Poverty Dynamics, Ecological Endowments and Land Use among Smallholders in the Brazilian Amazon

Gilvan Guedes
ECI/Brown University
Gilvan_Guedes@brown.edu

Leah VanWey
PSTC/Brown University
Leah_Vanwey@brown.edu

Mariangela Antigo
CEDEPLAR/UFMG
maantigo@cedeplar.ufmg.br

Ana Flávia Machado
CEDEPLAR/UFMG
afmachad@cedeplar.ufmg.br

Eduardo Brondízio
ACT/Indiana University
ebrondiz@indiana.edu

NOTE: an earlier version of this paper was presented at the European Population Conference in Vienna in August 2010.

draft – comments welcome

Annual Meeting of the Population Association of America
Washington, DC, 2011

Introduction

Poverty is associated cross-sectionally and in many qualitative long-term studies with low levels of natural capital and with high rates of overuse of natural capital, caught in so-called "poverty traps." This leads to a view that the poor adopt low-technological and ecologically threatening land use practices (Chomitz, 2007; Reardon & Vosti, 1995). Alternatively, we might argue that natural capital exploitation can be associated with an investment in other forms of capital (e.g. human capital, financial capital or physical capital). In this paper, we assume that a transition out of poverty allows families to both meet immediate needs and increase long-term income and therefore focus on the ability of natural capital, land use, and other resources to move people out of poverty in the Brazilian Amazon.

In the Amazonian context, the image of the rural poor as overusing natural resources stems from the association made by some scholars between the expansion of settlers into the Amazonian region and the highly publicized environmental degradation and social unrest (Millikan, 1988; Schmink & Wood, 1984). Environmental and social scientists became concerned about the pace of deforestation and conversion of pristine forests into long-term unsustainable land use practices, such as slash-and-burn agriculture and pasture formation for extensive cattle ranching (Walker, Moran & Anselin, 2000). These environmental impacts pushed policy makers to propose myriad public interventions to curb deforestation, such as a reduction in road building investments and increases in protected areas (Fearnside, 2005).

In order to illustrate the links suggested by the dual relation between environment and rural well-being, we take advantage of a longitudinal dataset based on a representative sample of rural smallholders in the colonization area of Altamira, Pará State[1], Brazil. We examine the time spent in poverty for households with different endowments of natural capital and other resources on their properties using a Markovian approach to estimating the time in poverty from estimated transition probabilities, estimated in a simple cross-tabulation and then using a probit regression modeling approach. Results of these analyses show the importance of property accessibility (to the city) and show multiple pathways to less time in poverty, including perennials production and pasture production.

Rural Poverty & the Environment

Two general views on the interaction between poverty and the environment predominate in the literature. The first tends to blame environmental degradation on the poor, stressing the negative feedbacks between their livelihoods and the conservation of nature. Although considered a misconception (Brondizio et al., 2009; Lambin et al., 2001), poverty is seen as the socio-

[1] Until 2008, Pará State was the highest contributor to the aggregate annual deforestation rate in the Legal Brazilian Amazon. The state alone contributed 43.3% to the total of 11,968 km^2 deforested between 2007 and 2008 in the Brazilian Amazon (INPE, 2008).

economic driving force behind environmental degradation. The second view emphasizes that, to the contrary, historical processes have pushed the poor to inhabit "marginal" areas where degradation is predominant and a product of capitalist expansion (Fearnside, 2008).

Our recent experience in some Amazonian frontiers such as Santarém and Belterra (Pará State) and Machadinho do Oeste (Rondônia State) suggests that rural households now have to meet livelihood needs in the face of lack of formal title, low technology, and low initial levels of capital. Resources embodied in the land and the activities households can use on the land are the key for potential future upward economic mobility. As a consequence of adaptation to local restrictions and as a response to market demands, some land use practices among smallholders, such as cattle ranching and pasture formation, are important livelihood options for poverty alleviation in the Amazon, despite their environmental costs for the regional landscape (Guedes et al., 2009). This helps to explain why, differently from other tropical areas, poverty and deforestation have loose and non-linear connections across municipalities in the Brazilian Amazon (Fernandes et al., 2009; Fearnside, 2008). Yet expansion of pasture reduces other available resources (e.g., NTFP, game, water, timber) and possibly opportunities for alternative land allocation. Pasture and cattle ranching has also intersectoral economic externalities. As cattle ranching demand little labor, diversification strategies of smallholders who are dependent on provision of labor to other farmers may be negatively affected (Walker et al., 2000). As a consequence, overall welfare of labor suppliers may be diminished in the long run, creating a negative spiral of informal credit and income constraints (VanWey et al., 2009). Such potential contextual evolution or endogenous change indicates the need for longitudinal studies of natural capital and poverty change.

Study Area – The Altamira Settlement Project

Despite being the strongest economy in Latin America, poverty is still widespread in Brazil. According to the United Nations (UNDP, 2003), over 72% of the Brazilian population live with less than U$ 500.00 a month. This national pattern, however, differs at the regional level. High levels of poverty are encountered mostly in the Northeast and North. In 2007, for instance, the proportion of poor is estimated as 36% of the Northern population (13% of extremely poor), comparing to 23% in Brazil as a whole (8% of extremely poor) (IPEA, 2008a).

If we turn our attention to state level estimates of poverty, Pará was considered the poorest among the Legal Brazilian Amazonian states[2] in 1997, with 50% of its population classified as living below the poverty line[3]. In 2005, this ratio (headcount ratio, HC) dropped to 44.0%,

[2] Excluding Maranhão, which has only a part of its territory included.

[3] The poverty line estimated by IPEA (2008b) is based on the amount of money required to buy a basket of essential products in order to supply the needs for caloric intake. The poverty line is regionalized and estimated separately for rural, urban and metropolitan area. By 2001, for instance, the estimated poverty line in the metropolitan area of

representing a proportional reduction of 12% in 8 years. If the extreme poverty line is considered, the HC ratio dropped from 21.0% to 16.0% (a relative decrease of 24%). Over the same period, the percentage of poor individuals in Brazil dropped from 35 to 31% (a relative reduction of 11%), while the percentage of extremely poor dropped from 16 to 11% (a relative decline of 31%). In spite of this decline, poverty in Pará continues to be widespread (IPEA, 2008b).

In this context, we focus on a single settlement area within the state of Pará. Data used in our analyses derive from a longitudinal study conducted in the Altamira settlement area, located in the state of Pará, Brazil. This area was initially settled during the 1970s when the TransAmazon highway was constructed through the city and on to the west, with settlers arriving from across Brazil to plots of land, most of which had 100% primary forest (Brondízio et al., 2002). Altamira was a model settlement area during the early years, with the government providing assistance to settlers in traveling to the settlement area and in clearing land and starting to produce. Settlers, however, were not well-screened in all cases for past agricultural experience, and the government support lasted only a few years. For these reasons, early years were characterized by many farm failures, high malaria rates, and high rates of outmigration. The area settled into a more stable pattern by the 1990s, with new areas still being opened, but more stable patterns of production and settlement.

Biophysically, the region is characterized by rolling (but steep) topography, and primarily oxisols (adequate but not ideal soils), with small patches of high quality soil (*terra roxa*) or flat topography. The topography, combined with the rapid rainfall in the rainy season and the practice of building bridges of wood, lead to precarious transport systems. These are aggravated by variable levels of government maintenance of infrastructure.

Given this setting, the most common productive land uses are annual food crops (manioc, beans, rice), pasture and perennial cash crops (overwhelmingly cocoa, with occasional black pepper or coffee). Cattle raised on these pastures are destined for local and regional markets, as the North of Pará (and all of Pará at the time of the surveys) still has uncontrolled endemic foot-and-mouth disease. The cocoa, in contrast, is destined for international markets (usually via domestic markets) and has reached the highest productivity per hectare in the country, although local production still represents a small share of the national total (CEPLAC, 2009). Cocoa production is mainly found among lots with patches of *terra roxa*, as cocoa demands high quality soil to grow (in comparison with coffee and black pepper, that grow in lower quality soils). While cocoa is mainly clustered around Medicilândia (see Map 1), where the bulk of *terra roxa* is found, pasture is widespread in the study area. However, larger and more successful cattle owners are clustered close to the Altamira urban area (on the very east of our study area) while

---

Belém (Pará state capital) was R$115,92 (U$47.70), while R$119,86 (U$49.32) for the urban area and R$104,88 (U$43.16) for the rural area.

small ranches (usually combining cattle and annual production) are clustered on the other end (west) or our study area, representing the most impoverished families (Guedes, 2010).

In general, farmers use very basic technology, reflecting both the inability to use much machinery on the steep slopes and the low cost of labor. Labor is readily available for hire at low cost, including permanent laborers, temporary laborers (hired by the day), and sharecroppers (most common for cocoa production). Deforestation radiates out from the main road (TransAmazon) to the feeder roads (*travessões*), and moves from the initial opening of the settlement in the east towards the west. Properties on the very west of our study area (towards Uruará) and in the back of the feeder roads have the highest proportion of their area in primary forest. Between 1997/98 and 2005, the average proportion of the property in primary forest declined from 45.3% to 31.3%.

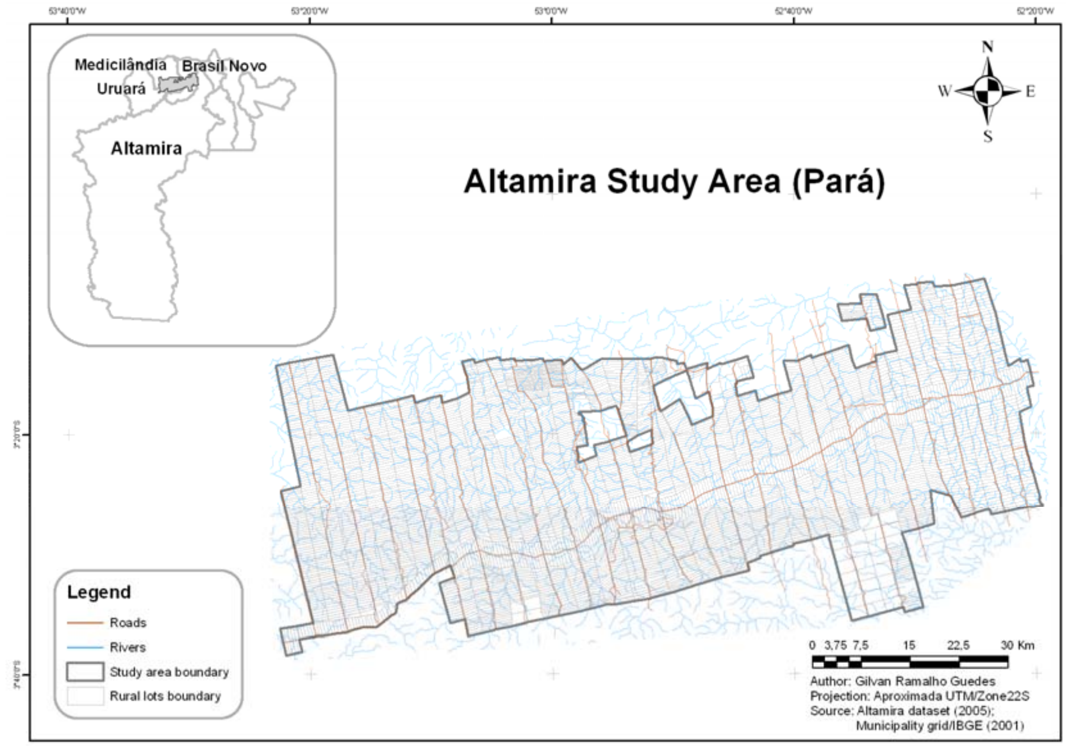
Sample and Measures

Analytical sample

This study takes advantage of a representative panel (1997/1998 and 2005) of rural properties containing information on socioeconomic characteristics of the households, biophysical endowment and land use/cover classes at the household and property level for rural smallholders along the Transamazon Highway, including the municipalities of Altamira, Brasil Novo, and Medicilândia, Pará State (see Map 1).

The initial sample of properties and households in 1997/98 included 402 observations, but we limit to a smaller sample that includes those households who remained owners of the same property and had valid data in both waves. Thus, our final analytical longitudinal sample totals 275 households.

Map 1: Altamira Study Area



Defining poor and non-poor

We focus in this paper on income poverty based on per capita household income. We create the household income variable by summing different sources of income reported in the questionnaires: off-farm income for each member of the household roster, income derived from rural retirement (rural social security system) for all eligible members of the household, and agricultural income.[4] Retirement income was computed rather than reported. It is a federal benefit that is pegged to the minimum salary, and we computed the household value by multiplying the number of people receiving the benefit in the household by the typical value of the benefit in the year of the interview (R$125.00[5] in 1997/98, and R$ 300.00 in 2005).

The estimation of agricultural income was a little more complex. We started from a table with detailed information per crop/animal by-products on the amount produced, destination of production (self-consumption or selling), amount sold, price per unit sold, and part shared with

---

[4] Although we collected information on cash transfers programs (such as Bolsa Familia, Benefício de Prestação Continuada, Vale-Gás, etc.) for the 2005 wave, the information was not available for the 1997/98 wave, so we excluded this income source from our analyses in order to preserve comparability over time.

[5] We averaged the minimum salary in 1997 (R$120.00) and 1998 (R$130.00) over the two years period.

sharecroppers in the year previous to the interview. We started by creating a kilo-equivalent measure of production per crop and, then, creating a total kilo-equivalent production. We then subtracted the amount not sold and the amount belonged to sharecroppers from the kilo-equivalent production and multiplied by the price per unit (we also created an equivalent measure of price per kilo).[6] As suggested by Barbieri & Bilsborrow (2009), production for self-consumption represents an alternative income for a considerable portion of rural households and must be considered when computing rural household income. Otherwise, final income will be dramatically underestimated. In reality, some families depend almost entirely on the non-monetary income. In order to evaluate the importance of production for self-consumption on poverty in our study area, we perform a counterfactual analysis. We ask what would be the poverty level and the income inequality should the production for self-consumption be totally sold and converted into money? In order to answer this question, we use the following strategy. First, we have taken the prices for which the crops were sold and applied these prices to the same crops and animals used/raised for self-consumption. In doing so, we make two main assumptions: a) perfect market absorption of all production not oriented to the market, and b) no scale-effect of additional supply on market prices. Our preliminary results (not shown) suggest that poverty is dramatically reduced (58%) when incorporating the production for self-consumption as a type of rural household income. As a result, we decided to monetize the production for self-consumption and add it to the total agricultural household income in both waves of data. The agricultural income was thus obtained by summing up the income derived from the selling of each crop/animal by-products and the monetized production for self-consumption of each crop/animal by-products for the same household unit.

We measured the total household income by adding the different sources of income, collapsed at the household level: off-farm income, retirement income, and agricultural income. We, then, converted the yearly-based to monthly-based household income and divided it to the number of household members to obtain the monthly *per capita* household income. To define the poverty threshold we used 60% of the median along the *per capita* household income cumulated distribution. Descriptive statistics on this variable are presented in Table 1, with an alternative absolute poverty measure and values for the state of Pará for comparison. The poverty rate in our study area reduced dramatically using this alternative measure of poverty as less than half of the minimum salary. If we consider the relative income distribution, however, reduction in poverty was modest: 3% over 8 years.

[6] A number of households had missing data for various parts of agricultural production and income, suggesting we might want to impute this income. However, preliminary work done by the authors with income as a dependent variable in regression models (not shown) suggested the use of data with non-imputation was actually more consistent. In this paper we use the agricultural income with no imputation only.

Table 1. Poverty in Altamira Study Area - 1997/1998 and 2005 (Estimates for Pará State for comparison)

FGT measure of relative poverty	Smallholders (Altamira)		Pará State (2005)	
	1997/98	2005	Urban	Rural
	Relative poverty line (60% median)			
Headcount ratio %	36.4	33.1	34.7	25.0
	Absolute poverty line (1/2 minimum salary)			
Headcount ratio %	53.1	16.4	38.6	59.4

Source: Altamira Study Area dataset (1997/1998, 2005); Brazilian National Household Survey - PNAD (1997, 2005).

Methodology

In this paper, we estimate the time spent in poverty by households with a variety of characteristics, focusing on the importance of natural capital and land use in how much time the household spends in poverty. We do this by applying a transitional matrix approach based on Markovian processes to estimate these durations spent in poverty and non-poverty using observed probabilities of transitioning from poverty to non-poverty or vice versa. We explore the importance of key independent variables and the relationships between them by calculating these observed transition probabilities in two ways. We first calculate raw transition probabilities for selected groups, and we second calculate probit-regression-based predicted probabilities controlling for other characteristics of households. We then perform simulations of the time spent in poverty for groups with different initial characteristics under their own and others' transitional probabilities to show the importance of selected ecological and land use variables for poverty structure among smallholders.

Matrices of transitional probabilities

In order to analyze the dynamics of transitions between poor and non-poor we apply a methodological framework proposed in Clark & Summers (1990). According to the authors, we can assume that individual behavior is described by a matrix of transitional probabilities, p^i given by:

$$p^i = \begin{bmatrix} p^i_{nn}\, p^i_{np} \\ p^i_{pn}\, p^i_{pp} \end{bmatrix} \qquad (1)$$

where p^i_{jk} represents the probability of individual *i* be in state *k* in period *t+1*, conditioned on having been on state *j* in period *t*.

Departing from the matrix of transitional probabilities p^i, we can estimate the proportion of time spent in each state for each individual *i*. Taking π_j^i as the proportion of the time individual *i* spent in state *j*, we have:

$$\pi_j^i = \begin{bmatrix} \pi_n^i \\ \pi_p^i \end{bmatrix} \tag{2}$$

Given that π_j^i is non-observable, we assume that transitions between the two states (poor and non-poor) are a Markovian process, in which the future development of the process depends solely on the state where individual is, independent of her trajectory up to that state. Therefore, the use of Markovian transitional matrices involves the assumption that decisions to move from one state to another do not depend on the time spent in each state.

The Basic Theorem of Markovian Chains postulates that any system defined by such a matrix will reach a steady state that is independent on initial conditions. Furthermore, the steady state portion of the time in each state must be solved as a function of the entire transitional matrix.

The relation between π_t^i and π_{t-1}^i can be written in matrix format as:

$$\pi_t^i = p_\cdot^i \pi_{t-1}^i \tag{3}$$

In steady state, $\pi_t^i = \pi_{t-1}^i$. Thus, $\pi_t^i = p_\cdot^i \pi_t^i$.

Assuming the steady state assumption holds and that transitional probabilities between the two states do not depend on time spent on each state, it follows that:

$$p_\cdot^i \pi_t^i = \pi_t^i \Rightarrow \begin{bmatrix} p_{nn}^i & p_{pn}^i \\ p_{np}^i & p_{pp}^i \end{bmatrix} \begin{bmatrix} \pi_n^i \\ \pi_p^i \end{bmatrix} = \begin{bmatrix} \pi_n^i \\ \pi_p^i \end{bmatrix} \tag{4}$$

$$\Rightarrow p_{nn}^i \pi_n^i + p_{pn}^i \pi_p^i = \pi_n^i$$
$$\Rightarrow p_{np}^i \pi_n^i + p_{pp}^i \pi_p^i = \pi_p^i \tag{5}$$

Any equation of the above linear system is linearly dependent on the others. However, because $\pi_n^i + \pi_p^i = 1$, we solve the system.

The distribution of population (N) under each steady state condition can be found by averaging individual probabilities, that is, $\Pi_j = \frac{1}{N}\sum_{i=1}^{N} \Pi_j^i$.

Simulations

In order to evaluate the likely impact of changes in some of relevant environmental and biophysical dimensions on smallholders' well-being, we then simulate the impacts of changing the level of natural capital through the use of two hypotheticals for each dimension of natural capital. For intuition, imagine two 2X2 transition matrices, one for those with low levels of capital and one for those with high levels of capital. We thus calculate (or estimate using a regression-based approach) the probabilities of transition from poor to poor, poor to non-poor, non-poor to poor, and non-poor to non-poor separately for low capital and for high capital. We then calculate our hypotheticals as follows:

1) If the poor at lower levels (*LL*) of a selected dimension take on the transitional probabilities of the non-poor in higher levels (*HL*) of that dimension, what happens to the proportion of time spent on each state (poor and non-poor) between 1997/98 and 2005?

$$ {}^{S}\pi_n^i = {}^{LL}p_{nn}^i \pi_n^i + {}^{HL}p_{nn}^i \pi_p^i $$
$$ {}^{S}\pi_p^i = {}^{LL}p_{np}^i \pi_n^i + {}^{HL}p_{np}^i \pi_p^i $$

2) If the poor at lower levels (*LL*) of a selected dimension take on the transitional probabilities of the poor in higher levels (*HL*) of that dimension, what happens to the proportion of time spent on each state (poor and non-poor) between 1997/98 and 2005?

$$ {}^{S}\pi_n^i = {}^{LL}p_{nn}^i \pi_n^i + {}^{HL}p_{pn}^i \pi_p^i $$
$$ {}^{S}\pi_p^i = {}^{LL}p_{np}^i \pi_n^i + {}^{HL}p_{pp}^i \pi_p^i $$

The use of both simulated scenarios allows us to test the influence of changing the initial characteristics and of the level of the selected dimension of capital on time spent in states.

We selected three blocks of dimensions for empirical analysis. Results are presented in the next section.

1) Biophysical capital

    a. If the property is accessible during the rainy season (0 – no / 1 – yes)

    b. Proportion of the property in *terra roxa* (alfisols) (1^{st} + 2^{nd} + 3^{rd} quintiles = low level; 4^{th} + 5^{th} quintiles = high level)

2) Land use classes

    a. Proportion of the property in pasture (1^{st} + 2^{nd} + 3^{rd} quintiles = low level; 4^{th} + 5^{th} quintiles = high level)

b. Proportion of the property in perennials (1^{st} + 2^{nd} + 3^{rd} quintiles = low level; 4^{th} + 5^{th} quintiles = high level)

c. Proportion of the property in annuals (1^{st} + 2^{nd} + 3^{rd} quintiles = low level; 4^{th} + 5^{th} quintiles = high level)

3) Natural capital

a. Proportion of the property in primary forest (1^{st} + 2^{nd} + 3^{rd} quintiles = low level; 4^{th} + 5^{th} quintiles = high level)

b. If the property has on site access to water (0 – no / 1 - yes)

Results

Table 2 shows the baseline transition probabilities for the entire sample. According to Table 2, 72.57% of the non-poor in 1997/98 remained as non-poor in 2005. However, among the poor in 1997/98, 57% left poverty by 2005. This is a remarkable change in the well-being distribution among smallholders, higher than in other Amazonian frontiers (Barbieri & Bilsborrow, 2009). This result may be reflective of a combination of events, discussed by Guedes (2010): a) reduction in household size, due to life cycle stage – a type of local demographic dividend; b) out-migration of children; c) reduction in fertility, and d) market smitulae, specially the increase in demand for cocoa, reflecting higher commodity prices. Also, the aging of the fontrier allows the household to enter into "retirement years", creating an income shock of 1 to 2 minimum salaries per eligible household.

Table 2. Transitional probabilities on poverty - Altamira Study Area (1997/98 and 2005)

	Non-poor	Poor	Total
Non-poor	72.6	27.4	100.0
Poor	57.0	43.0	100.0
Obs (1997/98)	175	100	275
Obs (2005)	184	91	275

Source: Altamira Study Area dataset (1997/98, 2005)

Using these transition probabilities, we estimate that smallholders in our study area spent 67.5% of the time-window (1997/98 and 2005) as non-poor and 32.5% as poor. This result reflects the high probability of moving out of poverty between waves of data in our study area (Table 2). When we disaggregate by type of biophysical constraints, we see a very different picture. Table 3 presents the results for the two selected biophysical characteristics of the lot: a) accessibility to the property during the rainy season, and b) proportion of the property in *terra roxa*. While households with no accessibility during the rainy season spent, on average, 55.7% of their time in poverty, households with good access throughout the year spent only 27.9% of their time as poor. If we consider the proportion of *terra roxa* on the property, households with low proportion of the high quality soil spent 44.2% of their time as poor, compared to only 15.9% among the households with a large proportion of the property in *terra roxa*.

Turning to our simulation results, we see that if we apply the transitional probabilities associated with good accessibility (for the poor and for the non-poor) to the poor with no accessibility to the property in the rainy season, we see an accessibility effect. the proportion of time spent in non-poverty state (among the original poor with no access) change from 44% to 64% - an increase of approximately 20%. We see little difference between the initially poor when with give them non-poor, high accessibility transition probabilities and when we give them poor, high-accessibility transition probabilities. This shows that the effect of accessibility on poverty reduction is independent of initial condition, that the accessibility did not act primarily through its effect on 1997/98 status. It continues to have an effect through the study window.

Table 3. Markovian matrix with the proportion of time lived in poverty and non-poverty according to simulated change in levels of biophysical characteristics of the property - Altamira Study Area, 1997/98 and 2005

	Non-poor	Poor	Δ (Simulated - Observed)
Full sample	67.5	32.5	
Accessibility to the property during the rainy season			
Observed			
No access	44.3	55.7	
With access	72.1	27.9	
Simulated (probabilities of the "with access" group)			
Non-poor	67.6	32.4	23.3
Poor	64.3	35.7	19.9
Proportion of the property in "terra roxa"			
Observed			
Low %	55.8	44.2	
High %	84.1	15.9	
Simulated (probabilities of the "high %" group)			
Noon-poor	70.4	29.6	14.7
Poor	68.3	31.7	12.5

Source: Altamira Study Area dataset (1997/98, 2005)

Performing the same type of simulation for natural capital in the form of soil, we see the same pattern. If poor households with a small portion of alfisols were giving the same poverty-nonpoverty transition probabilities as the households with high proportion of the property with *terra roxa*, the time spent as non-poor increases from 55.8% to approximately 68%. This represents an average increase in the time spent as non-poor of about 13%. Again, the difference is small between those with the same initial conditions but low soil quality transition probabilities and those with high soil quality transition probabilities. Soil quality has a continuing effect in the observational window and less effect as a factor in selection into poverty or non-poverty at the first observation.

Table 4

Markovian matrices with the proportion of time lived in poverty and non-poverty according to simulated change in levels of land use classes on the property - Altamira Study Area, 1997/98 and 2005

Full sample	Non-poor	Poor	Δ (Simulated - Observed)
Poor	67.5	32.5	
Proportion of the property in perennials			
Observed			
Low %	62.6	37.4	
High %	74.9	25.1	
Simulated (probabilities of the "high %" group)			
Non-poor	68.8	31.2	6.1
Poor	63.5	36.5	0.9
Proportion of the property in pasture			
Observed			
Low %	54.8	45.2	
High %	80.8	19.2	
Simulated (probabilities of the "high %" group)			
Noon-poor	69.1	30.9	14.3
Poor	69.8	30.2	15.0
Proportion of the property in annuals			
Observed			
Low %	70.2	29.8	
High %	62.8	37.2	
Simulated (probabilities of the "high %" group)			
Non-poor	66.0	34.0	-4.2
Poor	58.9	41.1	-11.3

Source: Altamira Study Area dataset (1997/98, 2005)

Table 4 shows the same analyses of the impact of selected land use classes on time spent in each state (poverty and non-poverty). Results suggest that the baseline difference between those with high and low levels of pasture is larger than the baseline difference between those with low and high levels of perennials, but that only the pasture area has a continued impact through the time window under study. Transition probabilities of the poor and non-poor, among only those with high levels of perennials, produce persistent differences in time spent in poverty, suggesting that perennials in 1997/98 are not producing a continuing return over the observation window. The different impacts on time spent in poverty and non-poverty when simulating the level of perennials on the property suggest that being poor affects the probability of also having a lower proportion of perennials on the property. In contrast, the differences between the poor and non-poor are virtually eliminated among those with the high levels of pasture on their property, suggesting both that pasture area is exogenous to initial conditions and that pasture continues to have a strong effect through the study period. This result is consistent with previous work suggesting the importance of cattle for livelihood strategies among rural households of Amazonian frontiers (VanWey et al., 2007; Walker et al., 2000). Finally, results suggest that households with a higher proportion of annuals have lower level of well-being and tend to spent a higher proportion of their time in poverty. This result is expected for our study area as the production of annuals is basically oriented to self-consumption and properties with higher proportion of the area in annuals indicate low levels of integration into markets. As with perennials, simulations with annuals suggest a positive correlation between being poor and having a higher initial proportion of annuals.

Table 5

Markovian matrices with the proportion of time lived in poverty and non-poverty according to simulated change in levels of natural capital of the property - Altamira Study Area, 1997/98 and 2005

Full sample	Non-poor	Poor	Δ (Simulated - Observed)
Poor	67.5	32.5	
Proportion of the property with primary forest			
Observed			
Low %	78.1	21.9	
High %	48.9	51.1	
Simulated (probabilities of the "high %" group)			
Non-poor	62.0	38.0	-16.1
Poor	52.4	47.6	-25.6
Does the property have on site access to water?			
Observed			
No	61.2	38.8	
Yes	70.6	29.4	
Simulated (probabilities of “with access” group)			
Noon-poor	66.2	33.8	5.0
Poor	66.6	33.4	5.4

Source: Altamira Study Area dataset (1997/98, 2005)

Table 5 summarizes the results for indicators of natural capital. It shows that, contrary to a simple assumption that more forest (natural capital) is associated with less poverty, those with high proportions of their property in forest spend considerably more of their time in poverty. The simulated results show that there is a strong association between forest and initial poverty as well as a persistent effect of poverty. We see that time spent in poverty is higher when all households are assigned high levels of forest cover, but that the time spent in poverty is still higher for those who start in poverty. In contrast, access to water appears to act exogenously, with high levels of access to water associated with less time out of poverty independent of whether you start in poverty or not.

Regression-Based Results

Simulations using non-parametric Markovian processes are an illustrative way to describe the influence of selected characteristics on time spent in poverty between two points in time, and are suggestive of what factors act exogenously and what are endogenous to intial poverty status. However, they do not control for other characteristics that might create a spurious observed relation in the simulated results. In this section we briefly present predicted probabilities of transition in and out of poverty (and immobility in or out of poverty) for the same selected dimensions previously used in the Markovian simulations, modeling the change in poverty status by means of an ordered probit model[7]. Our dependent variable corresponds to the following statuses from first wave (1997/1998) to the second (2005): poor in both waves (Poor → Poor), transition to poverty (Non-poor → Poor), transition away from poverty (Poor → Non-poor), non-poor in both waves (Non-poor → Non-poor).

In Figures 1-3 we show a standard approach to presenting probit results through showing the impact of our key independent variables on the probability of being in each of the four outcome categories. As already suggested by the Markovian simulation, lower levels of some forms of capital increase the probability of remaining in poverty or transiting into poverty over the period. After introducing the covariates the accessibility of the property, measured here by the distance to the city was statistically significantly related to probability of transitions between poverty states, while percent of property in *terra roxa* was marginally significant (p-value=0.081). Figure 1 shows that the probability of moving out of poverty is non-linearly related to the distance to the main urban center of our study area. This may reflect a spatial association between distance to Altamira and land use systems based on perennial production. The bulk of cocoa production is concentrated around the municipality of Medicilândia, approximately in the center of the study

---

[7] We started by estimating a multinomial logistic model and, then, tested for the independence of irrelevant alternatives using the Hausman test. The test suggests that the exclusion of one of the categories affect the estimated coefficients in all remaining equations. Thus, we moved to a generalized ordered probit model and allowed the model to find the variables for which the assumption of parallel regressions was violated. Using a significance level of 0.05 none of the state variables in the model (biophysical capital, natural capital and land use classes) violated the assumption. So, for the sake of simplicity, we opted for the basic orded probit model, as shown in Table A (annex).

area. Increase in the price of cocoa during the survey years may explain the inverted U-shape relation between transition out of poverty and distance to Altamira. Figure 1 also shows that increasing levels of terra roxa are associated with being out of poverty in both years, but not with other categories of state transitions.

Figure 1: Predicted Probabilities of Transition on Poverty by Level of *Biophysical Capital*

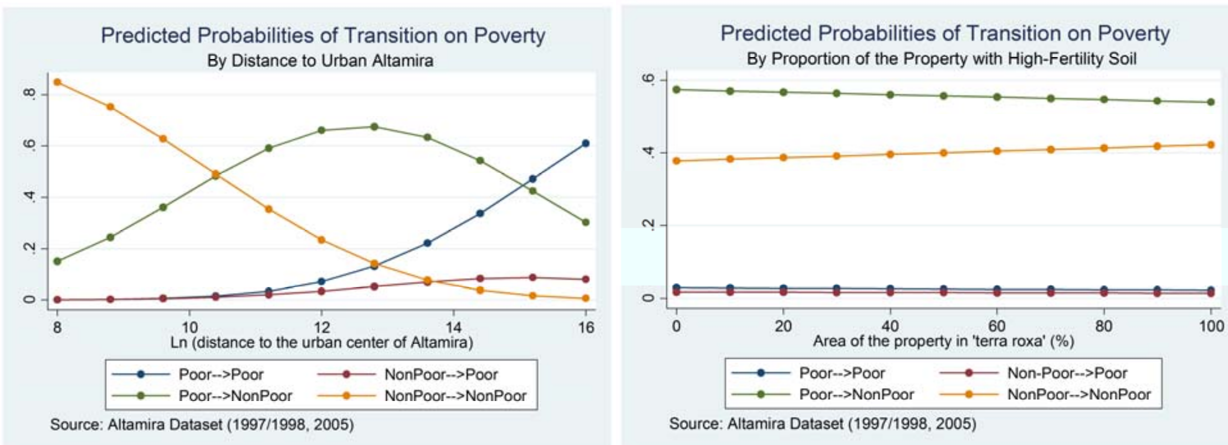


Figure 2: Predicted Probabilities of Transition on Poverty by Level of *Land Use Classes*

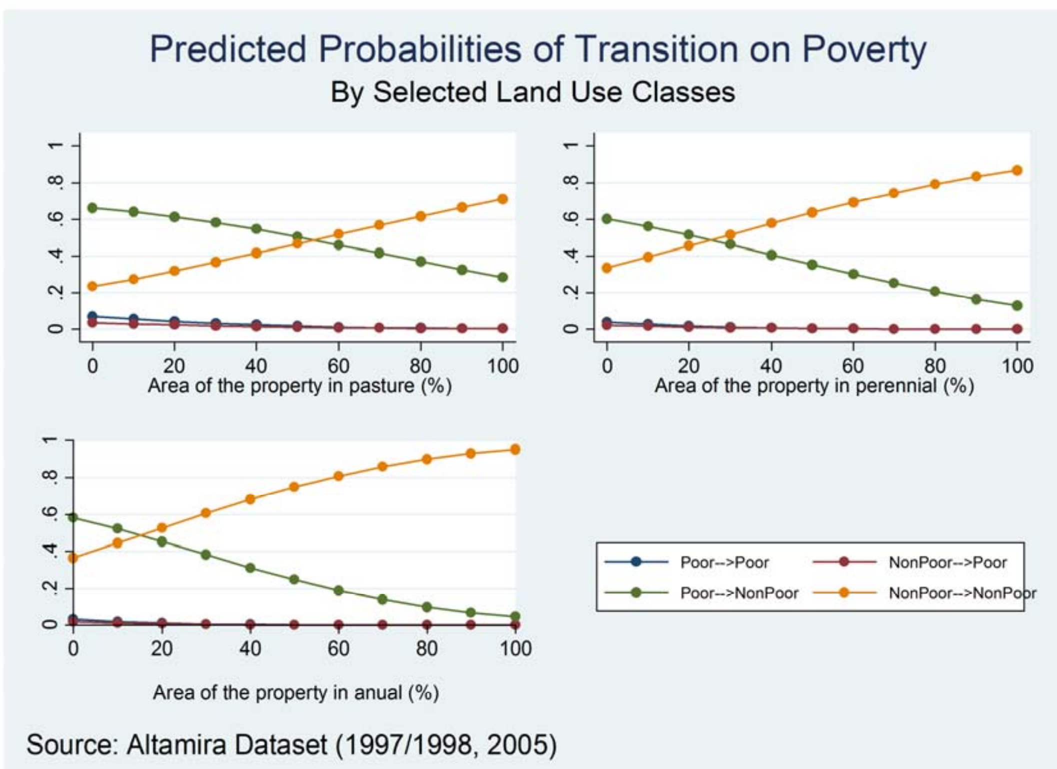
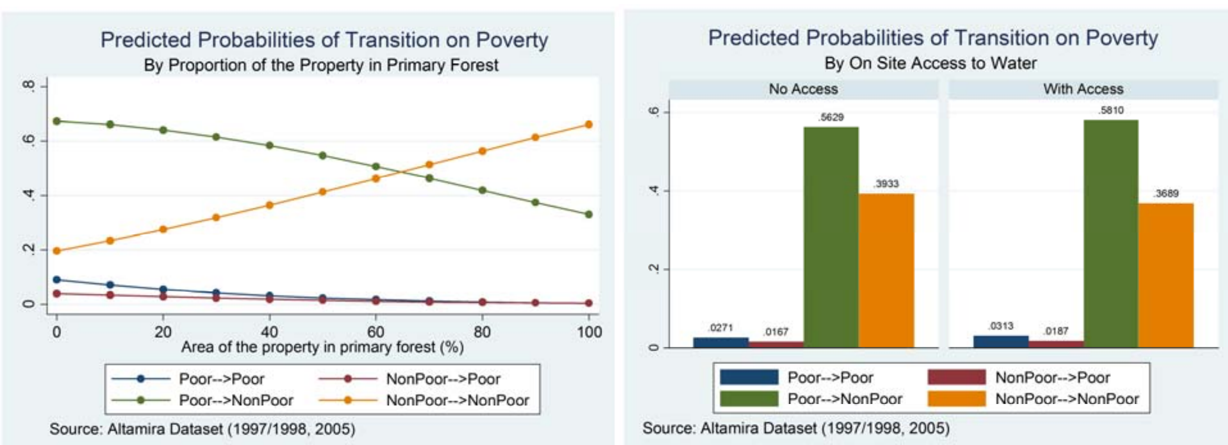


Figure 2 shows the predicted probabilities of transition on poverty for the three main land use classes in our study area. Only pasture and perennials, however, are statistically significantly related to poverty transitions after introducing the control variables in the model. In general, higher proportion of the property in pasture increases the probability of remaining out of poverty. The effect of perennials is even higher. While the probability of remaining out of poverty is lower than leaving poverty among households with low levels of both pasture and perennials, the amount of perennials necessary to have a higher probability of being out of poverty than leaving poverty is only 31% compared to 57% for pasture (Figure 2). This suggests that increases in perennials have a larger impact on spending more time out of poverty than do pasture (as also shown later, in Figure 4).

Finally, results from Figure 3 contradict those found in the Markovian simulation. While the simulation suggested that time spent in poverty was higher among households with higher proportion of the property in forest (Table 5), the regression results predict the opposite. Primary forest is actually associated with a higher probability of staying out of poverty, consistent with the suggestive result in the Markovian simulation that much of the effect of forest was due to the association of initial forest cover with initial poverty level (and presumably with other variables controlled in the regression model). Households with smaller areas in forest have a higher probability of leaving poverty while households with larger shares of the area in forest have a higher chance of being out of poverty for the whole period. On site access to water has no statistical effect on transition on poverty during the period under analysis, with the covariates explaining away the impact previously seen in the Markovian simulation (Figure 3 – right panel).

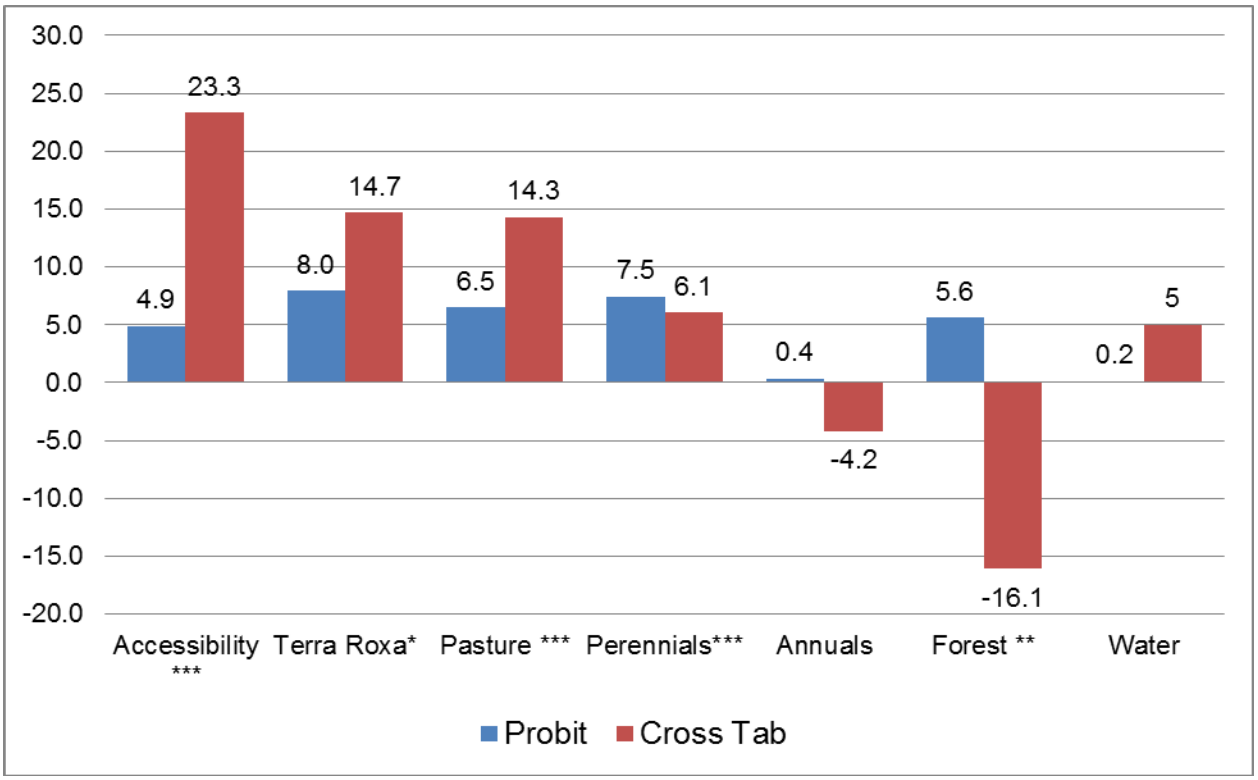
Figure 3: Predicted Probabilities of Transition on Poverty by Level of *Natural Capital*



Comparing Simulated Time Spent in Poverty

In order to access the final impact of the environmental dimensons on the time spent as poor and non-poor between 1997/1998 and 2005, we re-estimated the Markovian matrices replacing the cross-tabulated values used in the first part of the paper with the predicted transitional probabilities using the ordered probit model (Table A). The results reveal a somewhat different scenario. While in the cross tabulation version of the Markovian simulation accessibility ranked as the most important dimension to increase time spent as non-poor, the regression-based simulation show that it ranks fourth among the significant factors, lagging behind proportion of the property in perennial, pasture and forest. In addition, the impact of the forest on time allocation is reversed. This result is actually not surprising, as the simulations refer to recent change in poverty status; poor smallholders would benefit more from higher areas in forest as it facilitates access to cash and provides soils with higher levels of nutrient. This is especially true among the poor, who cannot afford the use of fertilizers to correct gradual loss in soil productivity and must rely on virgin soils.

Figure 4: Impact of Environmental Dimensions on Time Out of Poverty between 1997/98 and 2005, Results from Cross-tabulation and Regression Predictions – Altamira, 1997/1998 and 2005



Source: Altamira Dataset (1997/1998, 2005)
*** p<0.01, ** p<0.05, * p<0.1

Concluding Remarks

This paper uses longitudinal dataset on rural farmers – a rare dataset structure for agrarian frontiers in developing countries – in order to investigate the impact of selected environmental and biophysical dimensions on poverty dynamics among rural smallholders.

Our results show an increase in monetary well-being over time, with emphasis on poverty reduction followed by decline in inequality among the poor. We focus here on the role of biophysical characteristics, land use, and natural capital for understanding who is spending less time in poverty. Biophysically, acessibility to the property during the rainy season is an important element in reducing time spent in poverty among rural smallholders in our study area. The impact of accessibility on poverty reduction is complemented by the highly significant effect of distance to the main local urban market on staying out of poverty throughout the period. Although availability of high quality soil on the property seems also important for a successful trajectory over time (Moran et al., 2002), accessibility is particularly important because it can be directly manipulated by public intervention (improvement in roads, bridges, etc.), fostering improvement in financial well-being among smallholders in the area by reducing transportation costs. On the other hand, there is evidence of the negative impact of road building for the landscape, with increase in deforestation rates and consequent loss of local biodiversity (Pfaff et al., 2009). Echoing other studies, we suggest that improvement in the existing roads may be a viable alternative for road building, with a positive impact on poverty alleviation without the negative environmental impact of new road building.

As our results also suggest, pasture (and indirectly cattle) is a key land use type to reduce the time spent as poor, although poor households with low levels of perennials spent less time in poverty than poor households with low levels of pasture. This is due to the higher profitability of perennial crops in the area (as cocoa price has increased dramatically in the last years – Mendes, 2007), but also a wider livelihood strategy, since perennials have higher rates of return in the long run (VanWey et al., 2009). Our results seem to be robust to the inclusion of other dimensions of rural livelihoods. In this paper we focus on environmental dimensions only, and concentrate the analysis on the recent change in poverty status among rural smallholders. The simulation results are also dependent on Markovian assumptions that the well-being trajectory before 1997/1998, as well as the time structure of poverty are both steady over time. As we use a settlement area as a research site, and colonists were mainly poor by the time of arrival in the Altamira frontier (Smith, 1982), we can argue that differentiation in well-being trajetories among the households at the time of the first interview is a relatively recent phenomenon. However, we cannot test how much differentiation has occurred by the time of our first survey.

References

Antigo, M.; Machado, A. F. 2006. Transições e duração do desemprego: uma revisão da literatura com novas evidências para Belo Horizonte. **Nova Economia**, 16: 375-406.

Baker, M.; Miceli, T. 2005. Land inheritance rules: theory and cross-cultural analysis. **Journal of Economic Behavior and Organization,** 56: 77-102.

Barbieri, A. F.; Bilsborrow, R. E. 2009. Dinâmica populacional, uso da terra e geração de renda: uma análise longitudinal para domicílios rurais na Amazônia equatoriana. **Nova Economia**, 19(1):67-94.

Barbieri, A. F.; Bilsborrow, R. E.; Pan, W. K. 2005. Farm household lifecycles and land use in the Ecuadorian Amazon. **Population and Environment**, 27(1): 1-27.

Bebbington, A. 1999. Capitals and Capabilities: A Framework for Analyzing Peasant Viability, Rural Livelihoods and Poverty. **World Development**, 27: 2021-2044.

Brockington, D. 2002. **Fortress conservation: the preservation of the Mkomazi Game Reserve, Tanzania**. Bloomington: Indiana University Press.

Brondizio, E. S., A. Cak, M. Caldas, C. Mena; R. Bilsborrow, C. T. Futemma, E. F. Moran, M. Batistella, and T. Ludewigs. 2009. Small Farmers and Deforestation in Amazônia. In: M. Keller, M. Bustamante, J. Gash, and P. Silva Dias (eds.) **Amazônia and Global Change: A Synthesis of LBA Research**. World Scientific Publishing (American Geophysical Union).

Brondízio, E. S. *et al*. 2002. The colonist footprint: towards a conceptual framework of land use and deforestation trajectories among small farmers in the amazonian frontier. In: Wood, C. H.; Porro, R. (Ed.). **Deforestation and land use in the Amazon**. Gainesville, FL: University Press of Florida. Cap. 5, p. 133-161.

Browder, J. O.; Pedlowski, M. A.; Summers, P. M. 2004. Land use patterns in the Brazilian Amazon: comparative farm-level evidence from Rondônia. **Human Ecology**, 32(2): 197-224.

Caldas, M. M. *et al.* 2007. Theorizing land cover and land use change: the peasant economy of amazonian deforestation. **Annals of the Association of American Geographers**, Washington, 97(1): 86–110.

Castro, M. C. 2009. Soil quality, agriculture settlement and deforestation in the Brazilian Amazon. **Proceedings** of the XXVII IUSSP INTERNATIONAL POPULATION CONFERENCE, 26, Marrakesh, 2009.

CEPLAC (Comissão Executiva do Plano da Lavoura Cacaueira). 2009. **Informe de pesquisa 1997 - 2003**. Belém: 2009. 278 p. Available at:

<http://www.ceplacpa.gov.br/site/wpcontent/uploads/2009/09/Informe%20Pesquisa%201997%20-%202003.pdf>.

Chomitz, K. M. 2007. **At loggerheads?: agricultural expansion, poverty reduction, and environment in the tropical forests**. World Bank, Washington, D.C., USA. [online] URL: http://go.worldbank.org/155PA8IUZ0.

Davis, K. 1963. The theory of change and response in modern demographic history. **Population Index**, 29(4): 345-366.

Diniz, M. B., R. B. S. Nascimento, M. J. T. Diniz, C. C. B. Puty, and S. L. M. Rivero (2007) ‘A Amazonia (Legal) Brasileira: Evidências de uma Condição de Armadilha da Pobreza (The (Legal) Brazilian Amazon: Evidence of a Poverty Trap Condition?)?’ **Proceedings** of the 35th Brazilian Economics Meeting. Brazilian Association of Graduate Programs in Economics, 090.

Fearnside, P. M. 2008. The Roles and Movements of Actors in the Deforestation of Brazilian Amazonia. **Ecology and Society**, 13(1): 23-45.

Fearnside, P. M. 2005. Deforestation in Brazilian Amazonia: History, Rates, and Consequences. **Conservation Biology**, 19(3): 680-688.

Foster, J.; Greer, J.; Thorbecke, E. 1984. A class of decomposable poverty measures. **Econometrica**, 52(3): 761-768.

Guedes, G. R. 2010. **Ciclo de vida domiciliar, ciclo do lote e mudança no uso da terra na Amazônia Rural Brasileira – um estudo de caso para Altamira, Pará**. Ph.D. disseration. CEDEPLAR, UFMG, Belo Horizonte, 2010. 223p.

Guedes, G. R.; Resende, A. C.; Brondizio, E. S.; Penna-Firme, R. P.; Cavallini, I. 2009. Poverty Dynamics and Income Inequality in the Eastern Brazilian Amazon: a multidimensional approach. **Proceedings of the International Union for Scientific Study of Population**, Marrakesh.

Hecht, S., B.; Cockburn, A. 1989. **The Fate of the forest: Developers, destroyers and defenders of the Amazon**. London, UK: Verso.

IBGE (Instituto Brasileiro de Geografia e Estatistica). 2007, 2005. **Pesquisa Nacional por Amostra de Domicílios**. Rio de Janeiro: IBGE. (microdata).

INPE (Instituto Nacional de Pesquisas Espaciais). 2008. **Monitoramento da cobertura florestal da amazônia por satélites: sistemas PRODES, DETER, DEGRAD e QUEIMADAS 2007-2008**. São José dos Campos, 2008. Available at: <http://www.obt.inpe.br/prodes/Relatorio_Prodes2008.pdf>.

IPEA (Instituto de Pesquisa Econômica Aplicada). 2008a. IPEADATA – Poverty

Series. Available at: <http://www.ipeadata.gov.br/ipeaweb.dll/ipeadata?SessionID=747832605&Tick=1221500688048&VAR_FUNCAO=Ser_Temas%281413839281%29&Mod=S>.

IPEA (Instituto de Pesquisa Econômica Aplicada). 2008b. Metodologia na determinação das linhas de pobreza e indigencia (por insuficiência no consumo de calorias por dia). IPEADATA. Available at: <http://www.ipeadata.gov.br/ipeaweb.dll/ipeadata?SessionID=747832605&Tick=1221500688048&VAR_FUNCAO=Ser_Temas%281413839281%29&Mod=S>.

Lambin, E. F.; B. L. Turner; H. J. Geist; S. B. Agbola; A. Angelsen; J. W. Bruce; O. T. Coomes; R. Dirzo; G. Fischer; C. Folke; P. S. George; K. Homewood; J. Imbernon; R. Leemans; X. B. Li; E. F. Moran; M. Mortimore; P. S. Ramakrishnan; J. F. Richards; H. Skanes; W. Steffen; G. D. Stone; U. Svedin; T. A. Veldkamp; C. Vogel; J. C. Xu. 2001. The causes of land-use and land-cover change: moving beyond the myths. **Global Environmental Change**, 11:261-269.

Ludewigs, T.; D'Antona, A. O.; Brondízio, E. S.; Hetrick, S. 2009. Agrarian structure and land use change along the lifespan of three colonization areas in the Brazilian Amazon. **World Development**, 37(10): 1348-1359.

Mendes, F. A. T. 2007 **A produção de cacau no estado do Pará: um enigma ou realidade não considerada?** Belém: CEPLAC/SUPOR/SEPES. (Technical report, 20.2007).

Millikan, B. 1988. **The Dialectics of Devastation: Tropical Deforestation, Land Degradation and Society in Rondônia, Brazil**, Master's Thesis, Department of Geography, University of California, Berkeley.

Moran, E. F.; Brondízio, E. S.; McCracken, S. 2002. Trajectories of land use: soils, succession, and crop choice. In: Wood, C. H.; Porro, R. (Ed.) **Deforestation and land use in the Amazon**. Gainesville, FL: University of Florida Press. p. 193-217.

Murphy, L. L. 2001. Colonist farm income, off-farm work, cattle, and differentiation in Ecuador's Northern Amazon. **Human Organization**, 60(1): 67-79.

Murphy, L. L.; Bilsborrow, R. E.; Pichón, F. J. 1997. Poverty and prosperity among migrant settlers in the Amazon rainforest of Ecuador. **Journal of Development Studies**, 34(2): 35-66.

Myers, N. 1993. Tropical Forests: the main deforestation fronts. **Environmental Conservation**, 20: 9–16.

Ostrom, E.; Gardner, R.; Walker, J. 2006. **Rules, Games, & Common-Pool Resources**. Ann Arbor: The University of Michigan Press.

Penna-Firme, R.; Brondízio, E. S. 2007. The risks of commodifying poverty: rural communities, Quilombola identity, and nature conservation in Brazil. **Habitus**, 5(2): 355-373.

Perz, S. G. 2003. Social determinants and land use correlates of agricultural technology adoption in a forest frontier: a case study in the Brazilian Amazon. **Human Ecology**, 31(1): 133-165.

Perz, S. G.; Walker, R. T. 2002. Household life cycles and secondary forest cover among smallholders in the Amazon. **World Development**, 30(6): 1009–1027.

Pfaff, A. *et al.* 2009. Road impacts in Brazilian Amazonia. In: Keller, M.; Bustamente, M.; Gash, J.; Dias, P. (Ed.). **Amazonia and global change**. Washington: American Geophysical Union. 565 p.

Piketty, M. *et al.* 2005. Determinantes da expansão da pecuária na Amazônia Oriental: consequências para as políticas públicas. **Cadernos de Ciência & Tecnologia**, Brasília, 22(1): 221-234.

Plantão. 2009. Medicilândia é o maior produtor de cacau do Brasil. Medicilândia: Notícias. Prefeitura Municipal de Medicilândia (site oficial). Disponível em: <http://www.medicilandia.pa.gov.br/portal1/municipio/noticia.asp?iIdMun=100115071&iIdNoticia=91006>. Acesso em: 23 set. 2009.

Reardon, T.; Vosti, S. A. 1995. Links Between Rural Poverty and the Environment in Developing Countries: Asset Categories and Investment Poverty. **World Development**, 23(9): 1495-1506.

Rodrigues, A. S. L.; Ewers, R. M.; Parry, L.; Souza Jr., C.; Veríssimo, A.; Balmford, A. 2009. Boom-and-Bust Development Patterns Across the Amazon Deforestation Frontier. **Science**, 324(5933): 1435 – 1437.

Sawyer, D. 2009. Fluxos de carbono na Amazônia e no cerrado: um olhar socioecossistêmico. **Sociedade e Estado**, Brasília, 24(1): 149-171.

Schmink, M.; Wood, H. C. 1984. **Frontier expansion in Amazonia**. Gainesville: University of Florida Press.

Sen, A. K. 1985. **Commodities and capability**. Oxford: Oxford University Press.

Sherbinin, A.; Vanwey, L. K.; Mcsweeney, K.; Aggarwl, R.; Barbieri, A. F.; Henry, S.; Hunter, L. M.; Twine, W.; Walker, R. 2008. Rural household demographics, livelihoods and the environment. **Global Environmental Change**, 18: 38-53.

Simmons, C. S. 2004. The Political Economy of Land Conflict in the Eastern Brazilian Amazon. **Annals of the Association of American Geographers**, 94(1): 183-206.

Simmons, C. S.; Walker, R. T.; Arima, E. Y.; Aldrich, S. P.; Caldas, M. M. 2007. The Amazon Land War in the South of Pará. **Annals of the Association of American Geographers**, 97(3): 567-592.

Smith, N. J. H. 1982. **Rainforest corridors:** the transamazon colonization scheme. Berkeley: University of California Press. 248 p.

VanWey, L. K.; D'Antona, A. O.; Brondízio, E. S. 2007. Household demographic change and land use/land cover change in the Brazilian Amazon. **Population and Environment**, 28(3): 163-185.

VanWey, L. K.; Guedes, G. R.; D'Antona, A. O. 2009. Out-Migration and Household Land Use Change in Altamira, Pará, Brazil. **Proceedings** of the XXVI International Union for Scientific Study of Population, Marrakesh.

VanWey, L. K.; G. R. Guedes; A. O. D'Antona. 2008. Land Use Trajectories after Migration and Land Turnover. **Proceedings** of the Annual Meeting of the Population American Association, New Orleans.

Walker, R. T. 1999. The structure of uncultivated wilderness: land use beyond the extensive margin. **Journal of Regional Science**, 39(2): 387-410.

Walker, R. T.; Moran, E. F.; Anselin, L. 2000. Deforestation and Cattle Ranching in the Brazilian Amazon: External Capital and Household Processes. **World Development**, 28(4): 683-699.

Walker, R. T. *et al*. 2002. Land use and land cover change in forest frontiers: the role of household life cycles. **International Regional Science Review**, 25(2): 169-199.

Wouterse, F.; Taylor, J. E. 2008. Migration and income diversification: evidence from Burkina Faso. **World Development**, Oxford, 36(4): 625-640.

Yang, D.; Choi, H. 2007. Are remittances insurance? Evidence from rainfall shocks in the Philippines. **World Bank Economic Review**, Washington, 21(2): 219-248.

Annex

Table A

Ordered Probit Coefficients of Transition on Poverty in Altamira (1997/98 to 2005)

Variables	Partial	Full
Biophysical Capital		
Ln(distance to urban Altamira)	-0.477***	-0.407***
	(0.149)	(0.153)

Proportion of property with high-fertility soil	0.006**	0.005*
	(0.003)	(0.003)
Land Use Classes		
Proportion of property in pasture	0.021***	0.021***
	(0.006)	(0.006)
Proportion of property in perennial	0.040***	0.038***
	(0.012)	(0.012)
Proportion of property in annual	0.021	0.018
	(0.017)	(0.018)
Natural Capital		
Proportion of property in primary forest	0.009	0.012**
	(0.006)	(0.006)
Does the property have on site access to water?	-0.058	-0.062
	(0.176)	(0.179)
Control Variables		
Time of arrival on the property		0.028***
		(0.010)
Does any household member have off-farm employment?		0.102
		(0.174)
Is the household head from the South/Southeast regions?		0.149
		(0.149)
Property size (ha)		0.0001
		(0.001)
Cut 1	-4.956***	-3.599**
	(1.679)	(1.762)
Cut 2	-4.758***	-3.394*
	(1.668)	(1.751)
Cut 3	-3.386**	-1.984
	(1.679)	(1.765)
Pseudo R2	0.1274	0.1435
Prob > Chi2	0.0000	0.0000
Observations	275	275

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Altamira Dataset (1997/1998, 2005)