THE EFFECTS OF CLIMATE CHANGE ON PROFITABILITY AND LAND USE IN BRAZILIAN AGRICULTURE: A MUNICIPAL CROSS-SECTION ANALYSIS

Report of the Research Project on Global Warming, Land Use and Land Cover Changes in Brazil sponsored by IPEA/PNPE

KATHRYN ANDERSON[1], EUSTÁQUIO REIS[2], JULIANA SPERANZA[3]

1 Visiting Researcher at IPEA, anderson.kathryn@gmail.com. 2 Research Economist, IPEA, Av. Antonio Carlos 51/1703, Rio de Janeiro, RJ 20.020-010., ejreis@ipea.gov.br . 3 Visiting Researcher at IPEA, speranza@ipea.gov.br

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ABSTRACT: This paper summarizes results of Anderson and Reis (2006) which presents a model to simulate the effects of global climate changes on land values and land use patterns in Brazilian agriculture. The contribution in relation to previous literature is improved data used to estimate and simulate the effects of climate change, in particular spatially disaggregated projections of climate change in Brazil obtained from General Circulation Models (GCM). Results show that, ceteris paribus, climate the effects of global climate change on both land value and land use in Brazilian agriculture will be drastically different depending on the region of the country. In the North region, which overlaps the Amazon rain forest, simulations show reductions in land uses and land values, while in the South increases are forecasted in both of them.

Key words: climate change, global warming, land use and land cover

OS EFEITOS DA MUDANÇA DE CLIMA NA RENTABILIDADE E USO DA TERRA NA AGRICULTURA BRASILEIRA: UMA ANÁLISE MUNICIPAL DE CROSS-SECTION

RESUMO: Este artigo sumaria os resultados de Anderson e Reis (2006) que apresenta um modelo para estimar os efeitos das mudanças climáticas no valor e nos padrões de uso da terra na agricultura brasileira. Nossa contribuição em relação à literatura anterior é melhorar a base de dados utilizada para estimar e simular os efeitos da mudança climática, em particular as projeções para o Brasil das mudanças climáticas espacialmente desagregadas obtidas a partir de Modelos de Circulação Geral (MCG). Os resultados mostram que, ceteris paribus, os efeitos climáticos da mudança de clima global tanto no valor da terra como no uso da terra na agricultura brasileira serão drasticamente diferentes dependendo da região do país. Na região norte, que sobrepõe a floresta tropical Amazônica, simulações mostram reduções no uso agro-pastoral e no valor da terra, enquanto no Sul há aumentos previstos para ambos.

Palavras chaves: mudança climática, aquecimento global, uso e cobertura da terra.

1. INTRODUCTION: One of the most significant ways that global climate change is expected to affect human well-being is through its effects on agriculture. General circulation models (GCM) estimate that Brazil will warm less rapidly than the global average and that warming will vary by season with smaller changes in the wetter months (December to February) than in the drier ones (June to August). Warming will likely be greatest over the Amazon rainforest and least in the southeastern coastal states (HULME and SHEARD 1999, NOBRE et al. 2005). The spatial differences in climate change on its turn are likely to imply significant changes in the spatial patterns of profitability and land use in agriculture. The objectives of the paper are twofold. First, to simulate the effects of global warming upon the spatial distribution of profitability in Brazilian agriculture, thus contributing to the design of government policies, particularly in the areas of agricultural research and development and carbon mitigation policies. Second, to examine how climate change affects agricultural land use patterns and forest conversion in particular. The motivations in this case is to improve the understanding of the feedback loops between climate and land use changes thus providing inputs to models that project climate change.

2. METHODOLOGY: The methodology is based upon municipality-level cross-section regression analysis that exploit the spatial co-variation across Brazil between climate, land values, and land use patterns, allowing in addition for a rich complement of control variables. The dependent variables are long run profits as proxied by the municipal average value of lands in farm establishments in the Agricultural Censuses from 1970 to 1985 and the use of land as synthesized by the average proportion of farm area used for agricultural purposes in Agricultural Censuses form 1970-95. The main independent variables are the 30 year average precipitation and temperature in the period 1961-1990, and a set of additional control variables derived from the integration of the socio-economic data from the Brazilian Agricultural and Demographic Censuses with geo-referenced edaphic and geographic data produced by Embrapa and IBGE, and temperature and precipitation data from the Climate Research Unit (CRU). The estimated models are then used to simulate the spatial effects on land value and land use of projected changes in precipitation and temperature. Spatially differentiated climate scenarios are based upon the projections of four GCMs (HadCM3 from England, CSIRO from Australia, CCCma from Canada, and CCSR/NIES from Japan). Each model predicts daily temperature and precipitation given parameter specifications as described by the IPCC A2 (high emissions - estimated for Brazil as a rainfall decrease of 4.2% and a temperature increase of 3.7ºC by the 2080s) and B2 scenarios (low emissions - estimated for Brazil as a rainfall increase of 1.0% and a temperature increase of 2.5ºC by the 2080s). When reporting results (centered in 2050s and 2080s), we focus on the A2 scenario because we wanted to highlight a worst case scenario. Our geographic unit of analysis is either the municipality in 1995 or the *minimum comparable area* (MCA) in the period from 1970 to 1995, that is, the smallest aggregation of municipal areas that accommodates in a consistent way the changing geographic boundaries of municipalities in this period.

3. SPECIFICATION AND ESTIMATION: The land value function is specified as follows:

$$V_i = \alpha + \beta T_i + \delta T_i^2 + \gamma P_i + \phi P_i^2 + \sum_c \eta_i T_{ic} P_{i_c} + \sum_c \lambda_c Z_{i_c} + e_i,$$

where V_i is average municipal per hectare value in farm areas ; T_i and P_i represent seasonal temperature and precipitation measures; T_iP_i represents erosion-climate interaction terms; and Z_{ic} represent the edaphic and socio-economic control variables; e_i represents an error term; α, β, δ, γ, ϕ, η, and λ_c are parameters to be estimated. Both models assume that profit-maximizing farmers have adapted their land uses to suit the climate (MENDELSOHN et al. 1994). The model therefore allows for maximum human adjustment. As described above, for our dataset, we constructed measures of a number of non-geographic factors that influence land use and land productivity. Socio-economic variables are no included in our model because they tend to be correlated confound the climate variables (problems with endogeneity). The land value analysis is performed only on the MCA-level *means* dataset because the most recent year that land value was collected in the Agricultural Census was 1985. The specification for the land use equation is:

$$\log\left(\frac{ARALT_i}{1-ARALT_i}\right) = \alpha + \beta T_i + \delta T_i^2 + \gamma P_i + \phi P_i^2 + \sum_c \eta_i T_{ic} P_{i_c} + \sum_c \lambda_c Z_{i_c} + e_i,$$

where ARALT is the total area used in agro-pastoral activities including six land use categories (temporary and perennial crops, planted and natural pasture, planted forest and short fallow) and measured as a proportion of the geographic area of municipalities. The logistic specification is introduced because has a minimum of zero and a maximum of one. In all, 288 separate models were estimated. Estimation methods were OLS and Weighted Least Square (WLS). In the latter case, observations were weighted by the area of the municipality to give more weight to observations with a lower probability of being an outlier – larger observations, which are effectively to the average or aggregation of a number of smaller observations. It was also found to reduce heteroskedasticity. Multicolinearity, a significant problem in past research, was assessed using the *variance inflation factor* (VIF). While information from all of the specifications informs our understanding, in what follows we report results from a specification where socio-economic variables are excluded, creating a purely reduced form geographic model. Erosion-climate interaction effects are also excluded because they introduce substantial multicolinearity and because many coefficients are not statistically significant. Since we are specially concerned with endogeneity in socio-economic variables, as well as with multicolinearity this is our preferred model. In the simulations, the effects of climate change on the amount of converted land are calculated by comparing the *estimated* (not the *observed*) values from the *simulated* values. In this way, we expect to eliminate systematic bias in our econometric model when we calculate the simulated amount of change in land value/land use due to climate change. We simulate the values of land use for agrpastoral purposes and land values for two scenarios (A2 and B2 from IPCC 2001)

4. RESULTS AND DISCUSSION: LAND USE – Simulations show that the climate change associated with the IPCC A2 Scenario will result in an increase in total area used for agropastoral purposes in agricultural establishments (ARALT) of 14% by the 2080s (see Table 3 and Maps). This overall effect masks substantial regional variation including a *decrease* of 27% in the North Region which overlaps the Amazon basin, as well as an increase of 32% in the South Region. The huge decrease in agropastoral area in North Region is driven by a substantial rise in temperature in a region where plants are already near the upper bound of their tolerance (see Table 1). Also, in the North Region occurs a big reduction in precipitation (see Table 2). The increase of agropastoral areas in the semi-arid Northeast (27%) is a suspicious result probably due to estimation errors. Large increases in agropastoral areas are simulated for the Southeast (15%) and the South (32%), driven by the temperature increases. This made possible by a southward shift of the frost-belt which acts as a barrier to growing valuable crops like citrus and coffee and shortens the growing season for temporary crops. The small increase of agropastoral area in the Central-

West Region is explained by the increase of simulated temperature, the greater between the regions of Brazil.

LAND VALUE: When reviewed together, the land use and land value region-specific simulation results make sense for the North and South regions. The North Region will suffer the greatest reduction in land profitability (land value per hectare) in tandem with decrease in agropastoral areas (see Table 4). In contrast, simulation shows that land value per hectare in the South Region are likely to increase while agropastoral areas also increase. For the other regions, simulations are contradictory showing that land values per hectare will increase despite a greater use of land for agropastoral purposes. The only exception is the land value in the 2080´s in the Northeast Region. The results certainly require further analysis.

Table 1: Variation of Temperature Yearlong Average in (ºC)

Region	Base	A2 2050s	A2 2080s	B2 2050s	B2 2080s
North	26,4	2,2	4,0	1,8	2,8
Northeast	25,1	1,8	3,4	1,6	2,4
Southeast	21,3	2,1	3,8	1,7	2,6
South	19,3	2,2	3,7	2,0	2,6
Central-West	24,1	2,4	4,3	1,9	3,0
Brazil	**22,7**	**2,0**	3,7	**1,7**	**2,5**

Table 2: Percentage variation of Precipitation Yearlong Average in (mm/month)

Region	Base	A2 2050s	A2 2080s	B2 2050s	B2 2080s
North	189,0	-4,1	-6,7	-1,8	-4,5
Northeast	83,8	-2,0	-10,0	-0,4	-0,2
Southeast	114,9	-1,7	-5,0	0,2	0,6
South	131,5	1,7	5,3	0,5	3,3
Central-West	130,8	1,1	-0,6	4,3	0,7
Brazil	**110,4**	**-1,1**	**-4,2**	**0,3**	**0,5**

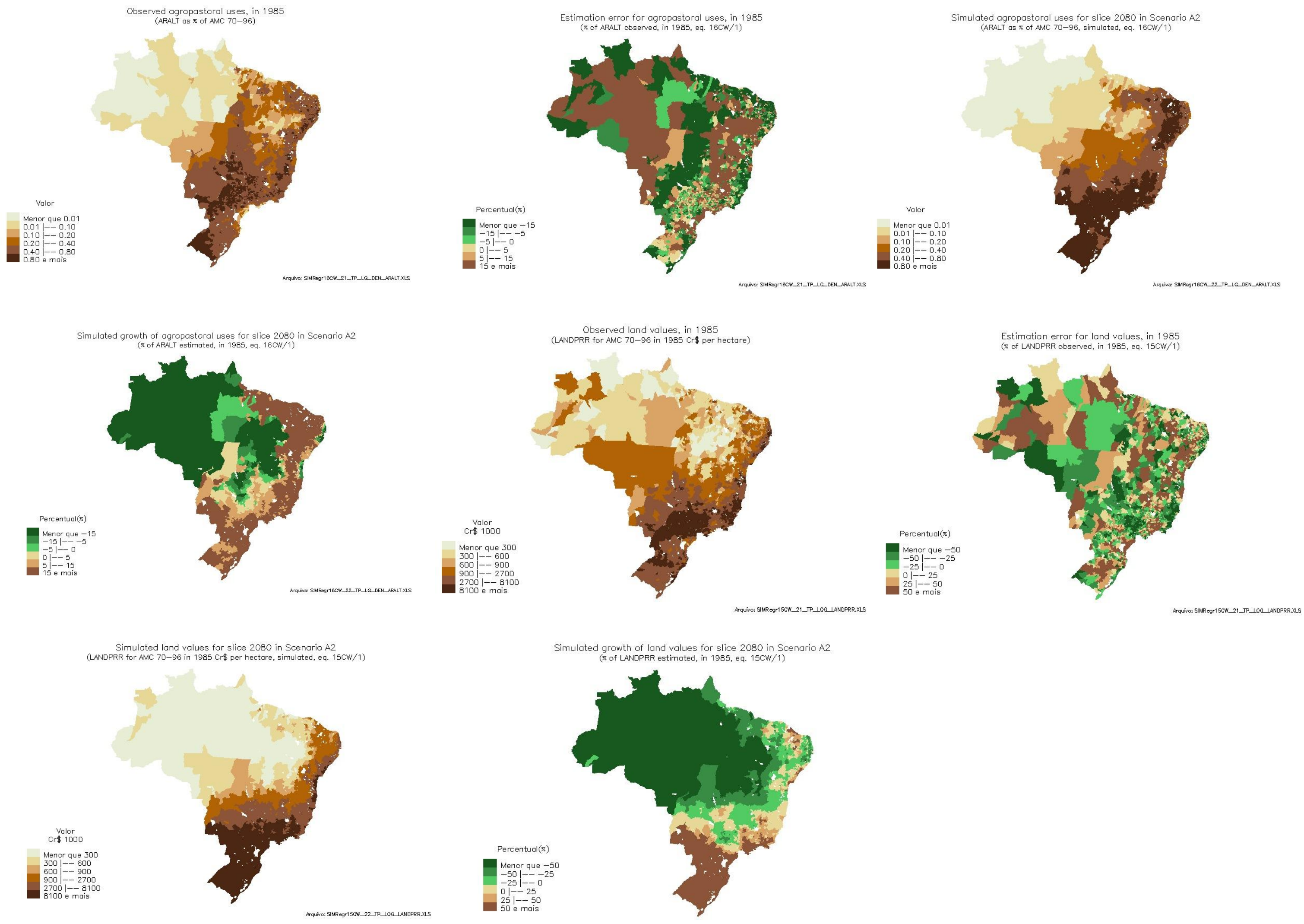
Table 3: Simulation of Percent Change in Converted Land per Hectare of MCA Land

Region	Model Error	A2 2050s	A2 2080s	B2 2050s	B2 2080s
North	-31,8	-13	-27	-21	-41
Northeast	16,2	11	27	1	9
Southeast	8,2	11	15	8	11
South	-0,9	24	32	18	19
Central-West	-5,6	12	2	9	-1
Brazil	0,3	12	14	6	5

Table 4: Simulation of Percent Change in Land Value per Hectare of MCA Land for the

Region	Model Erro	A2 2050s	A2 2080s	B2 2050s	B2 2080s
North	-21,3	-32	-63	-29	-53
Northeast	-1,8	6	-5	2	1
Southeast	-23,3	28	22	18	24
South	4,4	202	602	134	194
Central-West	-15,5	84	134	42	56
Brazil	**-12,4**	**90**	**221**	**57**	**79**

OBSERVED, ESTIMATED VALUES AND ERROR, AND PROJECTED CHANGE (%) IN LAND USE AND LAND VALUES FOR SCENARIOS A2 IN 2040-60 AND 2070-90



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