Demographic Dynamics, Livelihoods and Land Use Change in the Brazilian Amazonia: a Longitudinal Study for the Machadinho Region, 1985 to 2010

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Abstract. This paper discusses how the nature of land use and household livelihoods in the Brazilian Amazonia over time may be explained by the changing demographic composition, their access and diversification of sources of income and welfare, as well as stages of frontier development. We use as case study a colonization project in the municipality of Machadinho, occupied since 1984. We build on two theories that place key individual and collective decisions at the household level: "household life cycle", and "livelihood approaches". These theories are particularly useful in understanding the many components of colonist´s decision-making, individual aspirations of income and welfare, collective needs of familiar group(s) in rural settings, and how they are mediated by the context in which these decisions are made. We use a longitudinal panel of plots and their related households based on field surveys carried out in 1985 (285 farm households), 1986 (542 farm households), 1987 (817 farm households), 1995 (1,079 farm households), and 2010 (a sample of 259 farm households). We finally discuss how changing livelihood options are impacted and have consequences depending on the scale of analysis (household, communities, the larger political and institutional context), which poses a challenge for public policy interventions regarding sustainable livelihoods and land use in the Amazonia.

Introduction[1]

This paper aims to discuss how the nature of household livelihoods in the Brazilian Amazonia over time may be explained by the changing demographic composition, their access and diversification of sources of income and welfare, as well as stages and evolution of frontier settlements. In particular, we focus on the impacts, on livelihoods in the Amazon, of demographic changes over time including size, composition, mobility and aging; intergerational and government transfers, management of land, forests and natural resources, access to urban markets and sources of social and natural capital, and contextual changes related to urbanization and infrastructure development in the frontier.

Our case study is a colonization project in the municipality of Machadinho. Colonist settlers have occupied this region since 1984, leading to important socioeconomic, demographic and environmental changes in the following decades. We build on two theories that place key individual and collective decisions at the household level: "household life cycle", and "livelihood approaches". These theories are particularly useful in understanding the many components of colonist´s decision-making, individual aspirations of income and welfare, collective needs of familiar group(s) in rural settings, and the context (community, region, nation) in which these decisions are made.

Our analytical strategy correspond to a cross-sectional and longitudinal analysis of panel of plots and their related households based on field surveys carried out in Machadinho in 1985 (285 farm households and 1,697), 1986 (542 farm households and 2,608 individuals), 1987 (817 farm households and 3,961 individuals), 1995 (1,079 farm households and 5,025 individuals), and 2010 (a sample of 259 farm households and 917 individuals). The results will allow us to discuss specific contextual factors impacting farm household stages at lifecycles and livelihood strategies as well as their changes over time To our knowledge, it is the longest panel of farm plots in the Amazon, and the only one which follows colonists since the very beginning of the colonists´ occupation.

Study Area

Machadinho D´Oeste is a municipality located in the state of Rondônia, in the southwestern part of the Brazilian Amazon (Figure 1). A former totally planed Colonization Project, it has an area of 8,509 km^2, and the 2010 Census enumerated a population of 31,135.

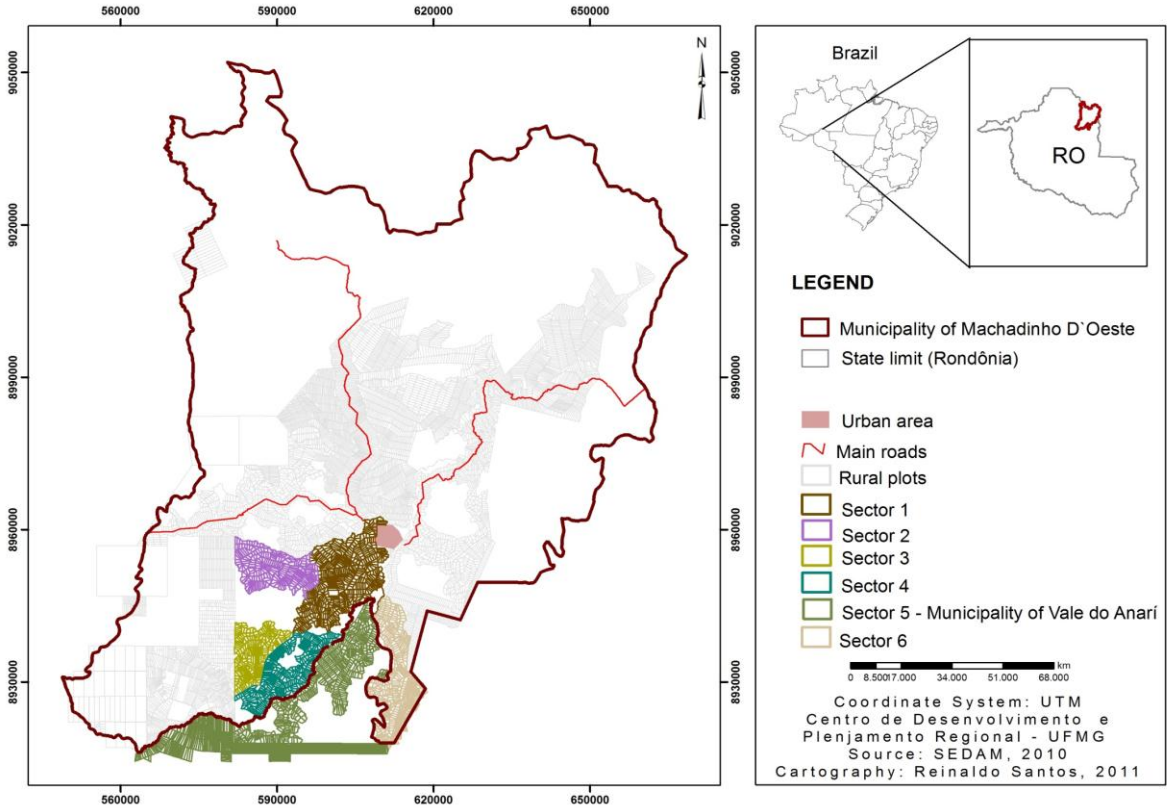
[1] Panel analysis is under way and will be available at the date of the European Population Conference. An electronic copy of the complete paper is available under request.

The Colonization Project was conceived in the Northwest Region Integrated Development Program (Polonoroeste), approved in 1981, and partly financed by the World Bank, and occupation of plots by farm colonists began in 1984 (see further discussion in Monte-Mór, 2004).

By July 1985, Machadinho's urban nucleus had become a booming little town, with over 1,500 houses, although about 30% of them were unfinished or only used as a second home—an "urban base"—for rural families (Monte-Mór, 2004). Although the main activity might determine where the family (or most of it) temporarily lives, the traditional urban-rural dichotomy also hides the real hybrid (urban) nature of contemporary Amazonian frontier settlements (Barbieri et al., 2009b). Those who live in the rural parcels may have succeeded due to comparative advantages in labor and/or technological resources. The ability to maximize opportunities and make a living from rural activities (staying in the assigned rural areas) resided on the capacity to guarantee both cash earnings and time and labor to work on the rural land (Monte-Mór, 2004).

On the other hand, a relatively strong urban economy offers job opportunities, goods, services (mainly education and health) and government support. Furthermore, since access to rural land remains the main motivation for the great majority of migrants, practically all urban dwellers own and exploit rural parcels, strengthening the land market on both urban and rural fronts (Monte-Mór, 2004).

Figure 1 – Study Area in Machadinho D´Oeste, Brazilian Amazonia



Conceptual framework: frontier development, farm household lifecycles and livelihoods

As in many other conceptual frameworks, we recognize that agriculture frontiers evolve in phases. However, we assume that the growing influences of macro and meso level factors on land use decisions at the household level takes place asymmetrically in different frontiers

(Rodrigues et al. 2009), setting the stage for a unique dynamic for each frontier (Sawyer 1984; Browder and Godfrey 1997).

Therefore, in each phase (for the same frontier), or in each frontier (in different phases), the connection of the household with each of these hierarchical levels may change, allowing households to articulate their connections to certain hierarchical scales while disarticulated of others (Browder & Godfrey 1997; Brondízio 2008). This non-linear dynamics of frontier development, and to a certain extent, of the property (plot), implies that contextual factors, such as the social profile of farmers, settlement history and the connection networks of the frontier with other frontiers and markets, determine the characteristics and the pace of change in each phase (Summers 2008). Although some frontiers may experience boom-and-bust cycles of development – from intense deforestation to land abandonment – there is a general trend of change in the economic environment of the frontier from subsistence to an increasing articulation with markets (Walker 2004). This implies that the influence of household life cycle factors on land use change and livelihood strategies decrease as frontier integrates into markets over time. At the same time, the more articulated a frontier is with higher level economic forces (national and global markets) the less household demography is able to explain change in local landscape

Two of the main factors that influence the decisions of small farmers are the rural-urban connections and the social networks (Bebbington 1999). Rural-urban connections are more than a simple spatial concept, it represents the space where social relations operate facilitating flows of information, technology, work, and money (Summers 2008). Therefore, the way the relation between the rural and the urban develops is key to understand how local farmers interact with the environment beyond the frontier boundaries (Monte-Mór 2004). Social networks, already existent by the time of frontier establishment, change their nature over time, from bonding social capital - tied to family or small farmers bonding agreements of mutual help, to bridging social capital - channeling the differential urban/rural wage rate through migrants' remittances or by non-local educational opportunities providing new informational input to the rural households. These more complex social networks widen the decision-making space of rural farmers by buffering their land use decisions with improved knowledge and larger funds for investment (Wouterse & Taylor 2008; VanWey et al. 2012).

Although at later stage farmers may become market-oriented (as in Caldas et al. 2007), they continue to derive some livelihood from subsistence agriculture. This is the basic difference between smallholders and large capitalist farmers in post-frontier scenario (Ellis 1993; Browder & Godfrey 1997). Evidences from different agricultural frontiers in the Amazon support this view. Although in some areas the share of agricultural production sold in the market reaches over 80%, an important part of this production is used for meeting immediate consumption needs of the household members (Marquette 1998; Walker et al. 2002; VanWey et al. 2007).

Understanding the characteristics and conditions of frontier development on the Amazon provides the context in which we will frame our analysis of the demographic and livelihood transitions in the study area in the Brazilian Amazon. This analysis is based on two major theoretical perspectives that place key individual and collective decisions at the household level: "household life cycle", and "livelihood approaches". These theories are particularly useful in understanding the many components of colonist´s decision-making, individual aspirations of income and welfare, collective needs of familiar group(s) in rural settings, and the context (community, region, nation) in which these decisions are made.

"Household Life Cycle" approaches can be examined by drawing upon Chayanov's peasant cycle (Thorner *et al.* 1986; Ellis 1988), as adapted by several authors to the Amazonian context (e.g., Walker and Homma 1996; Marquette 1998; McCracken *et al.* 2002; Perz 2001, Walker *et al.* 2002; Moran *et al.* 2003). The Russian economist, A.V. Chayanov, established a relationship between the demographic characteristics of farm households and agricultural land use in the years following the Russian Revolution in 1917. Chayanov stated that "demographic

differentiation", defined by age of the head of the household and the household ratio of producers to consumers (estimated from the number of children, adults and elders) influences the amount of cultivated land (see Thorner, 1986; Ellis, 1988). A basic assumption in Chayanov's model is that changes in household size and composition (specifically, the ratio of consumers to workers in the household) ultimately determines a household's decision on how to maximize utility in terms of allocating labor to farm production or to leisure, since farm labor is associated with drudgery or irksomeness (Ellis, 1988).

In a "household life-cycle" approach, the combination of individual life-cycle characteristics in the household, such as the age of household members and gender composition, conditions the degree of pressure on agricultural production (Pichón, 1997; Marquette 1998; McCracken *et al.*, 1999; Pichón and Bilsborrow 1999). The main argument of the Household Life Cycle approach is that changes in household size and composition affect land use and farm household labor allocation, and that evidently out-migration directly affects household size and composition. In periods of low household labor availability (e.g., early in the family life cycle when couples have young children, as well as later when adult sons or daughters marry and move away), households tend to adopt agricultural practices suitable to the low availability of labor, such as clearing little forest and raising annual crops, in the first case, or switching land use to cattle, in the second. The effect of the number of adults in the household on out-migration of a member can be positive or negative, depending, for example, on the amount of farm land available. A small amount of land will lead to decreasing returns to labor, as household size increases, favoring out-migration. On the other hand, a large farm will result in a high ratio of land to labor even with a large household, so the returns to labor may remain high even with the addition of a new adult or the aging over time of a child to becoming an adult in the household.

As households accumulate some capital over time, and have a higher availability of labor (viz., young children becoming teenage children or young adults), they usually shift land use from annual crops increasingly to cash crops and pasture. As young adults leave the household as a rite of passage or to take advantage of employment opportunities elsewhere, farmers switch to less labor-intensive forms of land use, notably pasture. However, to the extent that such a process is under way autonomously, that is, over time farmers seek to acquire cattle for other reasons, this will free up labor, which facilitates out-migration. Remittances sent by household migrants, in turn, may be invested on farm activities, particularly cattle given the dearth of labor.

From the livelihoods perspective, poverty in rural areas can be interpreted as the inability of rural households to select the portfolio of capitals that fights exogenous threats to their permanent well-being. In frontier settings, the source of inability springs from structural factors as well as unequal distribution of resources during frontier development (VanWey *et al*. n.d.). Rural well-being at the local level is thus a direct function of both the level (composition) and return (utility) to capitals and as an indirect product of exogenous constraints set up at higher scales (both temporal and spatial). Building on studies of rural poverty that previously have attempted to incorporate the relation between household traditional economic resources with other social forms of assets and natural resource provision (Reardon and Vosti 1995; Murphy 2001; Wunder 2001; German 2003; Caviglia-Harris and Sills 2005; Kay 2006), we define rural poverty as the general lack of choices and opportunities that are reflected in low levels of income, portfolio of physical assets, land use choices, land tenure security, access to natural resources, and social networks. Thus, in this paper we define well-being as the level of material satisfaction provided by certain livelihood strategies representing a specific portfolio of capitals (financial and non-financial) structured and modified by their ability to increase household's satisfaction (Bebbington 1999).

A key element in "livelihood approaches" is the household ability to respond to periods of scarcity through a diversity of mechanisms, such as participation in organizational membership, forms of *clientelism*, and different systems of reciprocity (Pieterse 2001). However, these forms of social capital *per se* have limited effect in overcoming more structural causes of rural poverty, such as land concentration and lack of credit (Kay 2006). As a reaction

to larger sociopolitical and economic transformations, small-scale producers are increasingly involved in off-farm activities (Murphy 2001; Perz 2005). Migration of family members to urban areas and the formation of multi-sited rural-urban households have also been common strategies adopted to generate income and bring about economic diversification (Barbieri *et al*. 2009b).

Finally, we will also discuss how structural, contextual changes over time on the frontier have affected demographic dynamics (particularly mobility) and rural livelihoods in the Amazonia, and Machadinho in particular. Regardless of land speculation which continues to be an important component of environmental change (and particularly deforestation) in the Amazon, expansion of soy bean, sugar cane and cattle ranching for national and international markets have redefined the nature of small agriculture and cattle ranching in the region. Large scale agriculture and cattle ranching are at least partially integrated to large infrastructure projects being developed in the Amazon - particularly highways linking Amazonian production to national and international markets, large scale mining projects and dams and hydroelectric power plants (Pfaff et al, 2009). While these projects have socioeconomic, demographic and environmental impacts per se, they increase land costs and create economies of scale for large agriculture and cattle ranching activities which become increasingly more competitive vis-à-vis traditional, small-scale colonization.

These infrastructure projects also create a new momentum on urbanization in the Amazon and creates (and increases) existing labor markets. Off-farm employment opportunities, together with relative new cash transfer programs in Brazil (such as rural retirement programs and the *Bolsa Familia* program) also creates off-farm cash opportunities and decreases small colonists' dependency on farm production and natural capital. Nonetheless, advancement of demographic transition in the Amazon, with decreasing fertility, population aging and relatively smaller population in the most active working ages (18-50 years old) may in the next decades challenge the sustainability of family labor intensive activities, such as traditional small scale agriculture not based on intensive use of forest resources and environmental services.

Methodology

We base the analysis on 25 years of information collected in five field surveys in the municipality of Machadinho D´Oeste, state of Rondonia in Brazil, by several teams of researchers at the Center for regional Development and Planning (CEDEPLAR) at the Federal University of Minas Gerais (Brazil). We thus have 285 farm households and 1,697 individuals in the 1985 survey; 542 farm households and 2,068 individuals in 1986; 817 farm households and 3,961 individuals in 1987; 1,079 farm households and 5,025 individuals in 1995; and finally 259 farm households and 917 individuals in 2010. The 1985, 1986, 1987, and 1995 surveys correspond to the universe of all farm households settled in the original colonization project in Machadinho, corresponding to *Sector 1* and *Sector 2*[2] (Figure 1). The 2010 survey corresponds to a sample of farm households. We then conduct a descriptive analysis of key factors representing farm household life cycles and livelihood strategies cross-sectionally (at each stage of frontier development represented by the five surveys) and over time.

Results: cross-sectional

As expected, farm households at later stages in the frontier (2010) have an older age structure, as indicated by mean age of household head and spouse and age structure. This pattern mirrors the advanced process of demographic transition in Brazil (with repercussions even in the Amazon) and assures smaller household size compared to earlier years. In association with the larger penetration of the Brazilian welfare state, these older households have a higher share of their incomes in governmental cash transfer programs and specialization

[2] In the Brazilian terminology, the sectors depicted in Figure 1 are named *Glebas.*

on less-demanding labor activities. Furthermore, the overall level of human capital increases significantly over time as indicated by the education of the household head, as well as the overall wellbeing in terms of access to basic utilities (water, electric energy).

The results show that farm households at later stages in the frontier adopt more profitable land use strategies based on cattle-raising. This is due to their smaller family size in accordance to the stage in their demographic life cycle, and as annuals and perennials are also more labor demanding. They also adopt more efficient income diversification strategies, with higher number of family members in off-farm activities and with remittances from out-migration (while this last is not measured for years rather than 2010), and higher number of off-farm labor hired.

Except for the first year of analysis (1985), where larger plot size and greater share of land in pasture indicate a process in which the first colonizers settled larger plots of land and forest was converted in pasture initially for later use in annual and perennials, subsequent land uses – an particularly between 1987 and 1995 - suggest an expected trajectory (from farm household lifecycle theories) in terms of increasing land converted from annuals and perennials to pasture. While the actual plot size remains basically the same over time (except for 1985 as suggested above), land consolidation and acquisition of new plots increase basically for cattle ranching, as indicated by the evolution of the mean number of cattle.

Furthermore, our findings suggest that demographic dynamics and land use in Machadinho reinforce independence of plot/land use life cycle related to household life cycle as suggested by other studies (Barbieri et al, 2005; Barbieri 2005; Guedes 2010). The independence and speed of household and plot life cycle transitions in Machadinho may be accelerated due to i) higher market integration, ii) the role of institutions affecting rural livelihoods (urban bias, cash transfer programs, infrastructure building which fosters rural out-migration), and iii) more advanced demographic transition and multi-generational cohabitation patterns (as indicated by the proportion of plots with other households and plots with vertically extended families).

In contrast, higher reliance on more profitable land use, off-farm employment and out-migration and cash transfer programs decrease reliance on natural capital as source of farm household income, as indicated by the decreasing share of land on forest and extractive activities.

Nonetheless, increasing population mobility in the Amazon has resulted in a pattern of population distribution which challenges a simple dichotomy between “rural” and “urban”. In Machadinho, an important proportion of farm households having a home in the local town, and the share of individuals engaged in off-farm employment and out-migration reinforce this challenge in the contemporary Amazon. In this regard, we suggest that future research in the study area must assess how rural changes are related to urban changes and the potential impacts on regional development and infrastructure building on land use and land cover changes.

Table 1 - Descriptive statistics of farm households and individuals in Machadinho D´Oeste according to survey and dimension of analysis

Dimension of analysis	Variable	Survey				
		1985	1986	1987	1995	2010
Sample characteristics	Number of farm households	285	542	817	1079	259
	Number of individuals in the plot	1,697	2,608	3,961	5,025	914
	Mean household size	6.0	4.8	4.8	4.7	3.5
Markers of farm household life cycle	mean farmland per people (ha/ hab)	17.5	12.7	11.7	11.6	15.6
	population age 12 or less (%)	40.2	40.6	39.6	34.0	18.2
	population age 13 to 24 years (%)	24.6	23.1	24.3	27.3	23.4
	population age 25 to 49 years (%)	28.8	29.8	29.1	29.1	31.5
	population age 50 or more (%)	6.4	6.5	7.0	9.6	26.9
	mean age of head of household (years)	39.3	39.9	39.9	42.3	52.2
	mean age of spouse of the head (years)	33.5	33.3	34.2	35.9	45.7
	land in pasture (%)[a]	70.1	27.0	22.0	34.0	N.A.
	land in annuals and perennials (%)[a]	10.3	52.9	62.8	49.5	N.A.
	farm households owning cattle (%)[a]	N.A.	6.8	14.1	64.5	85.3
	farm households hiring laborers (%)	N.A.	30.3	29.7	N.A.	44.0
Human Capital [a]	heads with more than 4 years of education (%)	12.7	9.4	5.2	11.9	33.9
	individuals in off-farm employment (% age 14 or more)	3.5	4.7	4.2	2.0	16.4
	sex ratio	1.3	1.3	1.3	1.3	1.2
Physical Capital*	mean plot size in hectars	105.1	60.8	56.1	54.8	54.7
	mean number of heads (cattle) in all plots	N.A.	0.2	8.8	12.2	92.4
	head own the plot in Machadinho (%)	90.8	99.1	88.4	76.7	90.2
	own other rural plots (%)	N.A.	15.9	8.2	20.4	32.4
	ownership of land / house in the city (%)	N.A.	N.A.	13.9	12.8	16.2
	access to electricity (%)[c]	virtually null	virtually null	virtually null	virtually null	virtually all
Financial Capital	households receiving governmnet cash transfers (%)	N.A.	N.A.	N.A.	N.A.	56.0
	households with credit or loans (%)	N.A.	N.A.	N.A.	18.4	47.3
	households receiving support from out-migrants (%)	N.A.	N.A.	N.A.	N.A.	17.4
Natural capital	land in primary forest (%)	19.7	20.2	15.2	16.5	N.A.
	households with good accessibility to water (%)[d]	16.4	32.1	45.5	72.0	83.6
	households with extractive products (%)[e]	N.A.	29.7	24.6	19.9	9.0
Social capital	heads born in South/Southwest Brazil (%)	86.8	65.5	67.8	70.1	70.5
	households with out-migrants in the last 5 years (%)	N.A.	N.A.	N.A.	N.A.	30.1
	households with at least one international out-migrant (%)[f]	N.A.	N.A.	N.A.	N.A.	13.5
	nuclear family - parents and sons only (%)	74.0	83.2	80.5	84.4	76.4
	vertically extended family (%)[g]	9.1	3.9	4.7	5.8	14.2
	plots with other households (%)	N.A.	N.A.	19.3	N.A.	32.6

[a] Land use and cattle variables are simultaneously markers of stage in farm household life cycle and indicators of physical capital. The Variables for 2010 are under construction using remote sensing.

[b] Euclidean distance from the plot centroid to the town centroid.

[c] Qualitative estimates from field observations.

[d] Well in the plot, pumped water or piped water. In 2010 this variable was estimated from The Brazilian 2010 census data.

[e] It refers, berore 2010, to the existence of seringas (rubber tree); in 2010, to seringas, apiculture and fish ponds.

[f] Living at the household or abroad at the date of survey. Total of 50 international out-migrants identified, in 35 households.

[g] Farm households cohabited by at least grandsons and grandparents.

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