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

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Introduction

Poverty in rural environments has been traditionally approached by the view that poor adopt low-technological and ecologically threatening land use practices (Chomitz, 2007; Reardon & Vosti, 1995). Building on theories of multiphase responses (Sherbinin et al., 2008; Davis, 1963) along with the capability approach (Bebbington, 1999; Sen, 1985), this paper takes a different view on poverty-environment link, emphasizing its endogenous relationship (Rodrigues et al., 2009) and analyzing how poverty changes over time and how it connects to land use, biophysical constraints and natural capital of rural smallholders.

In the Amazonian context, the negative image of rural poor is derived 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 (Schmink & Wood, 1984; Millikan, 1988). 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 suggested negative environmental impacts of smallholders pushed policy makers to propose a myriad of public interventions to curb deforestation, such as reduction in road building investments and increase in protected areas (Fearnside, 2005).

The underlying assumption behind these studies is that rural smallholders do not act strategically, by only considering their immediate consumption needs (Myers, 1993), what suggests that poverty and deforestation is strongly associated as a result of extensive demand for land (Chomitz, 2007). Nobel Prize in Economics Elinor Ostrom, using agent-based models applied to common-pool resource dilemmas, has shown the inappropriateness of this simplistic view about the tragedy of the commons, arguing that even beyond the economic and market fringe, rural population act strategically in order to maintain their long term well-being. This is accomplished by regulating the optimal stock of environmental services from which they derive their livelihoods (Ostrom et al., 2006). Other scholars have been showing that, in agricultural contexts, families develop endogenous strategies to cope with threads to long-term well-being maintenance through unequal inheritance practices and a combination of selective migration and remittances, contradicting the pioneer cycle prediction (Wouterse & Taylor, 2008; Yang & Choi, 2007; Baker & Miceli, 2005). Altogether, these results suggest that instead of a consequence, environmental constraints can be a driving force of poverty and a challenge for poverty alleviation.

Most of the literature about the relation between population and environment is committed to explain how population (and as a consequence, household behavior) affects the environment and modifies the landscape – known as population effect on frontier extensification (Caldas et al., 2007; VanWey et al., 2007; Barbieri et al., 2005; Browder et al., 2004; Walker et al., 2002; Perz & Walker, 2002). Little is known about the other side of this equation: the consequence of the environmental processes to local population – considered the ultimate driving force of environmental degradation (Barbieri & Bilsborrow, 2009; Murphy, 2001; Murphy et al., 1997). In this paper, we depart from a traditional concept of poverty as insufficiency and expand it to a multidimensional view of poverty as lack of opportunity to invest (Reardon & Vosti, 1995). This working definition of the poor links poverty and land use/cover within the rural livelihoods framework (Bebbington, 1999) and helps us to understand poverty configuration and drivers among the rural. Drawing on our previous work on multidimensional rural poverty and land use/cover change among rural smallholders in the Brazilian Amazon (Guedes et al., 2009), we analyze the extent to which poverty is sensitive to change in natural capital, land use strategies and biophysical characteristics of the lot among rural smallholders in the Amazon. We believe that looking at these different dimensions of human-environmental link in rural contexts is a useful way to inform public policy interventions, such as government sponsored settlement projects, implementation/expansion of conservation units, carbon payments for the standing forests and reforestation initiatives, and infrastructure development in the Amazonian region, taking into consideration the sensitivity of the rural poor to changes in environmental restrictions.

In order to illustrate the links suggested by the dual relation between environment and rural wellbeing, 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. This case study was considered a relatively successful settlement project in the Amazon 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, resulting in high rates of outmigration and high levels of malaria from the 1970's to the beginning of the 1990's (Brondízio et al., 2002). A more stable pattern of colonization and agricultural production started to emerge in the first half of the 1990's. However, due to the abandonment of government's support back to the 1980's and increasing land speculation since than, Altamira has now one of the highest lot turnover rates among settlement areas in the Amazon (Ludewigs et al., 2009). The high turnover rates may express the increase in environmental deprivation (pushing small owners to out-migrate) and an indirect consequence of land use systems, toward increase in cattle ranching – inducing further out-migration from the settlement area. Our dataset allows us to properly follow the original household interviewed in the first wave of data and track them in second wave, independently on them staying on the lot or having out-migrated.

This paper is organized as follows: the next section introduces the different views about the link between rural poverty and the environment, questioning the underlying assumptions of proposed

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[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).

models and discussing the regional environmental and economic consequences of local level livelihood options among rural smallholders. The next section presents the data used for empirical calibration, followed by the section describing the methodological strategy used. Results section presents the Foster-Greer-Thorbecke poverty ratios for our study area, the Markovian approach to transition on poverty over time and the simulated effects of change in levels of selected environmental dimensions (biophysical constraints, land use classes and indicators of natural capital) on time allocation between poverty and non-poverty states. The paper concludes by addressing the challenges to rural development of the Brazilian Amazon in face of structural poverty.

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-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). Alternative frameworks, such as that proposed by political ecologists, have began to recognize that under certain circumstances conservation of nature may reinforce the maintenance of local people under limited socio-economic development (Penna-Firme & Brondizio, 2007). The intersection of conservation and poverty poses particular challenges for development. Forced eviction or changes in resource use rights are examples of how conservation may depend on lessening people's ties to the local environment (Brockington, 2002) and in some cases promote a form of “poverty in paradise”.

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 equate their livelihoods in face of institutional restrictions to deforestation and lack of formal titles, which prevents them from having access to credit. This becomes particularly important as local regulations to avoid the use of fire in land preparation make difficult the growing of certain crops. To solve this problem, rural households would need to resort to using credit, investing in more advanced techniques for soil preparation. However, most of these families, living in settlement projects, do not yet have formal titles - a basic requirement for funding agencies to release the rural credit. This situation reaffirms the condition of poverty among these families, as they become increasingly dependent on the capacity of soil and natural resources to provide their livelihood over time (Diniz et al., 2007).

The increasing dependence on biophysical characteristics of the soil for livelihood strategies is reported by a couple of studies (Perz, 2003; Moran et al., 2002). Soil fertility, for instance, is considered a key determinant of economic wellbeing among rural smallholders as most of them have little or no formal credit to invest in more intensive techniques, such as water irrigation and soil fertilizers (Perz, 2003). Castro (2009) calls attention for the lack of detailed soil inventory in most of the settlement projects in the Amazon. Analyzing "PA Machadinho" (a settlement area, located in Machadinho do Oeste, Rondônia State, established by the Brazilian National Institute of Colonization and Agrarian Reform - INCRA), she concludes that substantial part of failure to stay on the lot was actually explained by the lack of colonists' knowledge about the type of soil they were being given. This story seems to repeat across the Amazon, given that with the frontier development and consolidation of land market new owners are pushed to inhabit marginal lands or, when they have access to credit, consolidate adjacent lots with sandy soil in order to raise cattle (Walker, Moran & Anselin, 2000; Walker, 1999).

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 has loose and non-linear connections across municipalities in the Brazilian Amazon (Fernandes et al., 2009; Fearnside, 2008). Expansion of pasture, mainly driven by ranchers and smallholders in settlement areas, reduces other available resources (e.g., NTFP, game, water, timber) and possibly opportunities for alternative land allocation. Pasture and cattle ranching has also intersectorial 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 deemed in the long run, creating a negative spiral of informal credit and income constraints (VanWey et al., 2009).

The challenge, thus, is to properly link livelihood strategies that improve wellbeing at the local level to environmental and economic benefits to the regional (community) level. Otherwise, particular labor-extensive land use practices may produce negative externalities to the community of rural farmers as a whole, resulting in dynamic increase of social deprivation and inequality over time. As farms are consolidated and families out-migrate, there is observable decrease in the availability of schools, transportation, and public services in general (Brondizio et al., 2009). As a process of positive feedback, the lack of services then forces remaining families to sell their lots and increase their vulnerability to poverty, especially when migrating to urban areas with limited supply of off-farm labor.

Study Area – The Altamira Settlement Project

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 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. This way, a stable and good accessibility from the lots to the market during the rainy season are an essential component of households' wellbeing as it may prevent them from adopting certain types of land use system and, ultimately, take advantage of market incentives.

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, 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 Altamira urban area (on the very east of our study area) while 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 laborer (hired by the day), and sharecroppers (most common for cocoa production). As a traditional fishbone style of rural settlement, deforestation radiates out from the main road (TransAmazon) to the feeder roads (*travessões*), suggesting the time pattern of settlement. Lots on the very west of our study area (towards Uruará) and in the back of the feeder roads have the highest proportion of the lot in primary forest. Between 1997/98 and 2005, the average proportion of the lot in primary forest reduced from 45.3% to 31.3%.

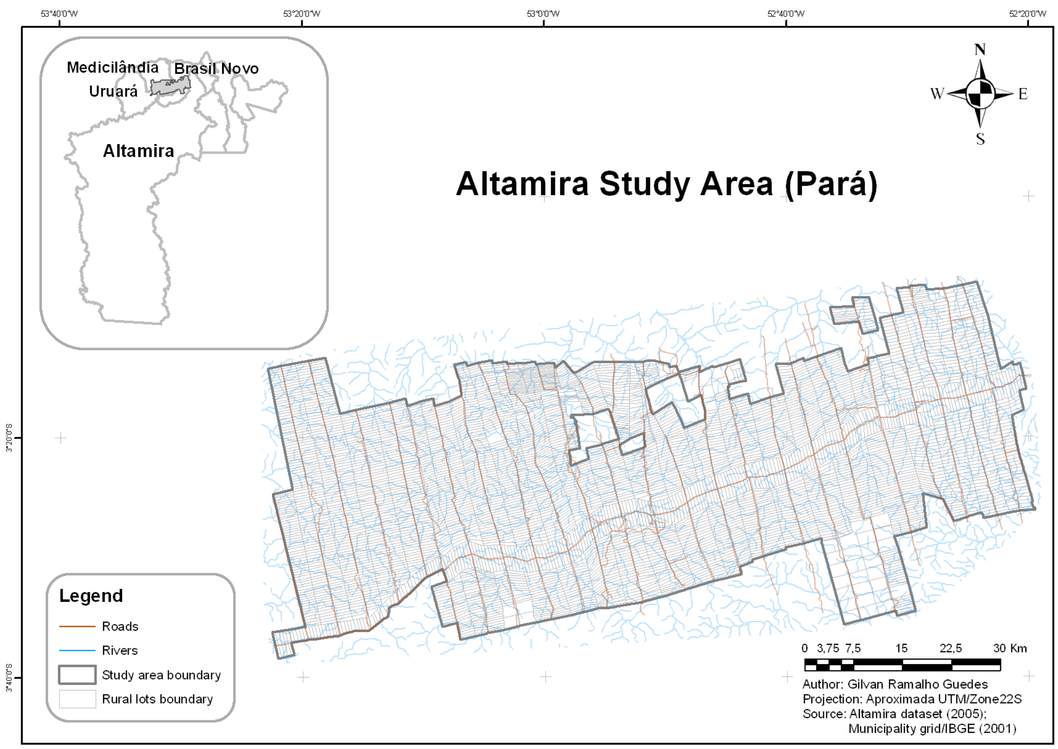
Sample and Measure

Analytical sample

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

The household level data is applied to estimate of the transitional probabilities on poverty and the time structure of poverty (Markovian approach). We also use the data to simulate changes in selected environmental dimensions of rural livelihoods identified in previous work done by the authors (see Guedes et al., 2009) and supported by the conceptual framework proposed by Sherbinin et al. (2008) and Bebbington (1999) on poverty transition. Our analytical sample for the household level analysis is restricted to 321 observations (rural lots) in 1997/1998, which correspond to the households interviewed in that year with available information for the livelihood dimensions considered (biophysical endownment; land use classes, natural capital). For the purpose of this analysis, we assume the household unit is the same over time if the original husband, wife or both (from 1997/1998 data) were still present in the revisited household (from 2005 data). Due to cases where persons could not be found (due to moving out of our study area) or refused to be interviewed in 2005, we missed information for 7 household units. We also excluded observations with missing information for income. Thus, our final analytical longitudinal sample totals 275 households with available information for the relevant dimensions in both waves.

Map 1: Altamira Study Area



Defining poor and non-poor

Despite the growing interest about the environmental consequences of frontier expansion into tropical forests, little research has been conducted in terms of detailed information about income and wellbeing at the household level (Barbieri & Bilsborrow, 2009). This is partially explained by the high cost of collecting, processing and analyzing data at this level of disaggregation. The only studies analyzing economic wellbeing of the families at the household level in the Amazon as far as we know are Almeida (1992) and Caviglia-Harris & Sills (2005), for the Brazilian Amazon, and Barbieri & Bilsborrow (2009), Murphy (2001) and Murphy et al. (1997) for the Equatorial Amazon. None of them, however, address dynamics of poverty as a response to environmental constrains.

Following the strategy suggested by the Barbieri & Bilsborrow (2009) to create the household income variable, we combined different sources of income reported in the questionnaires: off-lot 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. 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. The off-lot income was collapsed at the household level in order to create the amount of money derived from jobs/services remunerated off the lot (including urban services/jobs and temporary jobs on other lots). The retirement income was obtained 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$125.00[2] in 1997/98, and R$ 300.00 in 2005).

The estimation of agricultural income was a little more complex. We departed 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 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). As some of the crops had missing information for some of the values, we also performed two types of imputation. The first imputation corresponded to give the average amount of the specific crop or price of that crop among the sample observations to the missing information. The other imputation was to randomly assign a value for the missing information, conditioned on the amount of production for the specific crop in order to avoid scale-effect on price or potential bias on the distribution of agricultural production. Although we performed different types of imputation at the crop-per-household level before aggregation, some preliminary work done by the authors with income as a dependent variable in regression models (not shown) suggest the use of data with non-imputation was actually more consistent. In this paper we use the agricultural income with no imputation only.

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. This way, we decided to monetize the production for self-consumption and add it to the total

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

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-lot 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. Because we use a dummy variable for poverty state (0 – non-poor; 1 – poor), we did not deflate household income over time.

Methodology

In this paper, we apply a transitional matrix approach based on Markovian processes to estimate transition on poverty among rural smallholders. As will be seen, treating the transitions as a Markovian process allows us to empirically derive the time structure under each state (poverty and non-poverty) based on observed transitional probabilities on poverty. We then perform simulations of selected ecological and land use variables to evaluate its impact on poverty structure among smallholders.

Our results suggest that commercial land uses (pasture, cattle and perennials) and proper biophysical endowments of the lot (accessibility during the rainy season and high proportion of the lot in *terra roxa*) are important to reduce time experienced in poverty and to induce transition out of poverty (ascending socioeconomic mobility). On the contrary, areas in forest (primary and secondary, in a less extent) create barriers for poverty decline in our study area, a result predicted by the "poverty in paradise" scenario. These findings are in accordance to results from our previous work on multidimensional poverty (Guedes et al., 2009) and on land use/cover change (VanWey et al., 2008, 2009) in the Eastern Brazilian Amazon and call attention to the limitation of individual characteristics in overcoming structural bottlenecks to rural development.

Matrices of transitional probabilities

In order to analyze the dynamics 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:

$$p^{i} = \begin{bmatrix} p^{i}_{nn} p^{i}_{np} \\ p^{i}_{pn} p^{i}_{pp} \end{bmatrix} \tag{1}$$

where p^{i}_{jk} represents the probability of individual *i* be on 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 allocated in each state for each individual *i*. Taking π^{i}_{j} as the portion of the time individual *i* allot to state *j*, we have:

$$\pi^{i}_{j} = \begin{bmatrix} \pi^{i}_{n} \\ \pi^{i}_{p} \end{bmatrix} \tag{2}$$

Given that π^{i}_{j} is non-observable, we assume transitions between the two states (poor and non-poor) are treated as a Markovian process, in which the future development of the process depends solely on the state where individual is, independently on 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^{i}_{t} and π^{i}_{t-1} can be written in matrix format as:

$$\pi^{i}_{t} = p^{'}_{i}\pi^{i}_{t-1} \tag{3}$$

In steady state, $\pi^{i}_{t} = \pi^{i}_{t-1}$. Thus, $\pi^{i}_{t} = p^{'}_{i}\pi^{i}_{t}$.

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

$$p^{'}_{i}\pi^{i}_{t} = \pi^{i}_{t} \Rightarrow \begin{bmatrix} p^{i}_{nn} p^{i}_{pn} \\ p^{i}_{np} p^{i}_{pp} \end{bmatrix} \begin{bmatrix} \pi^{i}_{n} \\ \pi^{i}_{p} \end{bmatrix} = \begin{bmatrix} \pi^{i}_{n} \\ \pi^{i}_{p} \end{bmatrix} \tag{4}$$

$$\begin{aligned} &\Rightarrow p^{i}_{nn}\pi^{i}_{n} + p^{i}_{pn}\pi^{i}_{p} = \pi^{i}_{n} \\ &\Rightarrow p^{i}_{np}\pi^{i}_{n} + p^{i}_{pp}\pi^{i}_{p} = \pi^{i}_{p} \end{aligned} \tag{5}$$

Any equation of the above linear system is linearly dependent on the others. However, as $\pi_n^i + \pi_p^i = 1$, we can replace the previous sum in any of the equations and, by means of the replacement, solve the system.

The distribution of population (N) under each steady state condition can be found by averaging individual probabilities, that is, $\prod_j = \frac{1}{N}\sum_{i=1}^{N}\prod_j^i$. In our case, the steady state seems not limiting when studying rural poverty, as poverty mobility is lower in rural areas than in urban areas, where labor market shocks tend to increase volatility between poverty and affluence (Machado & Ribas, 2010; Antigo & Machado, 2006).

Simulations

In order to evaluate the likely impact of changes in some of relevant ecological and biophysical dimensions on smallholders wellbeing, we simulate two scenarios:

1) If the transitional probabilities of the poor in lower levels (*LL*) of a selected dimension are equaled to 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?

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

2) If transitional probabilities of the poor in lower levels (*LL*) of a selected dimension are equaled to 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?

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

The use of both simulated scenarios allows to test the influence of each selected dimension on time structure over states, independently on the initial condition if the structure is inelastic or quasi-inelastic to individual state (*j,k*) in period *t*.

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

1) Biophysical endowments

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

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

2) Land use classes

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

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

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

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

Results

Poverty Level

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[3] in 1997, with 50% of its population classified as living below the poverty line[4]. In 2005, the Headcount ratio dropped to 44.0%, representing a

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

[4] 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 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.

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).

Foster-Greer-Thorbecke poverty measures (Foster et al., 1984) for our study area are presented in Table 1, for both the study area and for Pará State as a whole. Poverty level in our study area reduced dramatically if we consider poverty measured as the proportion of Brazilian minimum salary. If we consider the relative income distribution, however, reduction in poverty was modest: 3% over 8 years. However, the reduction in the square poverty gap ratio [FGT(2.0)] – that takes the inequality among the poor into account – was striking, even considering the relative measure of poverty. This result is suggestive of a well-succeeded combination of endogenous characteristics of rural smallholders and synergistic interaction between them and external institutions (markets and government). Recently, smallholders have been benefited from market incentives through increase in the regional demand for beef (Walker, Moran & Anselin, 2000), and in the national and international demand for cocoa (Plantão, 2009).

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
Poverty gap ratio %	25.0	16.1	13.3	9.2
Index FGT(2.0) *100	21.4	10.3	7.2	4.8
	Absolute poverty line (1/2 minimum salary)			
Headcount ratio %	53.1	16.4	38.6	59.4
Poverty gap ratio %	34.5	8.1	15.6	26.8
Index FGT(2.0) *100	27.7	5.6	8.6	15.5

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

Markovian Matrices

We now turn our attention to the probabilities of transiting on povery and the time structure of poverty in our study area. According to Table 2, 72.57% of the non-poor in 1997/98 remained as non-poor in 2005. However, among the non-poor in 1997/98, about 27% became poor in 2005. Mobility was higher among the poor, as 57.0% of initial poor left poverty from 1997/98 to 2005. This is a remarkable change in wellbeing 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)

The results from previous table and review of literature on poverty-environment link motivated us to simulate three group of conditions (environmental dimensions) that affect poverty in the two points of data series: biophysical characteristics of the lot (% of the lot with *terra roxa*, and good accessibility from the lot to the market during the rainy season); natural capital (approached by the % of the lot in primary forest and in water), and, finally, land use classes (% of the lot in perennials, pasture, and annuals). All the selected dimensions were measured in 1997/98 (first wave of data) in order to reduce potential endogeneity issues in time allocation among states over time. Results are organized by each dimension at a time.

Overall, smallholders in our study area remained as non-poor 67.5% of the time-window (1997/98 and 2005) and 32.5% of the time as poor. This result is reflective of the high probability of migrating out of poverty between waves of data in our study area (Table 2). When we disaggregate the results by type of biophysical constraints, time experienced in and out of poverty changes considerably. Table 3 presents the results for the two selected biophysical characteristics of the lot: a) accessibility to the lot during the rainy season, and b) proportion of the lot in *terra roxa*. While households with no accessibility during the rainy season remained, 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 give the transitional probabilities of the poor and non-poor (each at a time) with good accessibility to the poor with no accessibility to the lot in the rainy season, the proportion of time spent in non-poverty state (among the original poor with no access) change from 44% to 65% - an increase of approximately 21%. As the impact of simulated time structure on poverty did not change significantly (by both giving the transitional probabilities of the non-poor and the poor with access to the poor with no access), we conclude that the major impact on poverty reduction relies on the accessibility to the lot instead of the initial condition of the household (being or not poor in 1997/1998).

If we consider the proportion of *terra roxa* on the lot, household with low proportion of the high quality soil spent 44.2% of their time as poor, against only 15.9% among the households with a large proportion of the lot in *terra roxa*. Performing the same type of simulation, we observe that if poor households with a small portion of alfisols were giving the same transitional probabilities on poverty of the households with high proportion of the lot with terra roxa, time spent as non-poor increase from 55.8% to approximately 69%. This represents an average increase in the time spent as non-poor of about 13%. Taken together, results suggest that biophysical characteristics of the lot have a significant impact on household wellbeing over time, and that accessibility to the lot seems even more important for reducing rural poverty.

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 lot - Altamira Study Area, 1997/98 and 2005

	Non-poor	Poor	Δ (Simulated - Observed)
Full sample	67.5	32.5	
Accessibility to the lot 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 lot 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)

Table 4 shows the impact of selected land use classes on time spent in each state (poverty and non-poverty). Results sugest that although time spent out of poverty is higher among households with low level of perennials then with low proportion of the lot in pasture (62.6% against 54.8%), the simulated impact of change in the proportion of the lot under pasture to the poor households is higher if compared to increase in perennials (an average of 14.5% against 3.5%, respectively). This result is consistent with previous work suggesting the importance of cattle for livelihood strategies among rural households of Amazonian frontiers (Guedes et al., 2009; VanWey et al., 2007; Walker et al., 2000). However, the sensitivity of time spent in poverty among the poor households is higher when we simulate change in levels of perennials. Results from Table 4 show that when we give the transitional probabilities of the non-poor households (in 2005) with high proportion of the lot in perennials to the poor households with low percentage of the lot in perennials, the increase in time spent as non-poor is 6.1%. If we give the poor with low % of perennials the transitional probabilities of the poor (in 2005) with high level of perennials, the impact on the time spent as non-poor is virtually zero (0.9%). At last, results suggest that households with higher proportion of the lot in 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 lots with higher proportion of the area in annuals indicate low levels of integration to markets.

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 lot - Altamira Study Area, 1997/98 and 2005

Full sample	Non-poor	Poor	Δ (Simulated - Observed)
Poor	67.5	32.5	
Proportion of the lot 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 lot 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 lot 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 5 summarizes the results of time structure on poverty for indicators of natural capital on the lot. As the measure of proportion of the lot in water shows low variability across sample, we added it to the proportion of the lot in primary forest to reduce potential effect of reduced heterogeneity in measurement. Results suggest that instead of an opportunity, forest may represent a barrier to household wellbeing. However, we may consider this result carefully, as we are not controlling for the timing of deforestation. Guedes (2010), for instance, suggest that lots with higher proportions of area deforested are concentrated close to Altamira, where the settlement project initiated. These lots are also the ones especialized in cattle ranching and where most of lot consolidation occurs in the study area. This way, Tables 5 and 4 must be analyzed together as forest clearing in our study area is predominantly oriented to agricultural production or cattle ranching (our study area shows very low level of lot abandonment).

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 lot - Altamira Study Area, 1997/98 and 2005

Full sample	Non-poor	Poor	Δ (Simulated - Observed)
Poor	67.5	32.5	
Proportion of the lot with primary forest			
Observed			
Low %	78.1	21.9	
High %	48.9	51.1	
Simulated (probabilities of the "with acess" group)			
Non-poor	62.0	38.0	-16.1
Poor	52.4	47.6	-25.6
Proportion of the lot with primary forest + water			
Observed			
Low %	78.0	22.0	

High %	49.7	50.3	
Simulated (probabilities of the "high %" group)			
Noon-poor	62.0	38.0	-15.9
Poor	53.2	46.8	-24.8

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

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 dimensions on povery dynamics among rural smallholders.

Our results suggest reduction in poverty level over time, with emphasis on poverty reduction followed by decline in inequality among the poor. The reduction in poverty levels for our study area suggests a successful combination of livelihood strategies among the rural households and also market stimulae, mainly increase in commodity prices (Mendes, 2007). Although restriction to the Brazilian meat due to endemic foot-and-mouth disease in Pará state prevented farmers to export their production overseas, domestic demand for meat was consistent through time period analyzed here (Piketti et al., 2005).

Biophysically, acessibility to the lot during the rainy season seems to be the most important exogenous element to reduce time spent in poverty among rural smallholders in our study area. Although availability of high quailty soil on the lot seems also important for a successful trajectory over time (Moran et al., 2002), lot accessibility can be directly manipulated by public intervention (improvement in roads, bridges, etc.). Although accessibility reduces transportation cost and, thus, makes production supply more stable throughout the year, there is evidence of its consequences for the landscape, with increase in deforestation rates and consequent loss of local biodiversity (Pfaff et al., 2009). The tradeoff between conversation and rural development is always a problem and there is no unique answer for it.

As discussed by some authors, making the standing forest profitable is a starting point to equate this problem (Sawyer, 2009). This environmental services solution, however, must be coupled with proper access to markets, as rubber production and gathering of forest nuts (such as Brazilian nuts) may also depend on accessibility to reduce transportation cost to the market and make such initiative viable in the long run. To date, it seems forest has been seen as a constraint to meet smallholders' economic aspirations, but is also part of a historical incentive in the Amazon to deforest in order to colonize and assure maintenance of land (Smith, 1982). As our results also suggest, pasture (and indirectly cattle) is the land use type that mainly affects reduction in poverty and time spent as poor, although our results also suggest poor households with low levels of perennials spent less time in poverty than poor households with low levels of pasture and cattle. This is due to higher profitability of perennials crops in the area (as cocoa price has increased dramatically in the last years – Mendes, 2007), but also a wider livelihood strategy, reducing the vulnerability to selling, as perennials have higher rate of return in the long run (VanWey et al., 2009). This high level of heterogeneity at the household/lot level raises concern about policy interventions when scaling up local determinants of poverty alleviation in terms of ecological sustainability at the community and regional levels.

Our results are limited as do not take into consideration the overall structure of rural livelihoods. In this paper we focus on environmental dimensions only, this way is difficult to respond to the importance of each dimension of smallholders livelihood on their overall wellbeing. Results are also dependent on markovian assumptions that trajectory before the first observed point of series (wellbeing state in 1997/98) and that time structure on poverty are steady over time. As we use a settlement area as research site, and colonists were mainly poor by the time of arrival to Altamira frontier (Smith, 1982), we can argue that differentiation of trajetories are a relatively recent phenomenon due to property turnover, resilience to shocks and appropriate selection of livelihood strategies overtime. However, we have no clue when differentiation starts to take place. To answer this question, our next step is to develop a probability model of poverty with Heckman selection for the initial condition in order to properly evaluate determinants of poverty in both points of time. With estimated conditional probabilities, we can simulate change in levels of each livelihood dimension and analyze to what extent poverty transition is affected.

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