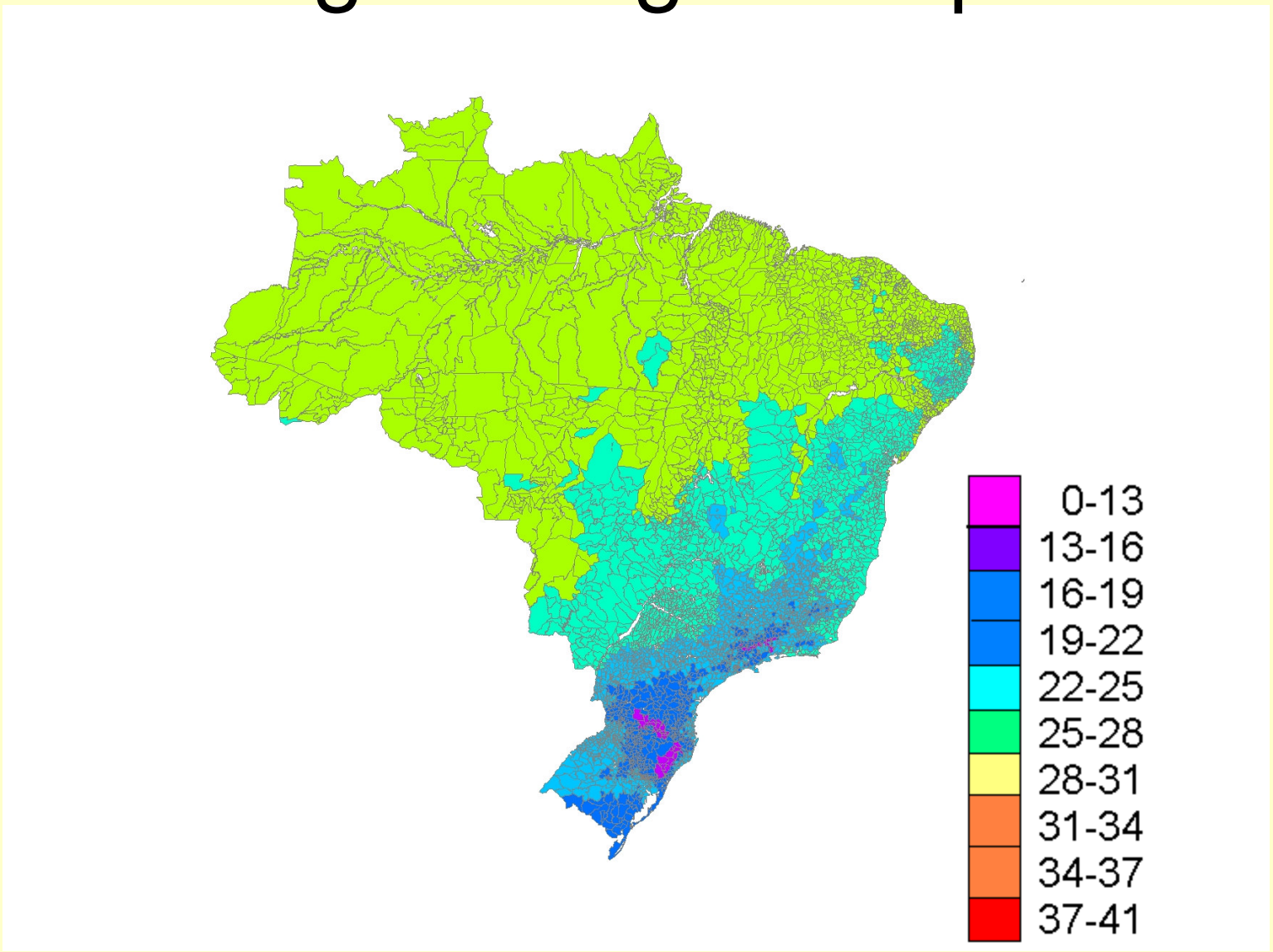
- The impact of climate change on ARALT (the amount of converted land) is calculated as the difference between *projected* and *predicted*.

Climate Data

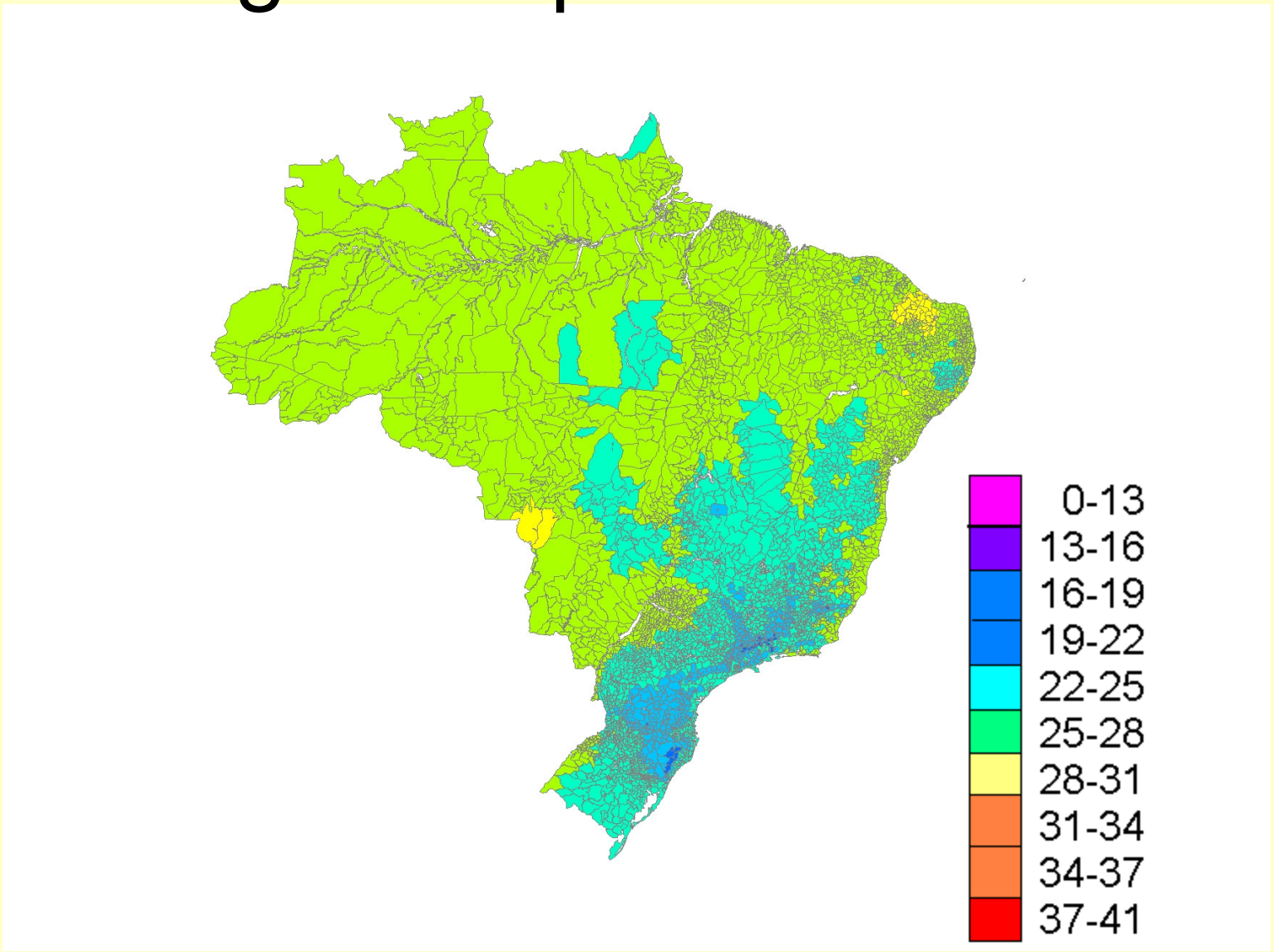
- Base climatology:
  - Climate Research Unit (CRU)
    - 10 minute (~20km) interpolated grids intersected with AMC boundaries
  - 30-year averages (1961-1990)
    - temperature (°C)
    - precipitation (mm/month)
  - Seasonal specification
    - December, January, February
    - March, April, May
    - June, July, August
    - September, October, November

TMP30DJF
TMP30MAM
TMP30JJA
TMP30SON
PRE30DJF
PRE30MAM
PRE30JJA
PRE30SON

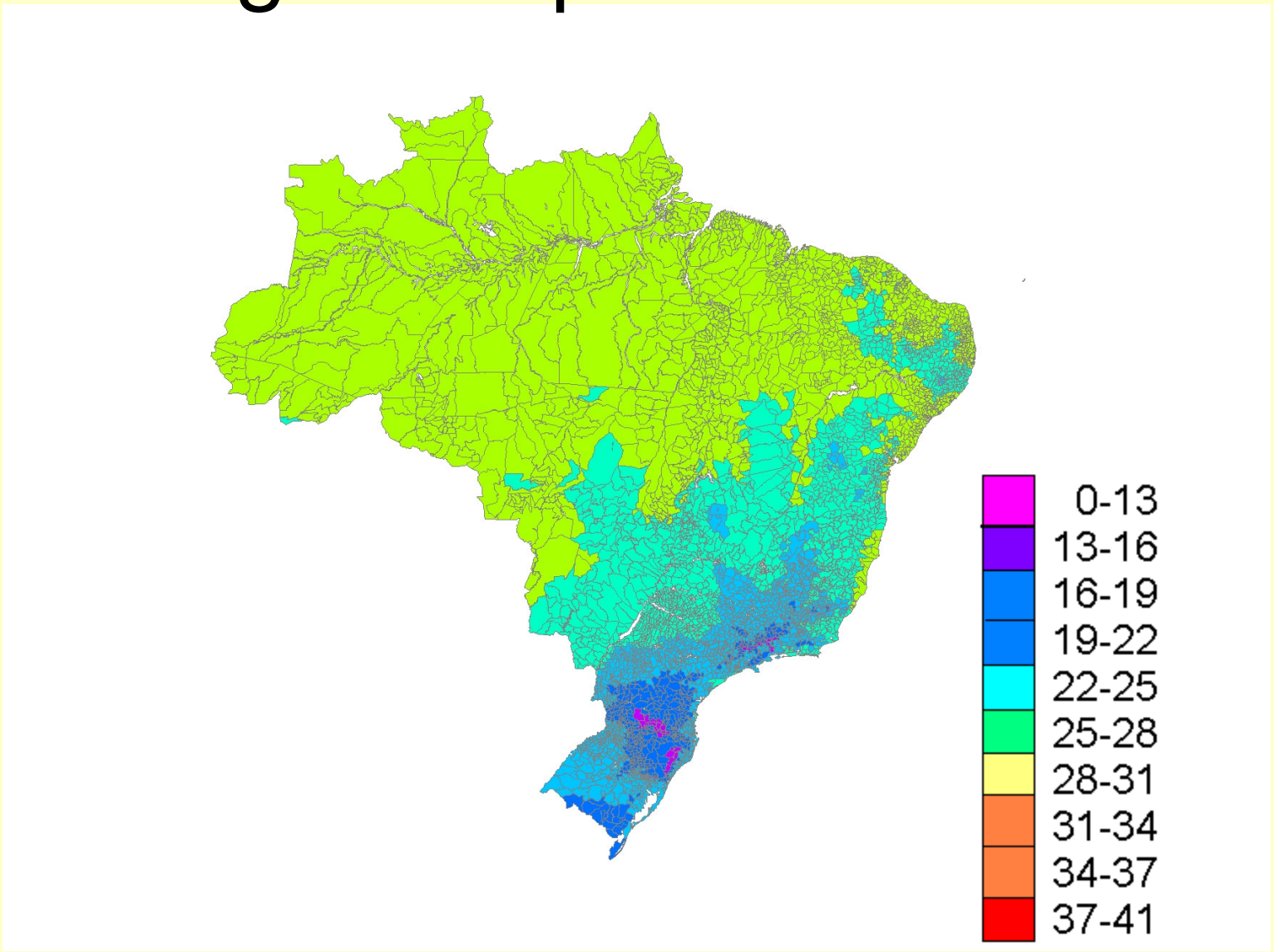
Yearlong Average Temperature



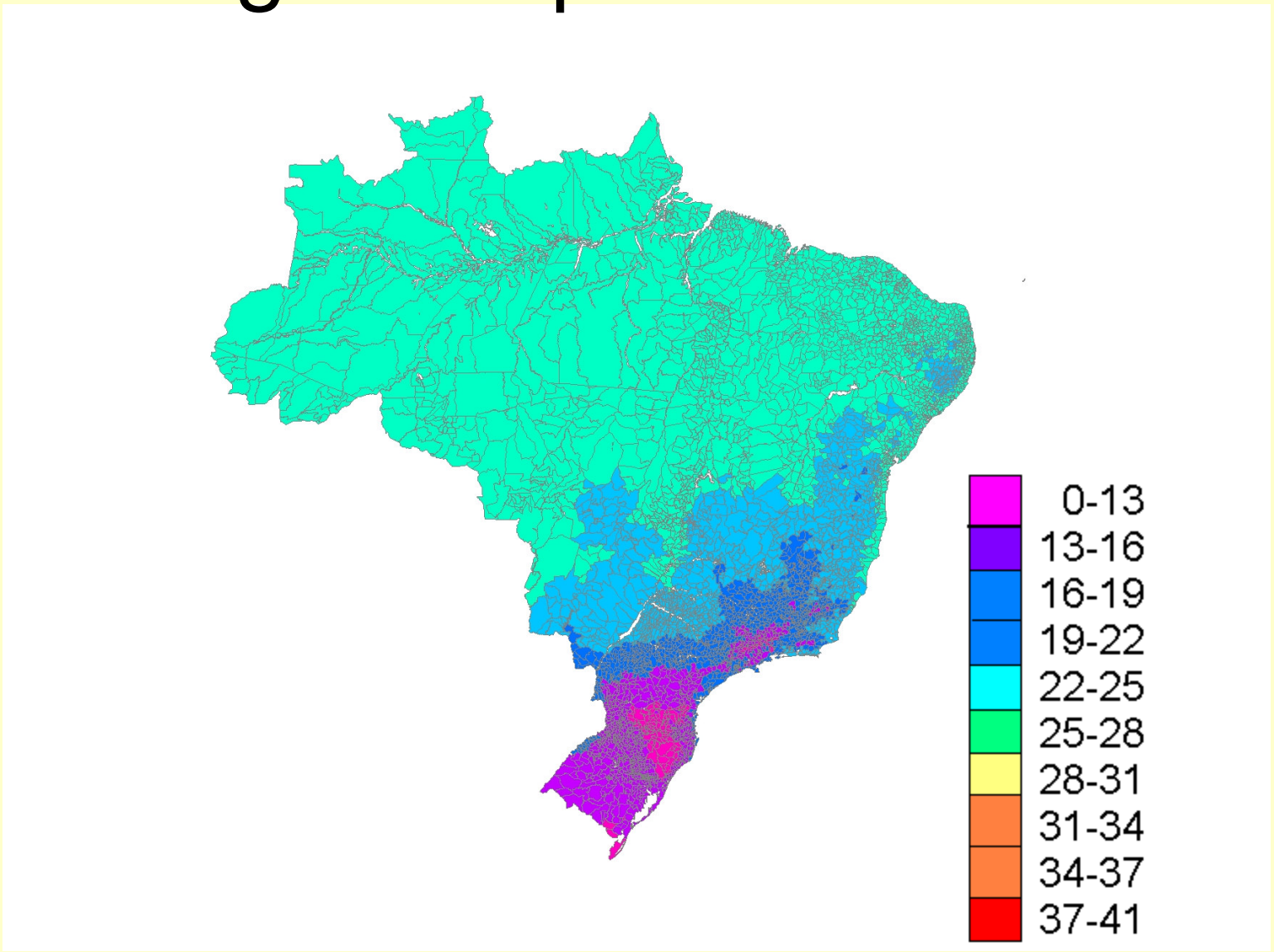
Average Temperature - DJF



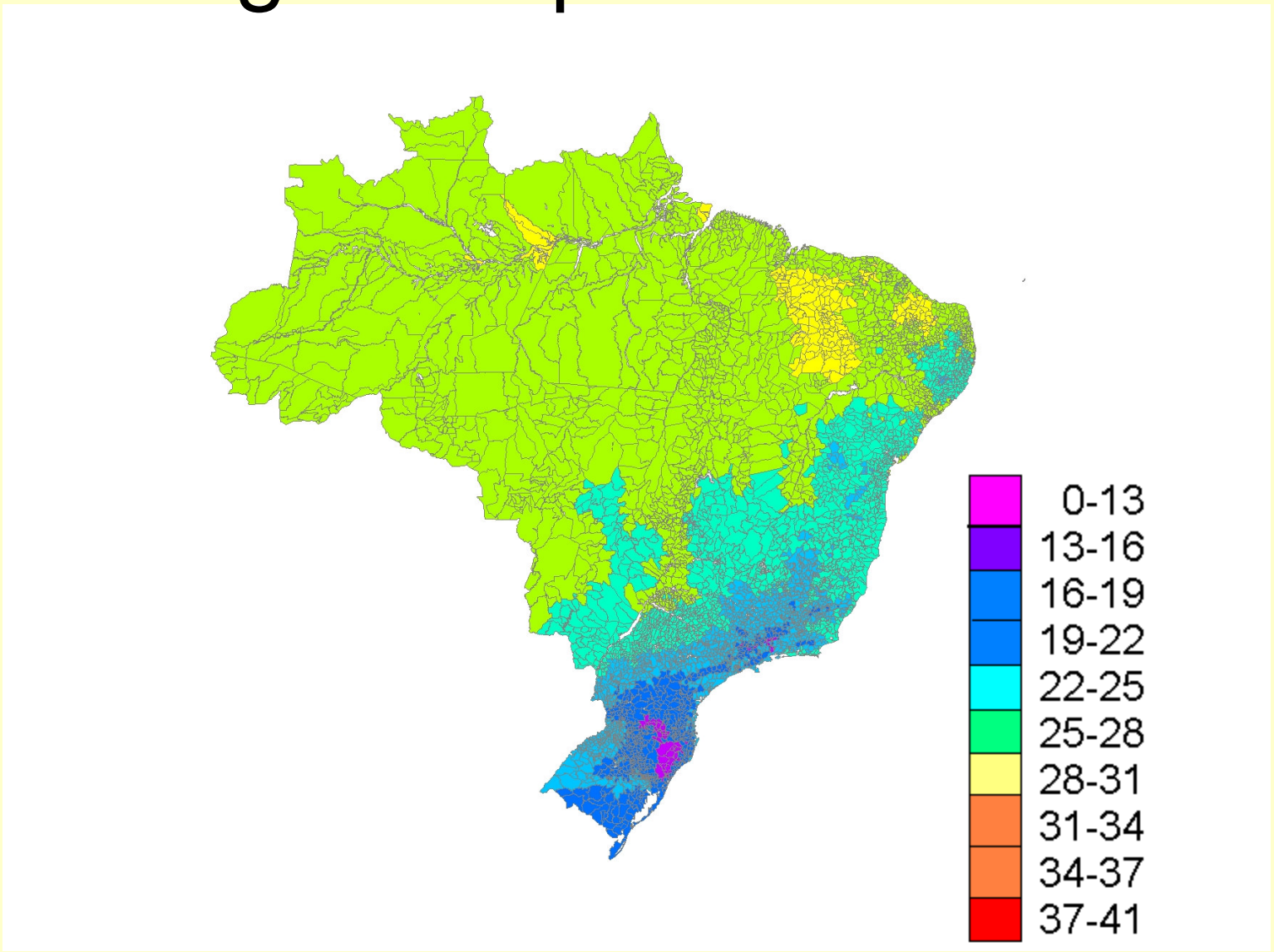
Average Temperature - MAM



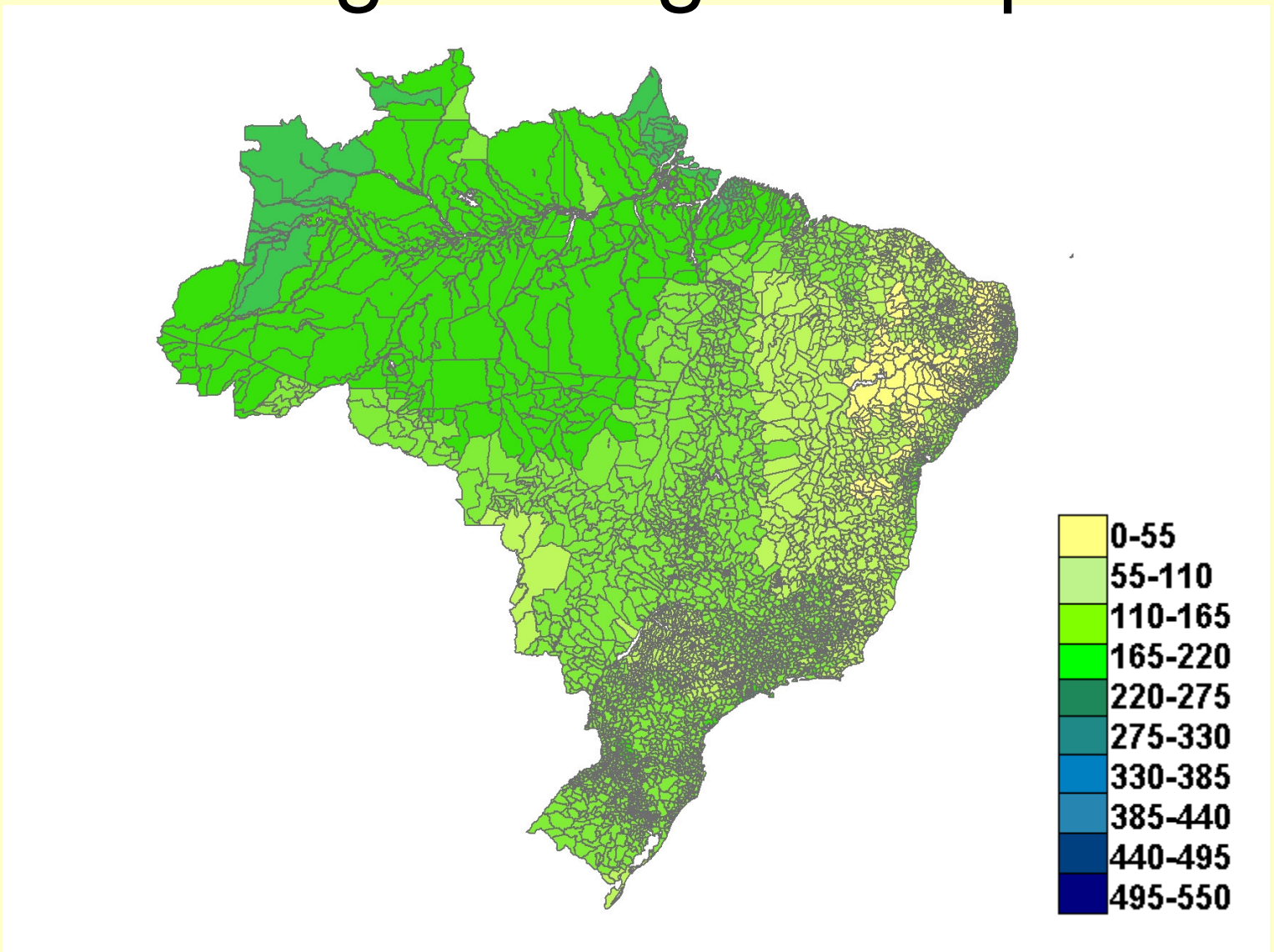
Average Temperature - JJA



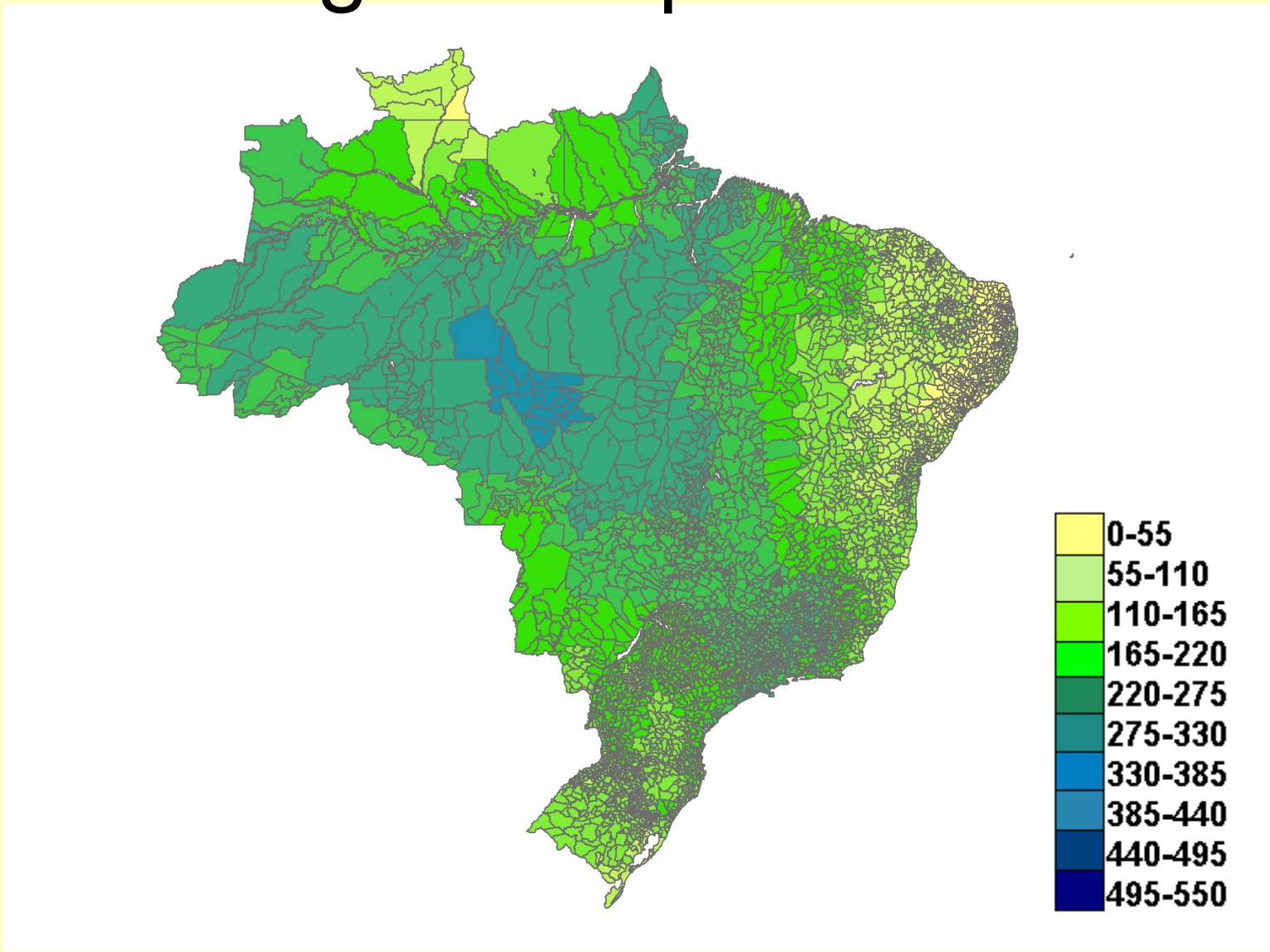
Average Temperature - SON



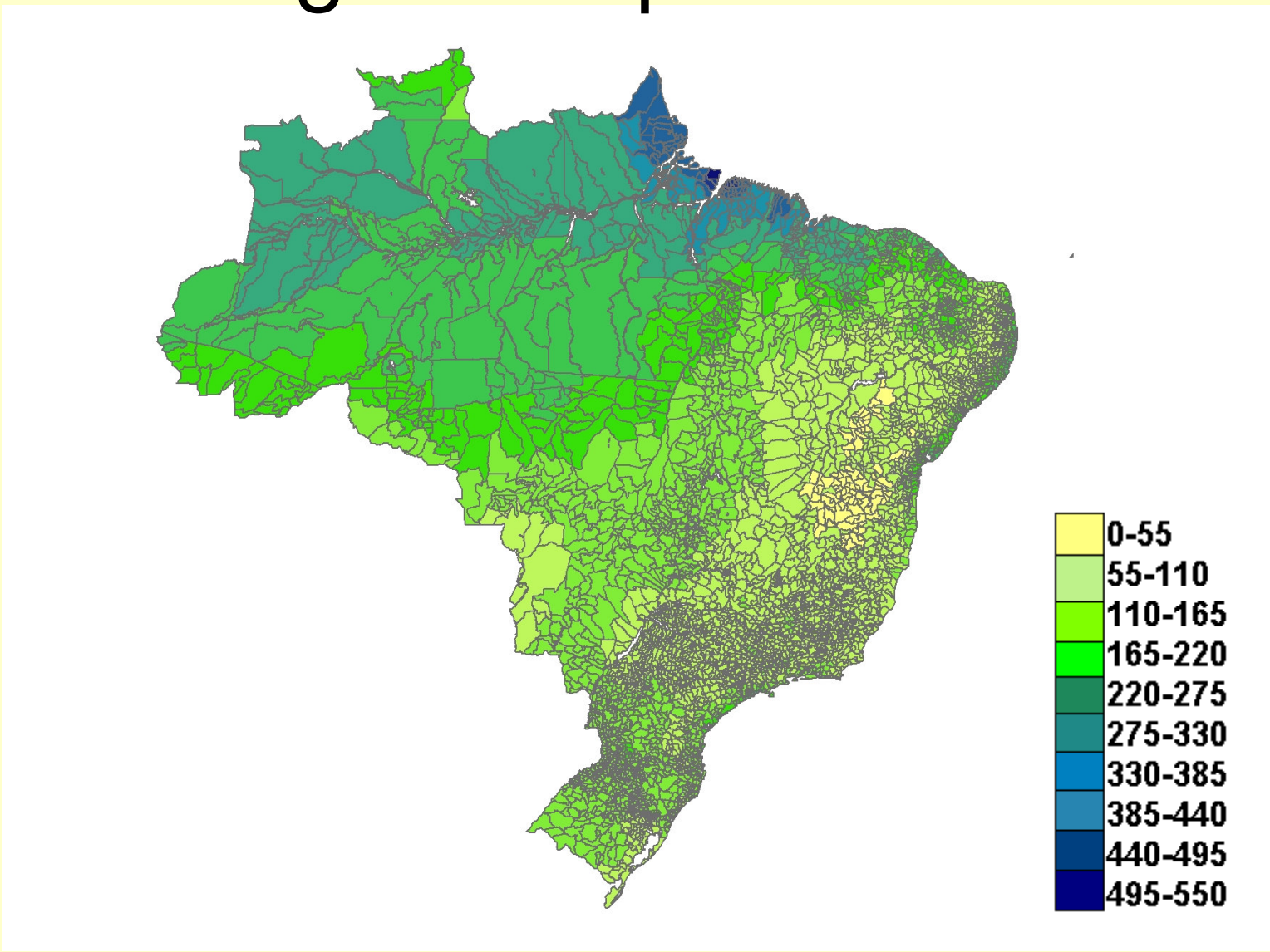
Yearlong Average Precipitation



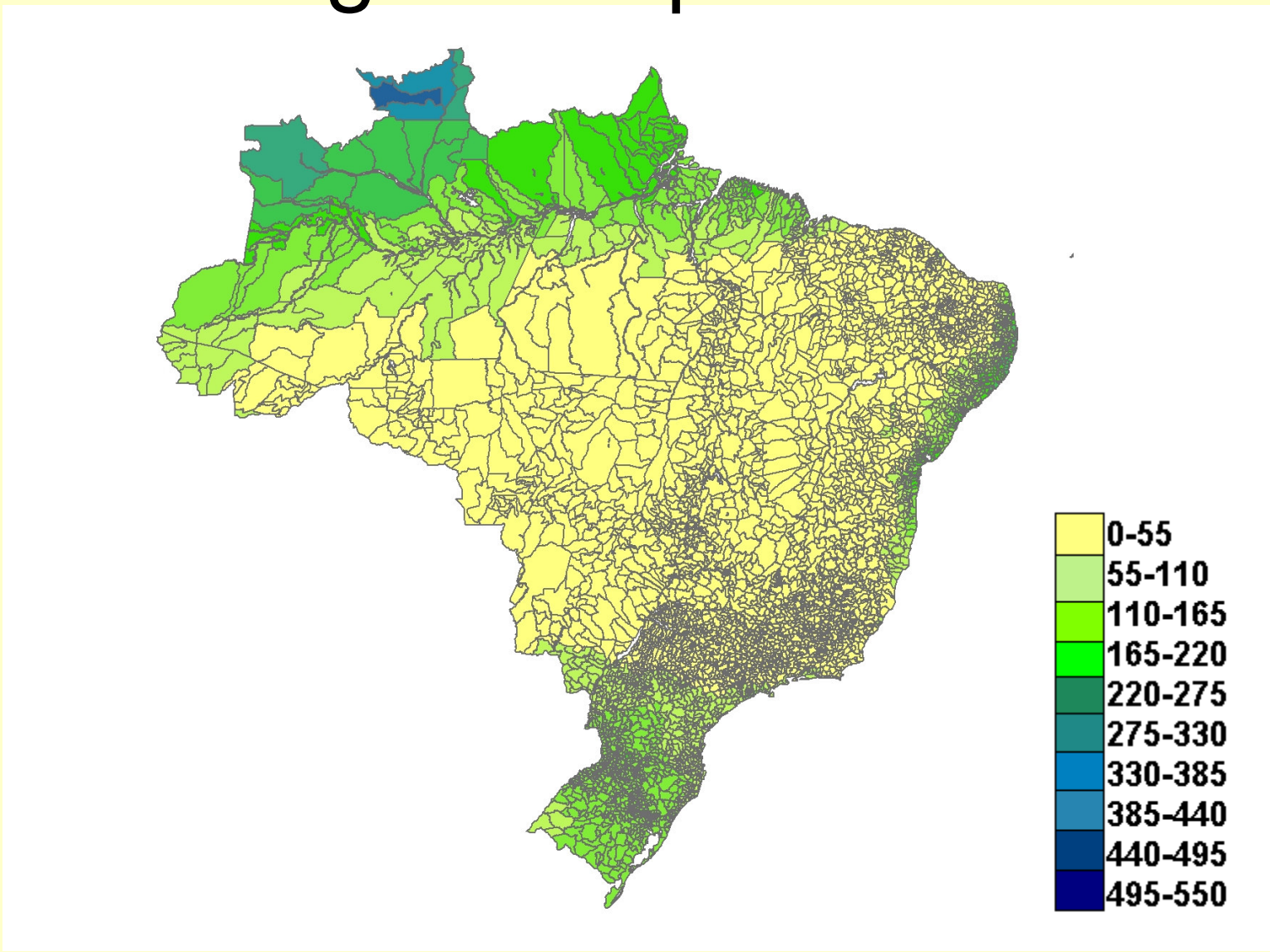
Average Precipitation – DJF



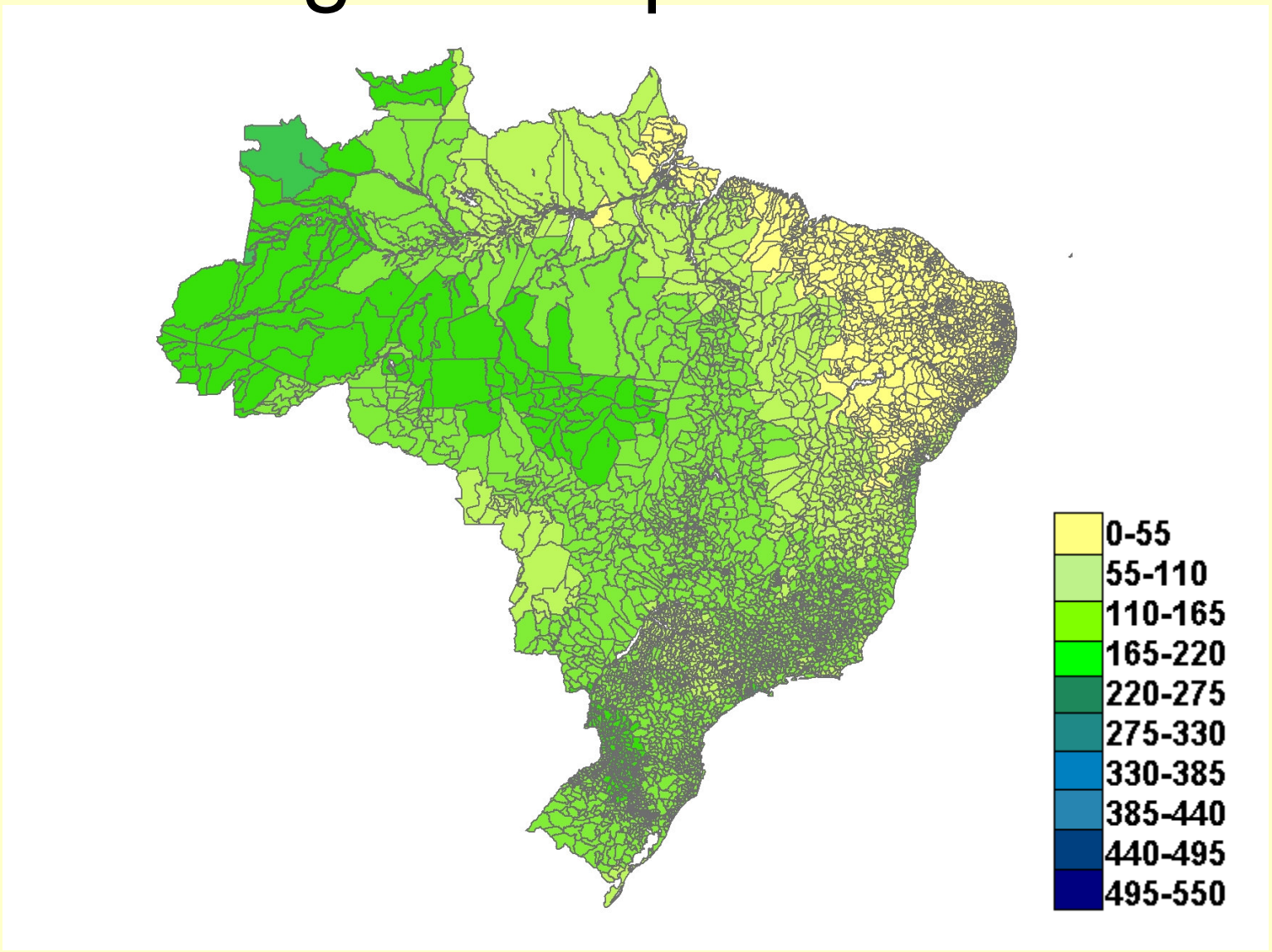
Average Precipitation – MAM



Average Precipitation – JJA



Average Precipitation – SON

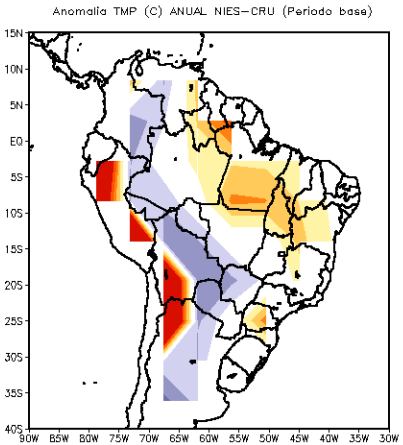


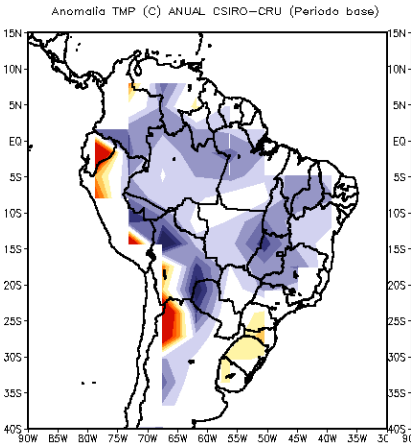
Climate Change Data

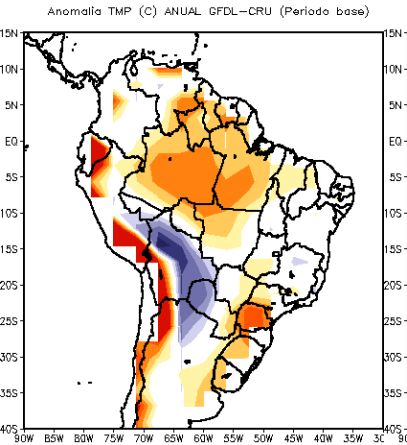
- General Circulation Model (GCM) projections
  - Wagner Soares, CPTEC
  - Projected timeslices
    - 1961-1990
    - 2020s
    - 2050s
    - 2080s
  - 5 GCMs
    - HadCM3
    - CCCma
    - CCSR/NIES
    - CSIRO
    - GFDL
  - Intersected grids with MCAs

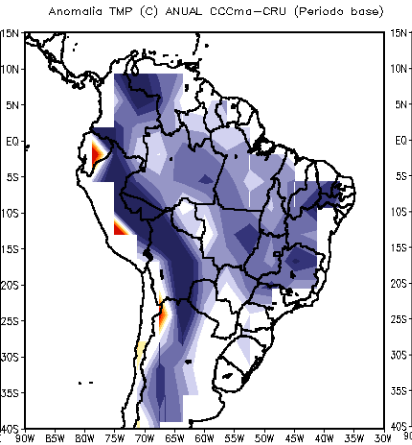
Projected climate change = observed (CRU) base + modeled anomaly

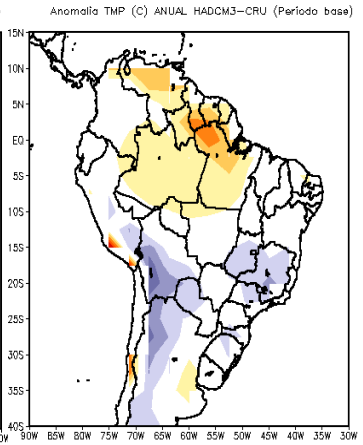
Climate Data – Modeled 1961-1990





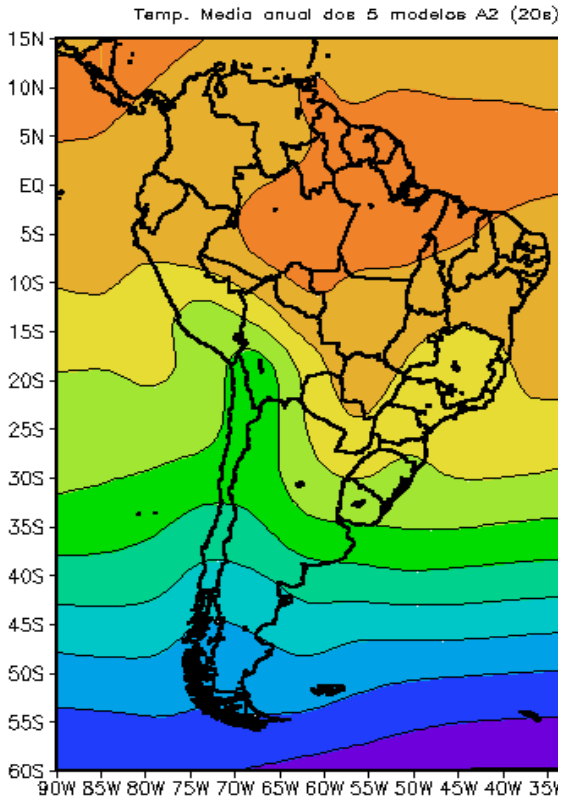


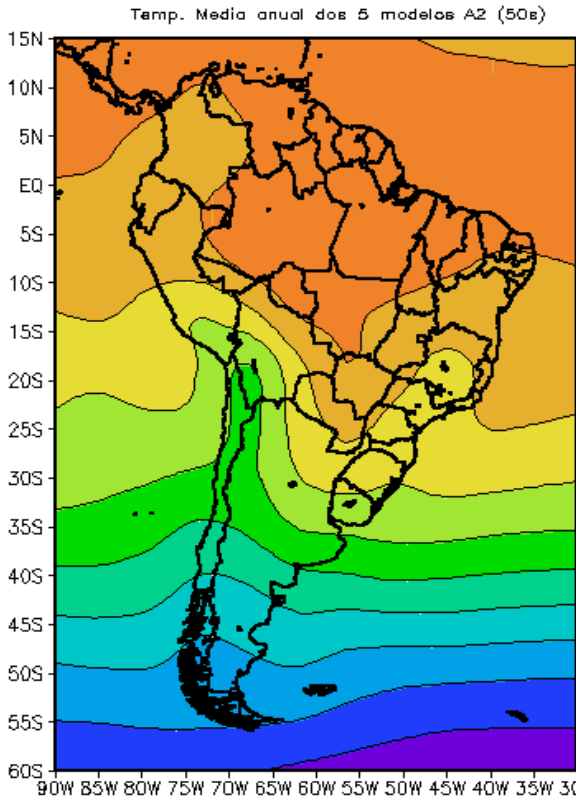


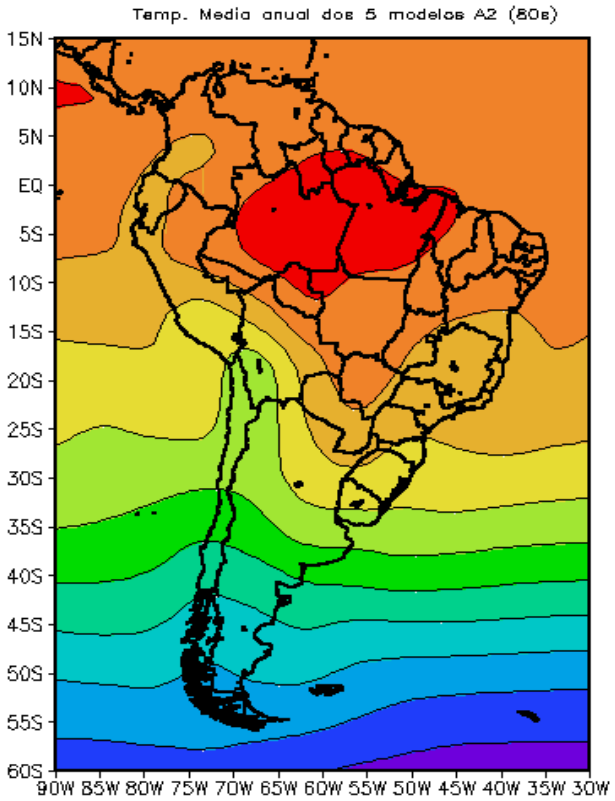


Climate Data –

5-model average of 2020s, 2050s, and 2080s temperatures

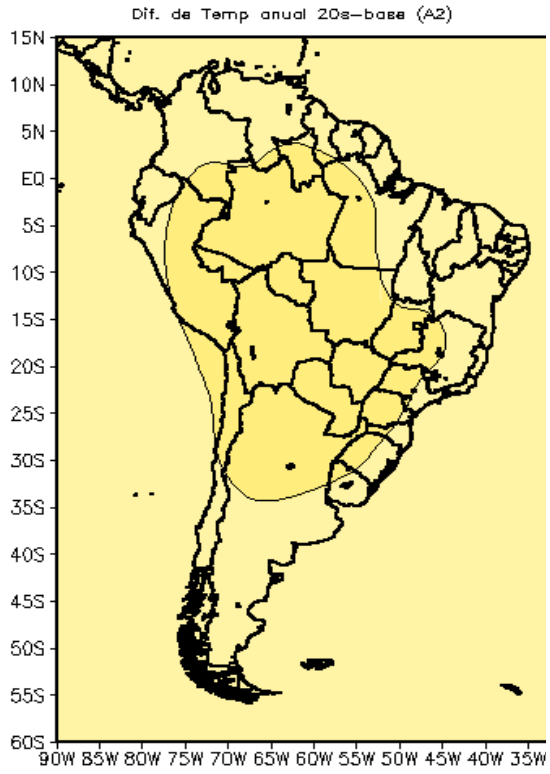


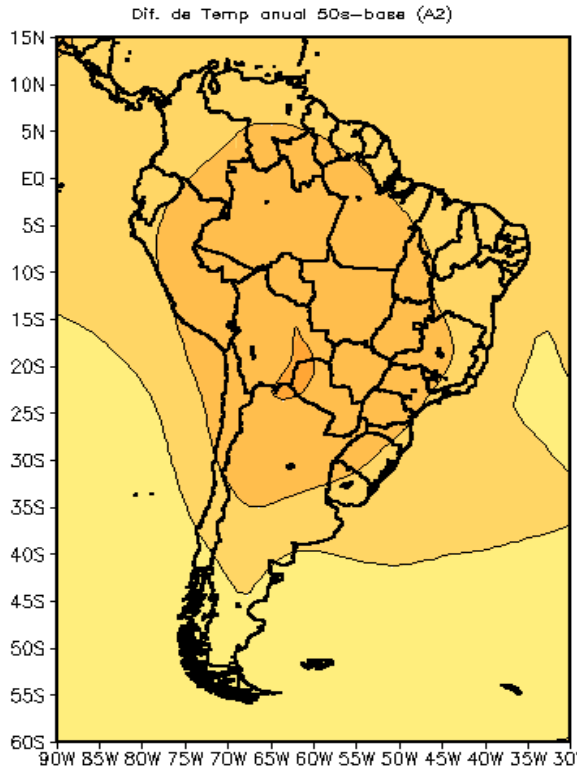


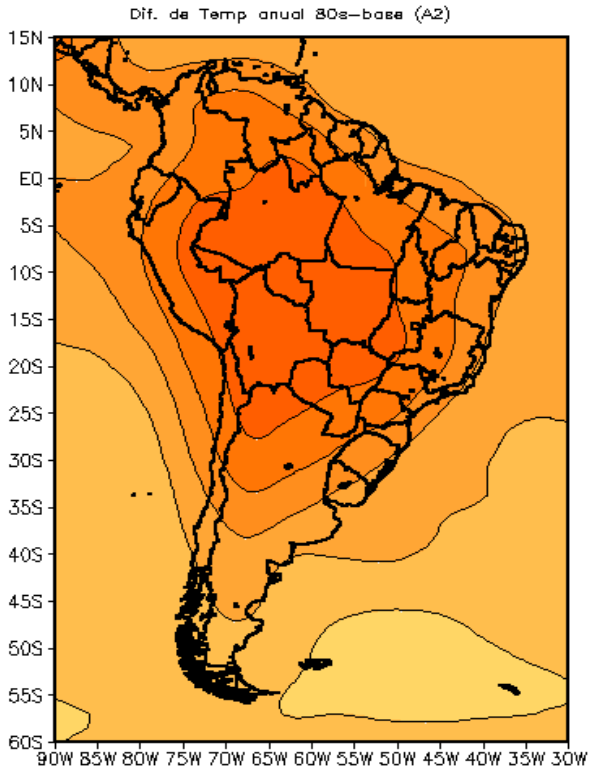


Climate Data –

5-model average of 2020s, 2050s, and 2080s anomalies





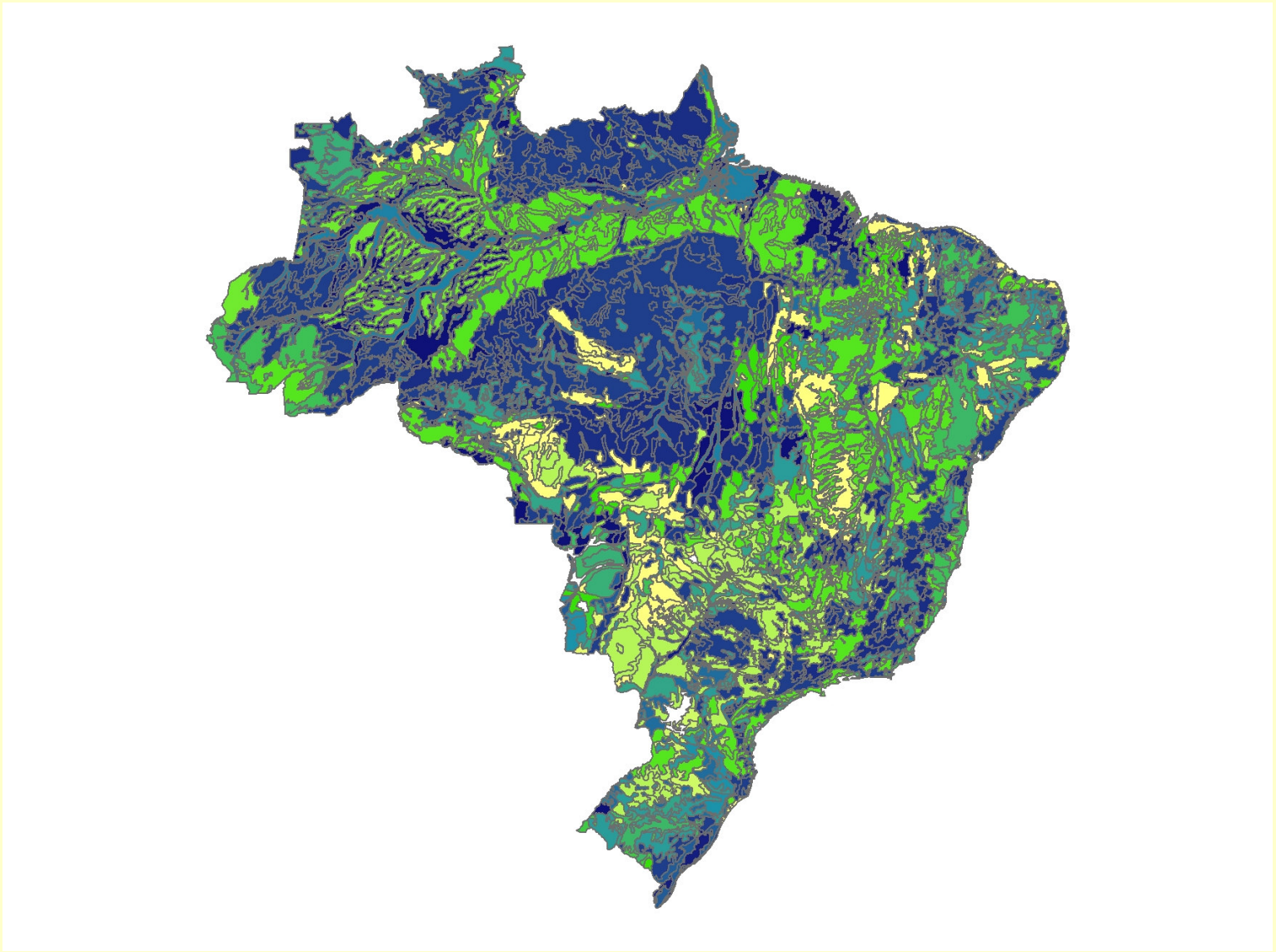


Geographic Data – Soils

- 1:5,000,000 digital maps of Brazilian soils (Embrapa)
  - Erosion
    - PERO1 = 7.5 - 15% inclinação
    - PERO2 = 30 - 45% inclinação
  - Proportion of município in each of 12 categories of soil type
  - Proportion in 5 categories of soil quality

PERO1
PERO2
PSOLO1-13
PPTNC1-5

Soil type – 1:5,000,000



Geographic Data

PALT1-7
DSHOR
DEN_TIND
DEN_UCI
DEN_UCS

- PALT = proportion of município in each of 7 classes of altitude.
- DSHOR = linear distance to the sea
- DEN_TIND = proportion of município in indigenous reserves
- DEN_UCI = proportion of município in protected areas (integral)
- DEN_UCS = proportion of município in protected areas (sustainable use)

Results: Logistic Estimation of Converted Land

- Adj. R-square = 0.78
- 24 out of 28 climate variables are significant
- F-tests find all variable groups to be significant

Results: Logistic Estimation of Land Use

"Exogenous Model" -- AMC-level -- Panel:1970, 75, 80, 85, 95/96 -- Weighted by municipio area

Dependent Var = ARALT: Proportion of municipio converted to agricultural use

Variable				
TMP30DJF**	-3.347		N.Obs.	15,598
TMP30DJF_2**	0.071		F-value	852.13
PRE30DJF**	-0.022		**Adj R-Sq**	**0.78**
PRE30DJF_2**	-0.00005			
TMP*PRE30DJF**	0.002			
TMP30MAM**	-6.544			
TMP30MAM_2**	0.096			
PRE30MAM**	-0.081			
PRE30MAM_2**	-0.00007			
TMP*PRE30MAM**	0.005			
TMP30JJA**	3.218			
TMP30JJA_2**	-0.048			
PRE30JJA**	0.067			
PRE30JJA_2**	0.00001			
TMP*A55PRE30JJA**	-0.004			
TMP30SON**	4.028			
TMP30SON_2**	-0.103			
PRE30SON	0.006			
PRE30SON_2**	0.000			
TMP*PRE30SON*	-0.001			

*significant at Pr>T=0.10, **significant at Pr>T=0.01

PERO1**	-31.047		PSOLO1	-0.053
PERO2**	-33.491		PSOLO2	0.391
PERO1*TMP30DJF	-0.440		PSOLO3	-0.236
PERO1*TMP30MAM**	2.263		PSOLO4	0.799
PERO1*TMP30JJA**	-2.038		PSOLO5	0.326
PERO1*TMP30SON**	1.367		PSOLO6	0.818
PERO1*PRE30DJF**	0.017		PSOLO7	-0.879
PERO1*PRE30MAM**	-0.022		PSOLO8	-0.789
PERO1*PRE30JJA**	0.039		PSOLO9	-0.082
PERO1*PRE30SON**	-0.035		PSOLO10	-0.125
PERO2*TMP30DJF	-0.088		PSOLO11	0.166
PERO2*TMP30MAM	0.891		PSOLO12	-3.064
PERO2*TMP30JJA*	-1.034		DSHOR**	-0.002
PERO2*TMP30SON**	1.601		PPTNC1**	1.052
PERO2*PRE30DJF**	0.025		PPTNC2**	0.338
PERO2*PRE30MAM**	-0.045		PPTNC3**	-1.406
PERO2*PRE30JJA**	0.069		PPTNC4	0.021
PERO2*PRE30SON**	-0.042		DEN_TIND**	-2.841
PALT2**	0.875		DEN_UCI**	-2.994
PALT3**	1.331		DEN_UCS**	1.244
PALT4**	0.751			
PALT5**	0.859			
PALT6*	1.484			
PALT7*	7.992			

*significant at Pr>T=0.10, **significant at Pr>T=0.01

Model Error – % Difference, Predicted vs. Observed
ARALT – Weighted Logistic

Region	1970	1975	1980	1985	1995	sum of abs(error) across years	sum of error across years
North	92.42	10.13	-47.54	-61.53	-71.00	282.61	**-77.52**
Northeast	35.22	29.65	-18.25	-27.74	-15.66	126.51	**3.22**
Southeast	37.79	27.37	-4.77	-11.11	-13.46	94.50	**35.83**
South	19.18	5.30	-12.11	-14.77	-9.09	60.45	**-11.49**
Central-West	89.72	16.18	-28.96	-46.19	-61.18	242.23	**-30.42**
Brasil	43.14	19.12	-18.71	-30.07	-36.76	147.80	**-23.27**

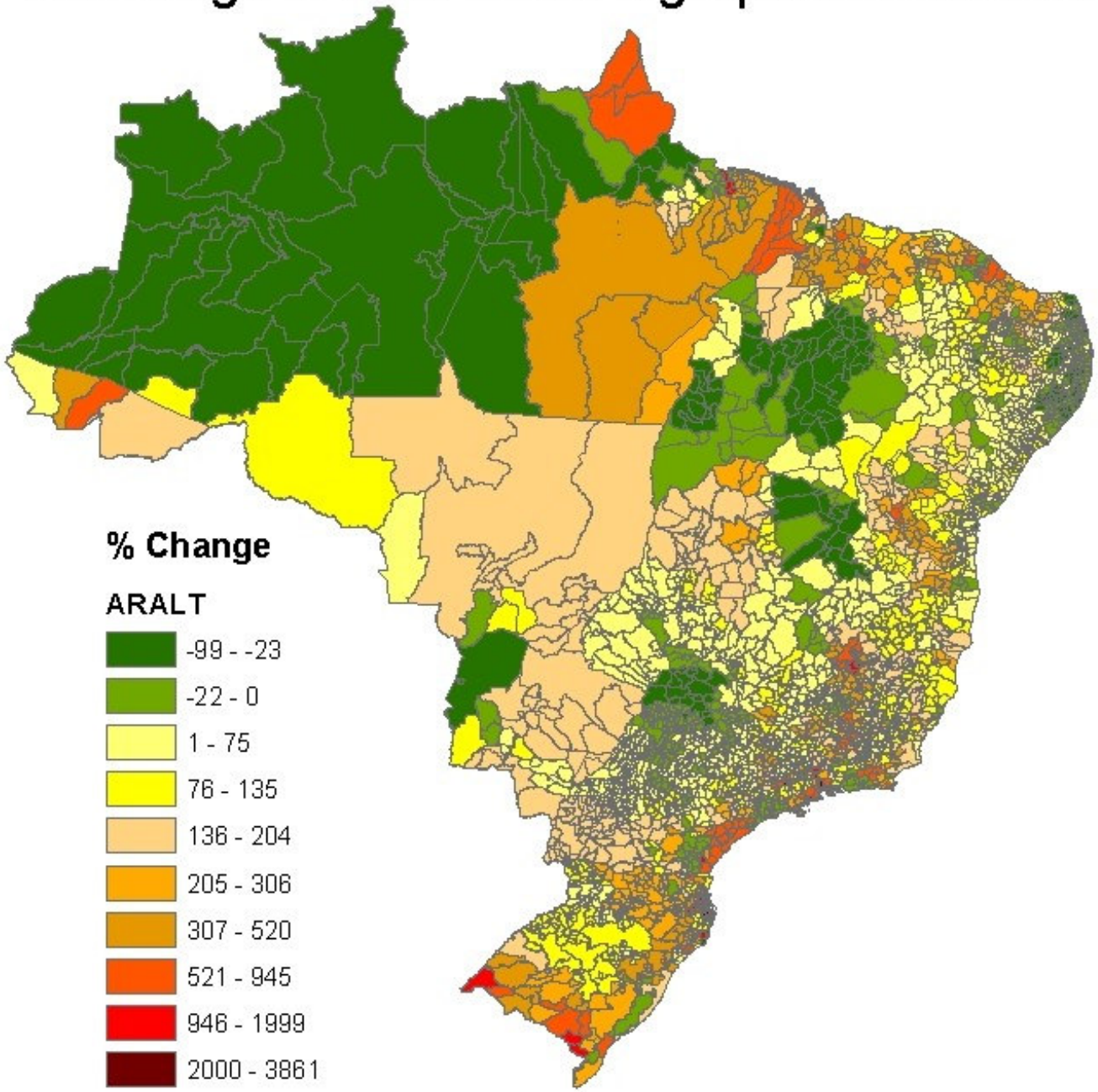
Model Error – % Difference, Predicted vs. Observed
ARALT – Un-weighted Logistic

Region	1970	1975	1980	1985	1995	sum of abs(error) across years	sum of error across years
North	313.06	136.41	12.62	-17.41	-37.75	517.26	**406.95**
Northeast	57.50	51.01	-4.77	-15.83	-1.76	130.88	**86.15**
Southeast	33.27	23.19	-7.89	-14.03	-16.30	94.68	**18.24**
South	36.22	20.37	0.47	-2.58	3.91	63.55	**58.40**
Central-West	188.01	76.37	7.85	-18.31	-41.07	331.61	**212.86**
Brasil	76.11	46.55	0.01	-13.97	-22.19	158.84	**86.51**

Simulation of Land Use

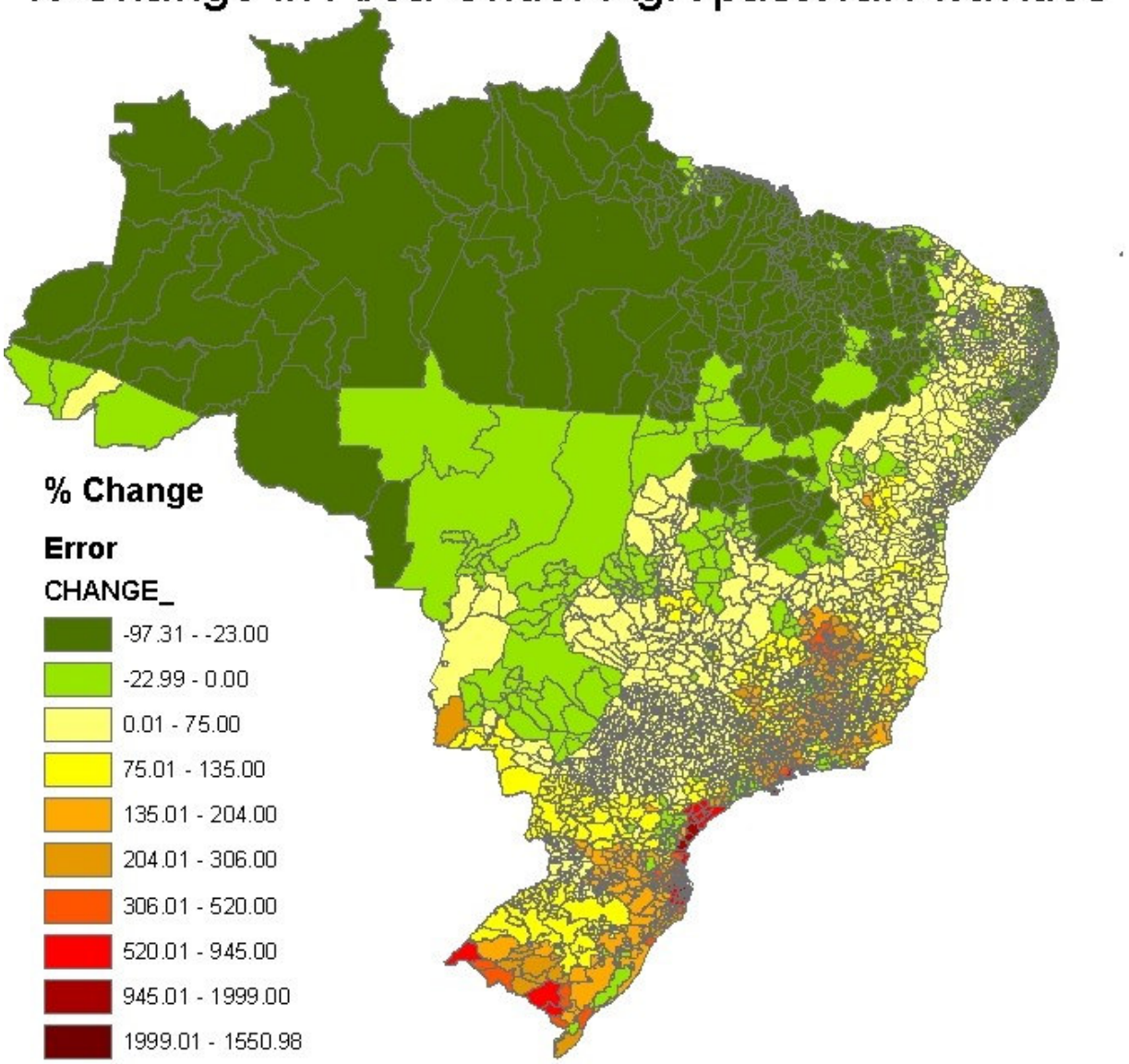
Weighted Logistic Estimation Projections – % Change in Area of Agropastoral Activity		
Region	*% Change – 2050s*	*% Change – 2080s*
North	71	116
Northeast	53	94
Southeast	43	56
South	75	117
Central_West	32	69
Brasil	51	83

% Change in Area Under Agropastoral Activities



Un-Weighted

% Change in Area Under Agropastoral Activities



Conclusions

- Evidence suggests the possibility that climate change may dampen deforestation in the Amazon and frontier areas, potentially causing a negative feedback into the greenhouse effect.

- Care must be taken with any econometric analysis where cross-section is taken over non-uniform units of observation.

Extensions – Land Use Model

- Control for spatial autocorrelation and heteroskedasticity
- Instrument for transportation costs and other endogenous RHS variables
- Joint estimation of 7 land use categories separately

Extensions – Productivity Model

- Hedonic land value
- Fixed effects
- Profits
- Ag GDP

- Best use land value function (hedonic)
- Fixed-effects model – 1970-1995 (minimum comparable areas).
  - Controls for non-time varying effects
    - Time: Isolates the effects of single-year climate on single-year profits.
  - Includes more variance in observations