The “Population Factor” and Deforestation in Brazilian Amazonia: Towards a Mediating Perspective[1]

John Sydenstricker-Neto
Department of Development Sociology
Cornell University
jms56@cornell.edu

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Abstract
Although significant progress in our understanding of the dynamics of land-use and land-cover change (LUCC) has been made, human population pressure continues to be portrayed as the major factor affecting forest destruction. This paper assesses the importance of the “population factor” as a cause of deforestation in Machadinho D’Oeste, Rondônia, Brazilian Amazonia. The analysis draws from multiple data sources (i.e. demographic census, household survey, land-cover maps, and in-depth interviews) and different methodological approaches (i.e. fuzzy sets statistics, remote sensing/GIS analysis, and interpretivist qualitative approach). The paper contends that a full account of the complex web of drivers involved in tropical deforestation needs to go beyond demographics *per se*. The paper shows that social structure and mediating factors such as cultural aspects and human capital involving education, managerial skills, previous rural experience, and integration to the local and regional contexts mediate migrants’ relationships with the local environment.

INTRODUCTION

As the saying goes, “where there is smoke, there is fire.” And one could add, “where there is fire, there is clearing; and where there is clearing, there are people” (*onde há fumaça há fogo;”* e *“onde há fogo, há derrubada e onde há derrubada, há gente*). In Brazilian Amazonia, a comparison between protected areas such as parks and reserves – Amerindian, extractive, and biological – and areas that have been more intensively occupied show that this saying holds true. Areas that have remained relatively inaccessible to people have a higher proportion of standing forest. The municipality of Machadinho D’Oeste (Machadinho) in Rondônia illustrates the case.

In the mid 1980s, Machadinho became known as a government-sponsored colonization area for small-scale farmers in a region of primary forest with almost no environmental disturbance at that time. The settlement project combined a grid of land parcels and blocks of forest reserves, which became extractive reserves in the mid 1990s.

Visual inspection of land-cover maps for the area reveals that forest reserves have remained almost entirely preserved. Figure 1 presents data on deforested area in 1999 and population size for 2000 at the census tract level. The twenty-one census tracts cover a total of 302,276 ha in the rural area and are home to over 10,000 people. Deforestation was estimated

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from Landsat satellite imagery, and demographic data was taken from the 2000 census. The census tract data were then sorted according to population size. The data show that as human population increases so does deforested area, with a strong correlation between the two variables (Pearson correlation equals 0.74, significant at the 0.01 level).

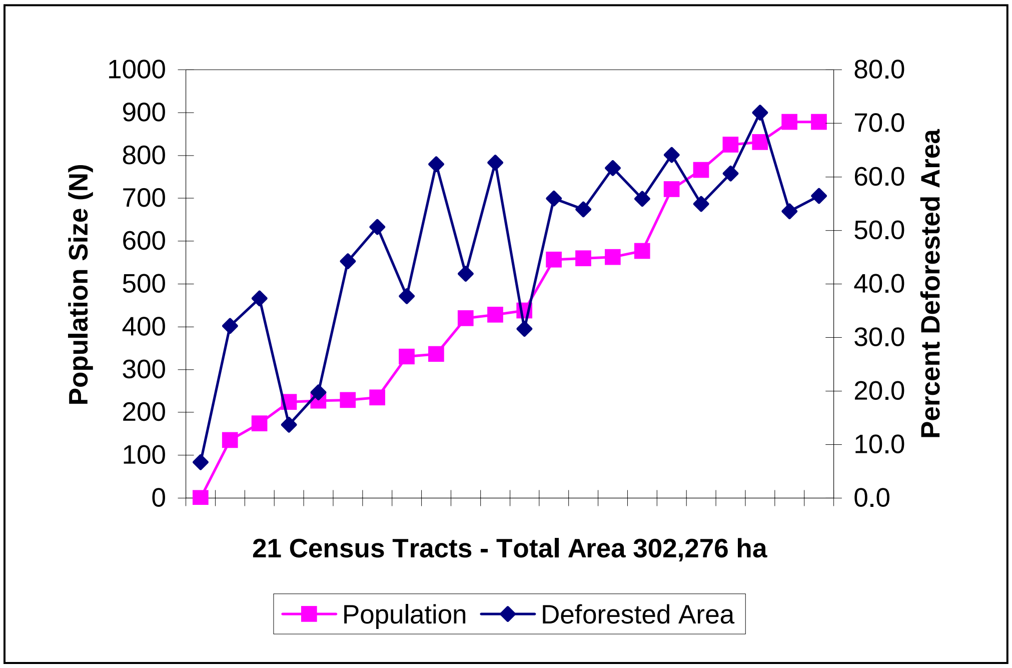


Figure 1 Population Size and Percent Area Deforested, 1999-2000

This example is just one among others for Amazonia and the data clearly show that population size matters. Generalization of findings such as the above can lead to the conclusion that population size is beyond doubt *the* driving force in deforestation in the tropics. This evidence has to be taken with caution, however. If for no other reason, caution is recommended because direction of causation is not established. Does human population size put pressure on deforestation or once an area is deforested does this area attract a growing population?

Even though several studies have correlated population size, growth or density with degradation of natural resources (Allen and Barnes 1985; Cropper and Griffiths 1994; Cropper et al 1999; Myers 1984), scholars are increasingly questioning these findings. The methodologies used in studies, including issues such as geographic and temporal scales, limited number of variables incorporated into the models and chain effects and feedbacks not taken into account, are at the root of heated debates. Also, it has been stressed that population is an endogenous factor and population migration occurs as a response to economic incentives.

Pfaff (1999), in a county-level analysis of Brazilian Amazonia for the period 1978-1988, found that population density was not a significant variable to explain deforestation for the region as a whole. Dimensions such as space and timing of population settlement, however, emerged as important factors to be taken into account. His major conclusion was that in-migration into “empty-counties” had significantly more impact on the environment when compared to the same absolute population increase in previously occupied areas.

These spatial and temporal dimensions gain new meaning when population is treated beyond synoptic measures such as size, density or growth. Looking at population more broadly taking into account its dynamics (i.e. migration, age structure, household composition, and marital status) becomes even more meaningful if analyzed at the parcel level, the *locus* of decisions that ultimately determine the fate of standing forests.

Sydenstricker-Neto and Vosti (1993) found that during the initial stage of parcel development in new areas such as Machadinho, the male household labor force was extremely important and hired labor did not play a relevant role. Deforestation rates were directly linked to the number of adult males residing on the parcel. Male labor force was key for establishing production systems involving the raising of small animals and obtaining the first harvest of subsistence crops. Males were also instrumental in ensuring minimum conditions for moving the family to the parcel. Data for the first year after receiving the parcel (1984-85) show a highly skewed initial age/sex structure distribution of household members and very rapid change in household composition. In one year, the sex ratio dropped from 3.2 to 1.3 and the proportion of head of households and teenager sons decreased from 87% to less than 50%. A decrease of more than ten years in the average age of household members and the jump in household size from 2.1 to 4.5 during the same period highlight the reunification of the nuclear family.

The importance of period, cohort, age, and gender effects on environmental change and land-cover at the parcel is captured by a model on the life cycle of households in the frontier proposed by McCracken et al. (1999). As households aged, moving from a nuclear family with small children to older households with young adult siblings or extended multi-generational households, land-use tends to change too. Conversion of forest gives way to pasture or annual/perennial crops as a result of availability of labor force. Using cross-sectional data McCracken et al (2002) validated the model and also confirmed the importance of the household labor force *vis-à-vis* hired labor, between 84-93% and 7-16%, respectively. Brondízio et al. (2002) using the same data and focusing on deforestation trajectories over time demonstrated that deforestation rates peak during the first five years, which is followed by a decrease and a subsequent peak four or five years later. This trajectory created a wave pattern or a "colonist footprint," which was very similar among various cohorts with different dates of arrival on the parcel along a period of approximately 15 years.

From the above discussion, it is clear that the neo-Malthusian approach is not the sole and best framework to capture human population-environment relationships. In this paper, I contend that population matters but the population factor cannot be confined to the pressure of human bodies over finite natural resources. A better account of population-environment relationships emerges if these relationships are conceptualized as being mediated by economic, social, cultural, and institutional factors.

CONCEPTUAL FRAMEWORK

Several frameworks conceptualizing society-environment relationships assume separation between society and nature. To overcome this dichotomy, Freudenburg et al. (1995) propose the concept of *conjoint constitution*, which contend that "nature and society give rise to one another." As these authors write, "what have been commonly been taken to be 'physical facts' are likely in many cases to have been shaped strongly by social construction processes, while at the same time, even what appear to be 'strictly social' phenomena are likely to have been shaped in important if often overlooked ways by the fact that social behaviors often respond to stimuli and constraints from the biophysical world" (Freudenburg et al 1995:366).[2]

The concept of *conjoint constitution* draws from the sociology of science and the fuzziness in clearly distinguishing the boundaries between physical facts and social definitions (Pickering 1996). But this does not mean subscribing to the notions of material agency and symmetry between physical/environmental and social factors (Freudenburg et al 1996). From an analytical and an empirical point of view, specific contexts can offer cases in which social or physical aspects could play a greater role in defining the outcomes. The point to be made is that in any given situation *both* social and physical aspects are present and they are *mutually constituted*, not leaving space for sociological determinism or biological reductionism.

Freudenburg et al. (1995) conceive of technology as mediating biophysical and social factors of the society-environment equation. This offers an opportunity to integrate the concept of *conjoint constitution* with other frameworks examining society-environment relationships. This is particularly the case of the *mediating perspective* used by demographers to capture population-environment relationships (Marquette and Bilsborrow 1994; 1997).

Hogan (1992:109) "recognizes how little demography has advanced beyond Malthusian arithmetic, when the relationships between population and the physical environment are considered." Indeed, the linear perspectives on population-environment relationships outlined by Malthus on the one side and by Boserup on the other still pretty much define the population-environment debate. This debate was popularized by the confrontation between Paul Ehrlich (1968; Ehrlich and Ehrlich 1974) and Simon (1981; 1990; 1996). While, Ehrlich has portrayed human population growth as a threat and offered the powerful metaphor of a bomb to explode in a foreseen future, Simon has argued for population as the greatest resource, as the source of ingenuity in identifying means to avoid possible overshoots.

As Marquette (1997) notes, Boserup does not entirely reject the Malthusian argument as she acknowledges that populations adapt to their environment. However, she conceives this relation mediated by technology. There have been some efforts to overcome the Malthus-Boserup divide, showing their complimentary positions (Bilsborrow 1992; Lee 1986).

Bilsborrow and Okoth Ogendo (1992), drawing from Davis' (1963) work, have proposed a multi-phasic approach to land-use change due to rural population growth in developing countries. Although Bilsborrow and Okoth Ogendo mention that four phases could be consecutive, concurrent, or cumulative and include adjustments, their original proposition states the phases consecutively. In order to cope with population growth, a given area would undergo changes in tenure regimes (phase I), extensification of agricultural area by incorporating more land into production systems (phase II), intensification of production through technological innovation (phase III), and demographic responses through fertility decline and out-migration (phase IV). Fertility decline emerges as the ultimate resource after the failure of all other alternatives (Bilsborrow and Carr 2001).

Although this framework advances the understanding of land-use change and population growth, it has some shortcomings. More generally, these authors are reluctant to fully incorporate the mediating factors into their analysis, which is the most innovative aspect of approach. They remain a tributary of a population-driven explanation, in which "the effects of

[2] Although the concept of *conjoint constitution* has not prompted an animated response from environmental sociologists, it has clear parallels with other theoretical efforts in the subfield. This includes efforts within ecological Marxism (Goldman and Schurman 2000) and the concept of co-evolution of society and nature outlined by Redclift and Woodgate (1994).

population growth, migration movements and their implications for population density and population quality [?] – cumulate inexorably over time, and create pressures for change in land-use patterns in rural societies" (Bilsborrow and Okoth Ogendo 1992:39). The framework is also dated or more fully addressed to traditional settings in regard to demographic processes and economic expansion.

In regard to migration, it does not consider more dynamic and complex processes involving other forms of migration such as return, commuting, circular, permanent, and temporary (Curran 2002). It also does not qualify the out-migration, which reduces numbers but is very likely to mean drainage of skilled and more prepared individuals (Taylor and Garcia-Barrios 1999). Considering fertility, cultural resistance to fertility decline is no longer the rule in many areas worldwide. More specifically, high fertility as a response to context specific conditions and incentives in rural settings with available land as proposed by Easterlin (1976) is no longer the case in frontier areas in Brazilian Amazonia (Fonseca 1990; PNUD et al 2003; Sydenstricker-Neto 1990).

The approach targets more traditional settings in which the rural-urban, settled-frontier dichotomies are pretty much in place. With expansion of transportation and communication networks and market integration, these dichotomies are rapidly loosing their explanatory power to understand rural-urban interface. Also, the framework places greater emphasis on economic processes and the biophysical context, leaving significantly less room for other important factors such as culture, social organizations, and institutions not directly related to land tenure and access to land.

Despite the elegance of models measuring population as population size, density or rate of growth, these measures are not sufficient. Demographic dynamics more broadly defined including population characteristics such as nuptiality, household structure, migration, and rural-urban linkages are important but remain just a piece of the explanation. It is important to recognize that population-environment relationships are mediated and shaped by socioeconomic, cultural, political, and institutional factors (Arizpe and Velásquez 1994; Bilsborrow 1992; Hogan 1992; McNicoll 1990; Schmink 1994).

A full account of population-environment relationships, including quite varied linkages and quite complex underlying dynamics has to place the demographic dynamics of a given human population in the specific biophysical and historical context. By doing so, one assesses how historically grounded local social relations and specific conditions of natural resource systems jointly shape the ways in which population-environment relations occur. This approach allows uncovering the population-environment interconnections in terms of their *conjoint constitution* (Freudenburg et al 1995).

The *mediating perspective* approach has been the target of several criticisms. One of the criticisms worth noting is the ambiguity of the *mediating perspective* approach in clearly spelling out and quantifying the causal mechanisms informing population-environment interactions. To a certain extent, this is still a challenge if one is restricted to a quantitative approach and does not include other sources of data and research tools in a study. However, there is currently sufficient evidence supporting the *mediating perspective* approach. The series of studies on population – development – environment (PDE studies) conducted by researchers at the International Institute for Applied Systems Analysis (IISA) in Austria is an example and the Mauritius study is the first and most well-known of these case studies (Lutz et al 2002).

Mauritius in the Indian Ocean was the object of a landmark study on population-environment interactions (Lutz 1994). Researchers from IISA developed complex quantitative models to understand and project scenarios addressing population, development, and the environment in this island nation. As researchers acknowledge, the models are far from including all relevant variables and they tested a selective number of scenarios. However, the simulations show the importance of education, health status, family planning, empowerment of people, and general accountability in shaping the outcomes. The results leave no doubt about how social, economic, institutional, and cultural factors mediate the population-environment equation and set the basis for moving or not towards more sustainable paths.

STUDY AREA AND POPULATION PROFILE

Established in 1988, the municipality of Machadinho D'Oeste (8,500 km^2) is located in the northeast portion of the State of Rondônia, western Brazilian Amazonia (Figure 2). The village of Machadinho D'Oeste is 150 km from the nearest paved road (BR-364 and cities of Ariquemes and Jaru), and 400 km from Porto Velho, the state capital. When first settled, the majority of the area was originally composed of untitled public lands. A portion of the area also included old, privately owned rubber estates (*seringais*) (Sydenstricker-Neto 1992).

The most recent occupation of the region occurred in the mid-1980's with the development of the Machadinho Colonization Project (P.A. Machadinho) by the National Institute for Colonization and Agrarian Reform (INCRA). This settlement was part of the Settlement of New Areas Project (POLONOROESTE III) sponsored by the World Bank. Compared to other settlement projects in Amazonia, the P.A. Machadinho has a better infrastructure and network of public services.

In 1984, the first parcels in the south of the municipality were delivered to migrant farmers. Since then the area has experienced recurrent migration inflows. From hundreds of inhabitants in the early-1980's, Machadinho's 1986 population was estimated to be 8,000 and in 1991 it had increased to 16,756. In 2000, the demographic census counted 22,739 residents, which represents a 3.5% annual population increase during the decade. Although Machadinho is an agricultural area by definition, 48.3% of its population lives in the major city or villages (urban area). In 1986, the city of Machadinho had an estimated population of 2,900 reaching 9,678 inhabitants in 2000 (IBGE 1994; 1998; Sawyer and Sawyer 1987)

Despite the importance of colonization in Machadinho, about 32% of the municipality is fairly well preserved. This area is designated for conservation purposes by the state-zoning plan. Natural resources can only be extracted through previously approved sustainable management plans (Rondônia 2000). Within the area for conservation purposes, there are forest reserves, mainly extractive reserves comprising over t 1,600 km^2 or almost 19% of the area of the municipality. Most of the reserves became state extractive reserves in 1995 and almost their entire area is covered with primary forest (Olmos et al 1999).

In biophysical terms, Machadinho's landscape combines areas of altiplano with areas at lower elevation between 100-200 m above sea level. The major forest cover types are tropical semi-deciduous forest and tropical flood plain forest. The weather is hot and humid with average annual temperature of 24° C and relative humidity between 80-85%. A well-defined dry season occurs between June and August and annual precipitation is above 2,000 mm. The soils have medium to low fertility and most of them require high inputs for agriculture development (INCRA and RADAMBRASIL 1985; Wittern and Conceição 1982). Timber extraction is an important business in the area, but agricultural production, mainly coffee, is the most important source of revenue. Although there have been material conditions and opportunities for Machadinho to move towards a more environmentally sound development model, production systems have been more aligned with traditional agriculture practices based on pastureland and monoculture. His has led to some land consolidation.

The specific study site examinedin this paper is the first phase (119, 400 ha, land tracts 1 and 2) of the former P.A. Machadinho occupied in 1984 and 1985 (Figure 2). These two land tracts are composed of multiple land uses of which 3,000 ha are designated for urban development, 35,165 ha are in state extractive reserves, and 81,235 ha are divided into 1,742 parcels (average size 46 ha) distributed to in-migrant small-scale farmers by INCRA (INCRA Rondônia. Divisão de Cartografia 1985). With the creation of the municipality of Vale do Anari in 1994, the Aquariquara Extractive Reserve with 18,100 ha and over 72% of the parcels in land tract 1 became part of the established municipality of Vale do Anari.

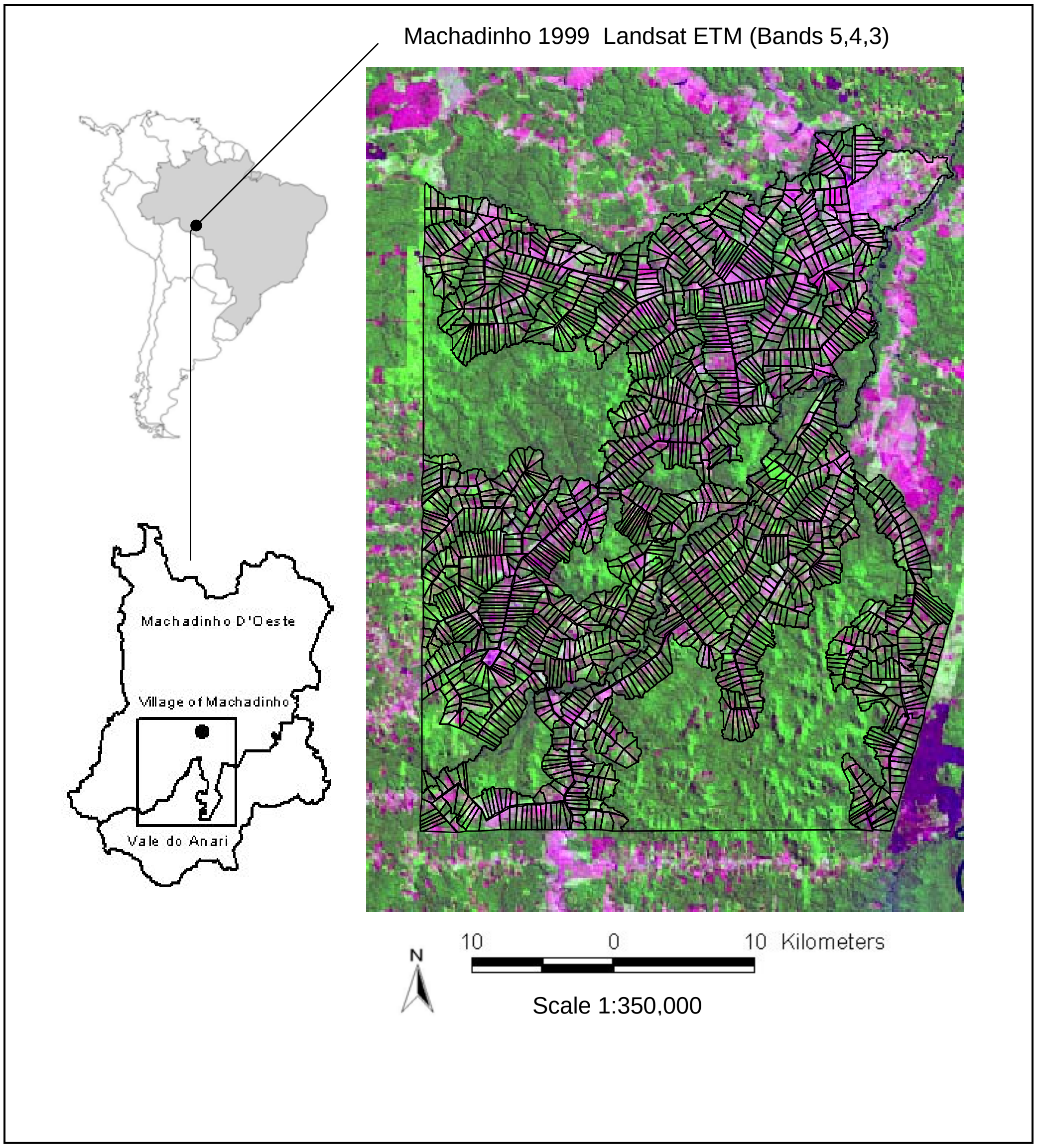


Figure 2 Study Site, Land Tracts 1 and 2, Machadinho D’Oeste Rondônia

The socioeconomic and demographic profile of the studied population is representative of the population in Machadinho and similar to the profile of other colonization areas in Rondônia and Amazonia in general. Table 1 presents characteristics of the studied population in 1995, approximately 10 years after the initial settlement of the area. The population is young and organized in nuclear family households. The average age is 23.1 years, almost 40% of the population is within the 0-14 years age group, and almost 10% are senior citizens (60 years and above). Households have on average 4.7 persons and are inhabited by a nuclear family.

Table 1 Studied Population – General Characteristics, 1995

Selected Variables	
Average age - total population (years)	23.1
Average household size (persons)	4.7
Population in selected age groups (%)	
0 – 14 years	39.8
15 – 59 years	50.6
60 and + years	9.6
Sex (%)	
Female	43.8
Male	56.2
Education of household head (%)	
Illiterate	33.4
1 – 3 years	33.1
4 and more years	33.5
Average number of years of schooling	2.3
Education of household spouse (%)	
Illiterate	30.5
1 – 3 years	27.7
4 and more years	41.8
Average number of years of schooling	3.2
Community Participation (%)	
Any community organization	38.8
Church	15.6
Farmers' association	13.9

Source: (CEDEPLAR 1995)

There is a somewhat higher proportion of males (56.2%) resulting in a sex ratio of 1.28 for the total population, which is much lower than ratio of 3.2 in the first year of settlement (Sydenstricker-Neto and Vosti 1993). In general, household heads and spouses have low formal education – an average of 2.3 and 3.2 years of schooling, respectively – but there are significant differences among spouses. At the same time illiteracy is as high as 33% for household heads, the same proportion of them have four or more years of schooling. Among the spouses, 42% have four or more years of education. Although a source of debate, high levels of illiteracy might explain in part the limited participation in community organizations in Machadinho.

As in any new colonization area, community organization started from the beginning and has increased over the years. In 1995, 38.8% of the households had at least one of its members actively engaged in a community (or local) organization. These organizations include mainly rural labor unions, neighborhood associations, parent-teacher associations, churches, small-scale farmers' associations, and other interest groups such as recreational and women's clubs. In terms of participation, the two most important local organizations are churches and small-scale farmers' association, with participation of 15.6% and 13.9% of households, respectively.

Migration data for household heads show that more than half of the household heads came to Rondônia from the developed south or southeast regions of Brazil. The most representative states in these sending regions are Paraná (South) and Espírito Santo (Southeast), home for 39.6% and 9.6% of interviewees, respectively. The state of Mato Grosso in the Central-West region of the country is also an important source area mentioned by 14.1% of interviewees (Table 2).

Table 2 Household Heads – Migration History, 1995

Selected Variables	%
State of origin	
Paraná (South)	39.6
Mato Grosso (Central-West)	14.5
Espírito Santo (Southeast)	9.6
Other states	36.3
Total	100.0
Rural experience	
Lived +1 year rural area	92.1
1 year or never	7.9
Total	100.0
Urban experience	
Lived +1 year urban area	57.4
1 year or never	42.6
Total	100.0
Larger city where has lived	
Larger than 100,000 inhabitants	56.1
50,000 to 99,000 inhabitants	25.9
Smaller than 50,000 inhabitants	9.6
Never lived in a city	8.4
Total	100.0

Source: (CEDEPLAR 1995)

Settlers combine rural and urban experience prior to Rondônia. While almost all settlers (92.1%) had lived for more than a year in the countryside before they migrated to Rondônia, more than half (57.4%) of them had also lived in an urban area. These urban areas include metropolitan areas with more than 1 million inhabitants. Cities with more than 100,000 inhabitants were mentioned by 56.1% of those with an urban experience and less than 10% lived in cities with fewer than 50,000 inhabitants.

DATA SOURCES

Data used in this paper are from four major sources. The 2000 demographic census was used to extract population size at the census tract level. The three primary data sources are: land-cover maps (1986-1999), a household survey (1995), and in-depth interviews (1986 and 2001).

Data on land-cover change are from the maps for 1986, 1994, and 1999 generated from Landsat imagery in a supervised classification approach using a maximum likelihood algorithm. The final land-cover classification scheme used in the maps includes seven categories: primary forest, secondary forest, transition, pasture, crops, bare soil, and water. Local communities participated in the process of producing the maps and accessing map accuracy. Land-cover change mapped from image classification fits the pattern of transition in forest cover in new settlement areas. Overall accuracy for each year ranged between 85 and 95% (Kappa 0.52-0.78) (Sydenstricker-Neto et al 2004).

The primary source of quantitative socioeconomic data is a household survey conducted in 1995 in the study site by the Center for Regional Planning (CEDEPLAR), Federal University of Minas Gerais (UFMG), Brazil (CEDEPLAR 1995). The 1995 household survey is a ten-year follow-up survey of the project "Malaria on the Amazon Frontier" (Sawyer and Sawyer 1987). Although the study focused on malaria, questionnaires incorporated a variety of other issues, including household size and composition, literacy, population mobility, migratory history, labor force, income, land use, agricultural production, livestock, farm infrastructure, parcel microenvironment, housing conditions, and available services. One of the limitations for my study was that the questionnaires did not have specific variables on environmental attitudes and behavior.

In 1995 a total of 1,130 questionnaires were administered and 5,265 individuals interviewed. In the survey, the household, not the parcel, was considered the unit of analysis. In this paper the parcel is the unit of analysis and only the primary questionnaire in each parcel is considered (N= 973). This primary questionnaire summarizes land-cover and agricultural practices for each parcel. Data on population size and number of adults living on the parcel was calculated taking into account all survey questionnaires (Sydenstricker-Neto 2004).

Qualitative data derive from in-depth interviews I conducted in 1986 among 24 farmers living in the study site. These interviews were part of a research project examining family arrangements, human fertility, and settlement strategies in the agricultural frontier (Sydenstricker-Neto 1990; 1992). In 1999 and 2001, I interviewed a sub-sample of the group of families studied in 1986.

METHODS AND HYPOTHESES

I adopted a mixed-method approach to integrate the multiple data sources mentioned above and the different methodological approaches outlined below. The mixed-method component design stressed triangulation and complementarity but there was also interaction between phases and instruments (Caracelli and Greene 1997; Greene and Caracelli 1997).

The statistical analysis presented in this paper uses fuzzy sets. Fuzzy sets analysis is a statistical approach to systematically representing vague, imprecise, and heterogeneous. It is appropriate to representing transitions and continua, offering better outcomes than models using crisp or discrete categories such as cluster analysis, and linear and logistic regressions. For instance, in a landscape it is somewhat arbitrary the distinctions between a pasture, a bushy pasture, and secondary forest re-growth. In an educational process, although graduation is a benchmark, development of skills and professional maturity is an incremental process. Fuzzy sets analysis is better suited in contexts where constructs have many dimensions represented by several variables.

I used the fuzzy set model known as "Grade of Membership" (GoM) developed by Woodbury and Manton, Center for Demographic Studies (CDS), Duke University (http://www.cds.duke.edu/). This approach and the original software to implement GoM analysis were developed in the 1970s and initially applied to analysis of medical diagnosis systems (Woodbury and Manton 1982; Woodbury et al 1978). Over the years GoM has been applied to fields such as psychology, gerontology, demography, remote sensing analysis, climatology, and forestry (Berkman et al 1989; Davidson et al 1988; Lamb 1996; Piccinelli et al 1999; Portrait et al 1999; 2001; Talbot et al 1999).

The GoM model is based on maximum likelihood principles for estimating parameters and assessing goodness of fit. Sample units referred to as i (i = 1,2,…n) are divided into subgroups known as "*pure types*" and referred to as k on the basis of shared similarities and dissimilarities towards other pure types. In this sense, it is a close parallel to conventional cluster analysis. The remarkable difference from cluster analysis, however, is that GoM does not assign sample units to a single subgroup. On the contrary, it assigns a score (g_{ik}) to sample units describing their degree of membership to each pure type. The GoM membership score (g_{ik}) varies from zero to one ($0 \leq g_{ik} \leq 1$) and sum to one for a sample unit ($\sum_k g_{ik} = 1$) (Manton et al 1994; Woodbury and Manton 1989).

One of the GoM outputs is the *GoM report*. The *GoM report* is a table showing all the statistics for the model. This includes a list of all variables in the model and the coding scheme, the frequency distribution including missing cases for each and every category also known as marginal frequency, and the parameter estimates. The parameter estimates, also known as lambda (λ) represent the probability that a specific category of a variable is contributing to the definition of a given pure type. Objective criteria define the statistical significance of GoM outputs (Woodbury et al 1978). A detailed description of the specific criteria I used to determine statistical significance can be found in Sydenstricker-Neto (2004:126-32)

The full GoM deforestation model used in the broader research this paper is based on Sydenstricker-Neto (2004) is a four pure type model with 40 variables extracted from the household survey and land-cover map and generated from geographic information system analysis. The variables are divided into four major constructs: production systems (land-cover and land-use), biophysical and spatial characteristics of the parcel, population dynamics, and mediating factors (culture, human and social capital, and socioeconomic status). This model resulted from extensive exploratory work and was the best model based on consistency and greater interpretability. This paper presents and discusses results on land-cover, population dynamics, and selected mediating factors. All variables but the ones on land-cover were extracted from the household survey.

Land-cover variables were derived from satellite imagery and include deforested area, area in pasture, and area in crops. The three variables were measured in hectares (ha).

Population dynamics was examined using three variables: total population on the parcel, number of adults in the household, and age of household head. Number of adults is a proxy for available labor force and age of the household head is a proxy for family lifecycle and long term perspectives regarding investing in the parcel. I hypothesized that availability of labor force and perspective of settling in the area would concur with developing the parcel and establishing agrosilvoralpastoral systems less dependent on a purely extractive economy.

A thorough examination of the entire range of factors mediating population-environment relationships was beyond the scope of this paper. Therefore, I restrict myself to a selected number of factors providing evidence of the spectrum of issues. For the mediating factors, I examined socioeconomic status and economic performance of the household broadly defined and cultural aspects and human capital of the household head.

Socioeconomic status and economic performance broadly defined were measured with four variables. I hypothesized that economic status and access to financial resources would hold a positive relation to deforestation and expansion of agrosilvopastoral activities.

Quality of the dwelling was used as a proxy for quality of life. It is a linear scale summarizing quality of walls, ceiling, and roof. Total annual household income in the previous year (1994-95) was a simple transformation of reported income into number of minimum wages (*salário mínimo, SM*) according to official data (www.ipeadata.gov.br). Contrary to previous decades with high inflation, during the 1994-95 year Brazil experienced annual inflation in the single digit. This allowed easier comparison of monthly wages throughout the year. A scale measuring the amount of farm equipment owned by the settler served as a proxy for available on-the-parcel facilities. There is a strong correlation between having or not a selected list of working tools or basic equipment and farm investments. The working tools/basic equipment included in the scale ranged from fairly simple tools such as a manual planter (*matraca*) to more expensive ones such as a chainsaw or a two-wheel cart.

Access to financial resources was measured by a dummy variable on ever having contracted an agricultural loan while in Machadinho. The great majority of loans in the area were for establishing or increasing areas that were planted with perennial crops (coffee) and farm improvements such as a small barn, a trough, and fences. Some loans also included establishing small areas of pasture or improving degraded ones.

Cultural aspects and human capital were captured with five variables on the characteristics of the household head: formal education, previous landownership, rural background, and number of years in the state and in the colonization area.

Formal education was measured by the number of years of schooling and previous land ownership had a dummy coding. Formal education and previous landownership were means of assessing knowledge and managerial skills that a settler brings into play in the new context, which should had a positive impact on establishing more successful production systems. However, in regard to formal education, I hypothesized that formal education would hold an inverse relation with concerns for the environment. Migrants even if very well educated are little informed or even misinformed about Brazilian Amazonia and its ecological realities. Moreover, although many efforts and genuine initiatives by government agencies and grassroots environmental NGOs, information on local agricultural systems that more closely resemble the forest such as agroforestry systems with native species is still not well known and disseminated.

The variable on rural background was a combined recoding of two variables in the household survey. The final coding allowed assessing the previous rural experience in general terms (having it or not) and if it was in Amazonia. The variables examining number of years living in the state of Rondônia and in the colonization project served as proxy for integration into regional and local culture. I hypothesized that rural background, especially in Amazonia and longer time in the region would contributed to better understanding of local practices and would be likely to lead to less deforestation.

In-depth interviews were analyzed using an interpretivist/constructionist framework (Guba and Lincoln 1989; Schwandt 1994). The category system I used to organize and analyze the data examined the relationships between local organization and management of natural resources (Sydenstricker-Neto 1997). In this piece of my research, I examined complementarities and tensions between contrasting views of human-nature relationships and formation of local alliances and social networks for conservation of natural resources.

RESULTS AND DISCUSSION

GoM Results – Land -Cover

Regarding land-cover, there were dramatic changes in the study site over the 1986-1999 period. The region predominantly covered by primary forest at the beginning of the settlement process was deforested and agropastoral systems – mainly pasture and coffee trees – became the predominant land-use practice. It was estimated a total conversion of 34,358 ha of primary forest or 52.8% of the total area covered by the parcels in the study site (79,061 ha).

Closer examination of deforestation patterns in the study site suggests a continuum regarding deforestation ranging from parcels mainly covered in primary forest and little "development" to parcels in which pasture dominates and few remnants of primary forest are left. This empirical evidence and other analyses offer a basis to contrast land-cover (measured by area in primary forest) and land-use (measured by area in agriculture) as a means to conceptually approximate the deforestation continuum and propose profiles of farmers.

The GoM model separated farmers in four distinct groups (pure types). There is a clear and solid break of categories for area deforested, area in pasture, and area in crops for each of the four pure types in the model. This break is consistent with the deforestation continuum. Deforested area is uniquely identified for three pure types with probabilities of 100% in different categories. The exception is *pure type II*, but still with strong results fitting the general trend of increasing deforestation from *pure type I* to *pure type IV*. Table 3 presents land-cover data. Shaded cells represent statistically significant results according to criteria outlined in Sydenstricker-Neto (2004:126-32).

Pure type I, the *forest farmer* is well defined with less than 10 ha of deforested area and the smallest areas in pasture and in crops, mainly perennial (coffee). Available data does not allow me to contend that this farmer uses the forest sustainably and is proportionally less dependent on commercial agricultural systems. At the other extreme, *pure type IV* represents farmers with 20 ha or more of deforested area and the largest area in pasture (≥ 5ha) and in crops (≥ 6.25 ha) as well. While *pure type IV* definitely includes *ranchers* with most if not all of their parcel area devoted to pasture, farmers with larger areas with coffee trees are also part of this subgroup. Therefore, *pure type IV* is named the *rancher/coffee farmer*.

The middle groups (*pure types II and III*) fit the deforestation continuum as well. However, characterization of these types in regards to area in pasture and area in coffee is somewhat blurred. Independently of statistical significance, the cases are dispersed into two and three categories out of a total of five. Take for instance *pure type III*.

Table 3 GoM Results – Land-Cover

Variables	**Marginal Frequency**	**Pure Types**			
		I *Forest*	**II** *Transition*	**III** *Diversified*	**IV** *Ranch/coffee*
Area Deforested – ha					
0 - 9.99 ha	16.86	**100.00**	0.00	0.00	0.00
10 - 14.99 ha	24.67	0.00	**76.00**	0.00	0.00
15 - 19.99 ha	23.54	0.00	24.00	**100.00**	0.00
20 ha and +	34.94	0.00	0.00	0.00	**100.00**
Area in Pasture – ha					
0 - 1.24 ha	22.30	**100.00**	0.00	0.00	0.00
1.25 - 2.49 ha	18.40	0.00	**49.00**	29.97	0.00
2.50 - 3.74 ha	14.39	0.00	**51.00**	0.00	0.00
3.75 - 4.99 ha	10.69	0.00	0.00	**70.03**	0.00
5.00 ha and +	34.22	0.00	0.00	0.00	**100.00**
Area in Crops – ha					
0 - 2.49 ha	20.66	**98.27**	0.00	0.00	0.00
2.50 - 3.74 ha	18.40	0.00	**57.61**	0.00	0.00
3.75 - 4.99 ha	17.88	0.00	29.42	**52.04**	3.68
5.00 - 6.24 ha	14.29	1.73	12.97	**47.96**	9.31
6.25 ha and +	28.78	0.00	0.00	0.00	**87.01**

In terms of area of pasture, *pure type III* has only one significant category (3.75-4.99 ha) but 30% of the sample units following into this pure type report 1.25-2.49 ha in pasture. With crops, there are two statistically significant groups ranging from 3.74 to 6.24 ha. These results show that some farmers tend to favor coffee and have some area in pasture while others take the opposite approach favoring more pasture area.

Pure type III is distinct from pure type IV in regards to the three land-cover variables. Detailed data on production systems including subsistence farming and husbandry show that pure type III has the most diversified systems of all four types, which led to name it as diversified farmer. In relation to pure type II, it is definitely not a forest farmer having larger areas in pasture and in crops but is a type clearly separated from the other two pure types (II and IV). Considering these outcomes, it is a farmer in transition.

GoM Results – Population Dynamics

The population variables performed as anticipated and separated the pure types as anticipated. Departures are explainable and do not represent inconsistency of the model but rather suggest the complexity of issues involved in explaining deforestation. Results from the three variables portray a consistent trend among them. As population size increases, number of adults in the household and age of head of households also increase. This pattern is seen for the first three *pure types* (*I-III*) with statistically significant outputs for all variables. *Pure type IV* does not follow this pattern, a point to which I come back later. Table 4 presents the partition of probabilities according to categories and the four pure types.

Table 4 GoM Results – Demographic Dynamics

Variables	Marginal Frequency	Pure Types I *Forest*	II *Transition*	III *Diversified*	IV *Ranch/coffee*
Total Population on the Parcel					
1 - 2 persons	15.01	**43.38**	0.00	0.00	14.01
3 persons	12.02	15.46	**27.80**	0.00	6.56
4 persons	16.44	9.60	**40.25**	0.00	20.33
5 persons	17.06	17.20	**31.95**	10.50	9.94
6 persons and +	39.47	14.36	0.00	**89.50**	49.15
Number of Adults in Household *					
1 adult	7.91	**23.29**	1.08	0.00	7.32
2 adults	45.32	42.51	**84.75**	4.27	42.27
3 adults	18.29	16.04	14.17	30.03	13.93
4 adults and +	28.47	18.16	0.00	**65.70**	36.48
*** individuals 15 years and +**					
Age of Household Head					
Missing	0.10	0.41	0.00	0.00	0.00
20 – 24	4.84	**13.80**	0.00	0.00	9.00
25 – 34	22.94	0.00	**73.64**	0.00	0.00
35 – 44	26.23	20.84	19.84	**45.55**	16.68
45 – 54	25.10	31.57	0.00	40.78	36.01
55 and +	20.88	33.79	6.53	13.67	**38.31**

An initial reaction to results on population might be that they support the notion that population size *per se* has a direct positive influence on deforestation. As area deforested increases from *pure type I* to *pure type IV* so does population size. In 1994-95, or ten years after the study site was first settled, the site was not a new area and results cannot be interpreted as *in-migration* to sparsely occupied areas prompting increase in deforestation. Also, my results are cross-sectional and do not provide a temporal dimension, which is a limitation. Even if the trend remained with longitudinal data, this line of thought would be only one piece of the story. For a better account, I need to examine land-cover replacing primary forest and the relationships between the new landscape and labor demands, and not only population size or growth.

As mentioned above, increase in deforested area is followed by a proportional increase in area in pasture and area in crops (mainly perennial and coffee), the two major land-cover after forest clearing (Table 1). Across pure types, this is followed by a systematic increase in available household labor force. Because most parcels have agricultural systems that include both pasture and crops, it is hard, if not impossible, to disentangle the specific impacts of each system.

However, there are striking differences in labor requirement if a same area in primary forest was to be developed and maintained as pasture land or planted with crops.

Pasture requires significantly less labor force. After clearing an area, the major labor requirements are the initial seeding, fencing the area, and building a trough for mineral salt. These are one-time activities with fairly low maintenance requirements. Financially better off farmers also build a small stable where cows are milked. In several cases, fencing and other improvements will not happen right away because farmers will not be able to purchase cattle immediately. This will happen only a year or two after establishing grassland. Pasture is kept with almost no management, even if natural grass is the major fodder for herds. Three factors explain this behavior.

First, there is a misconception that good quality pastureland results from good initial seeding and then annual or bi-annual burning to eliminate weeds and stimulate dense growth. Second, insecticides and herbicides are beyond farmers' means and therefore are seldom, if ever, applied to pastures. Weeds and unwanted plants are a major problem and widespread. Third, use of legumes is not practiced and not seen as worthwhile by farmers. Legumes require labor that goes beyond household labor availability, increase chances of uncontrolled burning during the dry season, and have limited impact on soil fertility. Soils are of poor quality from the start and farmers tend to reserve better soils for crops.

Beef herds are left on their own, feeding themselves on grass with supply of mineral salt, the only outside input. In this context, a man can take care of a beef herd in parallel to other farm activities. Dairy livestock are more time consuming because of daily milking and other care. However, with dairy herds averaging 5.5 head per parcel, labor requirements are well met with the household labor force, including the participation of teenagers (CEDEPLAR 1995).

Crops require significantly more labor force. In more recent years farmers have started to use small tractors or simple plows. Household labor, however, is still the basic and far most important source of labor power used on crop fields. As in many rural settings, in Machadinho not only adults but also children are an important source of labor force.

Children start very early to be involved in activities that range from helping in the house to taking care of small animals. Even if they go to school, they have several tasks to perform and absence in school mirrors increased labor demands in particular times of the agricultural calendar (e.g. harvesting). At the age of 12, male teenagers are following other adult males to the fields and performing labor-intensive tasks such as underbrush clearing and tree felling. Teenage girls, even before this age, are largely in charge of domestic chores and have their share in activities related to farm productive systems *per se*. Although there is a more traditional division of labor based on age and sex in which men take care of the farm and women of the house and its surroundings, it is quite common to see these roles being redefined in response to greater demands of labor for farm work and/or to temporary absence of one of the household members from the parcel.

Labor demands vary dramatically across different crops and types of soil, if the field is newly burned or previously utilized, and other specifics of the area to be planted. As an example of labor demands, I refer to the average tasks involved with maintaining one *alqueire* (2.42 ha) of coffee. This does not include preparatory work in the greenhouse before transferring plants to the field, planting, and replacing dead or sick plants.

Weeding is done two to three times a year, involving on average a total of 15 full days of intensive hand labor. If using herbicides, there are savings in labor time, but a thorough weeding (six days of work) right before harvesting cannot be avoided. Addition of fertilizer and lime and other care such as pruning, ideally performed twice a year according to agricultural extension agents, involves another 12 or more days of work. Harvesting is the most demanding activity and can easily involve up to 20 days, not including hours of turning beans spread on a patio in order to minimally dry them, sacking, storing the bags, and later transporting the bags to the cooperative or local warehouse. Without these additional tasks mentioned above, the amount of labor would add to 47 days.

More diverse systems such as agroforestry systems, some of them combined with commercial perennial crops such as coffee and cacao, involve significantly more time and energy from farmers. Along with establishing the systems and maintaining them, farmers report spending a significant amount of hours in order to have access to seeds and plants. Regional plants and seeds are not easily available in commercial houses or in one single place, and time spent on trips and interactions to get plants and other supplies farmers need is reported as significant. Despite all the time invested, farmers frequently report poor or no success with initiating agroforestry systems with regional species about which they know very little.

Concluding this section, I would like to return to *pure type IV* and examine this type more carefully. Data for this type show no statistically significant outcomes for both variables: population size and for available labor force. However, outputs for this type show that it clearly retains the oldest heads of household with 55 years or more. The major reason for this outcome is that *pure type IV* includes sample units of parcels predominantly with crops and others with the majority of the area under pasture. This leads to confounding results, which were not the case for simpler GoM models.

Closer examination of frequency distribution of sample units falling under *pure type IV* shows that there are two distinct groups. One is formed by households with parents and youth 15 years and older. For this group perennial crops are the bulk of their production systems with a much larger area when compared to the one devoted to pasture. The other group includes couples in their sixties or more experiencing the “empty nest” and farmers with outside activities. Farmers in this second group tend to increasingly move to ranching activities and fewer crops, which is a response to available labor force constraints. These constraints appear because of aging and the family life cycle and/or new arrangements with greater attention of household members to off-farm activities. In all cases, labor demand plays an important role, be it for favoring activities that require labor and can be supplied or switching to less labor-intensive activities more correlated with diminishing resources.

GoM Results – Social Structure and Mediating Factors

Indicators of social structure and social well-being are a matter of debate. In addition to challenges of finding indicators that perform well and are widely accepted by scholars, there is always the problem of data quality. This is also the case in my research and unfortunately the household survey had a limited pool of variables I could draw from for my study. Even though some limitations were imposed by available information, variables capturing social economic status performed as hypothesized indicating a positive relationship with deforestation and expansion of agrosilvopastoral systems. For this discussion, I draw from survey data and qualitative interviews I conducted. Table 5 provides data on these variables.

Total annual household income measured in terms of number of minimum wages (*salário mínimo, SM*) showed an unequivocal trend. The *forest farmer* (*pure type I*) had the smallest deforested area and the lowest income (below two SM). Higher income was among the *diversified and rancher/coffee farmer* (*pure types III* and *IV,* respectively) with values reaching six or more SM or threefold the earnings of the *forest farmer*. It is important to keep in mind that income includes external sources, which is an important component for farmers in the upper income brackets.

Table 5 GoM Results – Social Structure

Variables	Marginal Frequency	Pure Types I *Forest*	II *Transition*	III *Diversified*	IV *Ranch/coffee*
Total Annual Income (SM)*					
Missing	9.66	10.78	9.24	8.97	9.65
Less than 1 SM	16.72	**35.59**	23.22	0.00	0.00
1 - 1.9 SM	20.93	**56.88**	20.40	0.00	0.00
2 - 2.9 SM	16.72	0.00	**48.25**	0.00	0.00
3 - 3.9 SM	14.56	7.53	8.13	15.92	**34.98**
4 - 5.9 SM	13.54	0.00	0.00	**40.03**	**23.93**
6 SM and +	17.52	0.00	0.00	**44.05**	**41.09**
*** number of minimum wages (SM)**					
Quality of the Dwelling (scale)					
Missing	0.10	0.41	0.00	0.00	0.00
3 - 4 points	7.92	**16.21**	**13.92**	0.00	0.00
5 points	15.02	24.46	7.49	**25.92**	3.22
6 points	23.35	16.83	36.61	21.36	17.15
7 points	22.12	26.90	26.39	14.99	19.08
8 points	11.73	9.36	6.52	11.58	**20.23**
9 points and +	19.86	6.23	9.07	26.14	**40.33**

Quality of the dwelling (proxy for assessing quality of life) also showed a similar trend for statistically significant categories. *Pure types I* and *II* remained in the lower level, followed immediately by the *diversified farmer* (*pure type III*). The *rancher/coffee farmer* (*pure type IV*) had the best dwelling reaching the highest scores in the housing scale. In a general sense, these are well-built wooden houses and some of them have screen on their windows. These houses represent a sharp contrast with the most modest ones such as the cabins or small dwellings with mud walls (*taipa*) with large wholes.

In a general sense these most modest dwellings are becoming less seen in the area. As farmers stay for a longer period in the area, they are slowly improving the dwelling and other farm facilities. This explains the spread of sample units among several categories for all pure types (Table 5). Extremely poor farmers are no longer seen either because they were able to develop the parcel and improve their conditions or because they eventually sold their parcels and left the area.

In Machadinho, socioeconomic status of farmers and their ability to maintain their farm as a healthy business was tied to out-of-farm opportunities. In 2000-01, interviews with farmers showed that farm activity by itself was seldom sufficient to provide the needed resources for family livelihood and farm investments. Households with external income sources, particularly if these income sources were stable throughout the year, gave farmers a remarkable edge.

This was the case of households where one of the spouses was an elementary teacher, a bus driver, or had another permanent job in the city. In these cases the dwelling had improvements such as electric power, indoor bathroom and kitchen, running water, and the farm was generally better maintained. In two specific cases of farmers living on the farm (not *ranchers*) I interviewed, external income had become the "investment account."

Basic monthly expenses were covered with farm revenues and the "investment account" provided a safe buffer for emergencies. However, these resources not consumed with ordinary expenses had provided the means for expansion of cropland, building a barn and new fences, acquisition of livestock, and, in one case, purchasing an additional parcel. Having more assets gave these farmers an additional edge when applying for an agricultural loan. One of the farmers was successful in re-negotiating his current loan and was planning to apply for a more substantial one. According to this farmer, with this latitude he was able to expand his production systems and reach a point where he could take advantage of economies of scale.

As the interviews highlighted, in-farm and out-of-farm opportunities also create tensions between competing demands and farmers were not always able to devote the time they wanted to farm activities. But even in these cases, farmers were very assertive about the importance of having a diversified source of income to remain as "successful" small-scale farmers. These cases exemplify the forest-city and rural-urban interconnections engendered with the process of *extended urbanization* (Monte-Mór 1994; 2004).

Regarding mediating factors, as mentioned above I examined formal education, rural background (including previous land ownership) and number of years living in Rondônia and in Machadinho.

Although local inhabitants knowledgeable about Amazonian systems were older and very seldom had a chance to acquire formal education beyond the initial grades in elementary school, results on education provided few statistically significant categories and no clear trend to strongly build upon. This might convey the tenuous and nebulous connections between education, appropriate knowledge, and environmental behavior. Table 6 provides data on education and other variables.

Landownership before arriving in Machadinho (proxy for managerial skills that the settlers bring into play in the new context) showed no significant result across pure types. In 2000-01, however, I was able to reconnect with some farmers I had interviewed and followed since 1986. With 15 years of history and observing how they had developed their parcels, I revisited my 1986 field notes. The trajectory of two of those farmers sheds light on the role of previous ownership.

One farmer had confronted several challenges and was doing poorly. He had sold his first parcel and tried to establish a small business (*boliche-armazém*) with no success. Before his resources were entirely consumed by his business, he traded it for 20 ha of land, about half of an ordinary parcel. The parcel's owner was not interested in developing it fully and wanted to diversify his activities. The deal sounded like the perfect match to both parties. Sr. Antônio later discovered that soil quality of his new land was quite poor compared to his previous parcel. Subsistence crops he was used to growing and managing well did not perform well and he now was left with few alternatives for maintaining a minimum livelihood. He decided not to get an agricultural loan for perennial crops because of his previous negative experience. Hearing his recollection and later revisiting previous records on Sr. Antônio, I noticed that he had always worked for others as a day laborer or a sharecropper on other people's land. He was not familiar with routines and procedures of managing a small business and being his own boss.

Table 6 GoM Results – Mediating Factors

Variables	**Marginal Frequency**	**Pure Types** I *Forest*	II *Transition*	III *Diversified*	IV *Ranch/coffee*
Education – years of schooling					
Missing	0.51	0.48	0.00	0.00	1.64
No education	33.78	37.06	26.11	35.42	37.16
1 year	10.02	12.32	0.00	**18.92**	9.89
2 years	10.23	14.86	9.16	1.64	14.93
3 years	12.91	12.83	8.88	16.26	14.15
4 years	21.38	10.40	**45.78**	15.96	11.48
5 years and more	11.67	12.54	10.07	11.80	12.40
Rural Experience					
Missing	0.31	0.36	0.81	0.00	0.00
No rural experience	7.11	7.74	0.00	0.00	**20.63**
Rur. exp., 1 year	19.59	**54.26**	0.00	0.00	18.99
Rur. exp. Amaz, 1 year	6.49	5.06	3.10	**12.57**	5.87
Rur. exp. Amaz, 2 year s +	66.80	32.93	**96.90**	**87.43**	54.51
Years in Rondonia					
Missing	3.08	3.06	5.70	0.00	3.21
0 - 4 years	6.79	**21.16**	0.00	0.00	0.00
5 - 9 years	17.07	**53.22**	0.00	0.00	0.00
10 – 11 years	20.68	13.16	0.47	**46.98**	26.60
12 – 13 years	14.10	6.18	11.92	13.29	**28.86**
14 – 15 years	15.59	0.00	**29.75**	24.84	13.71
16 – 19 years	13.04	0.00	**29.80**	12.10	15.05
20 years and +	12.73	6.28	**28.06**	2.79	15.78
Years in Machadinho					
Missing	0.92	0.41	1.74	0.00	1.46
0 – 1 year	7.57	**28.62**	0.00	0.00	0.00
2 – 5 years	27.49	35.13	**70.30**	0.00	0.00
6 – 9 years	36.10	36.25	0.00	**69.26**	33.92
10 years and +	28.84	0.00	29.70	30.74	**66.08**
6 – 10 heads	16.36	6.46	19.56	25.18	14.44
11 and more	13.89	5.82	3.16	**36.47**	13.07

The other case was a couple who grew up growing coffee and came to Rondônia to have their own coffee farm. Although the parcel in Machadinho was their first piece of land, they had previously rented tracts of land to farm coffee and explore the area for three to four full harvest seasons. In Machadinho, they were not doing as well as they anticipated and, as Dona Odélia put it, her dream of a "neat and sweet coffee farm" was a distant dream. At the root were severe impacts of malaria, which they had no knowledge about and unanticipated difficulties with coffee production in Brazilian Amazonia. Crop performance was quite distinct from the area they came from due to difference in soil and weather. But taking everything into account, they were making a living and were now able to slowly invest more in the parcel and upgrade the house and farm facilities. When I inquired about what kept them moving despite the challenges, turning them into a "successful case," Dona Odélia referred to never giving up her dream. For her husband, he was convinced that previous skills in running a business, and particularly with coffee trees, gave them an edge to jump the hoops and maneuver around problems they confronted throughout the years.

Regarding rural experience (Table 6), results show that previous background in rural areas and particularly in Brazilian Amazonia are related to deforestation and development of production systems on the farm. It is not surprising to see that farmers with no rural background are the ones with the largest deforested area (*pure type IV*). Among those are the business-oriented farmers pursuing the rancher path not requiring previous knowledge of cropping systems. On the other end, farmers with rural background and more experience in Brazilian Amazonia, are the ones with the more diversified systems (*pure type III*). These systems include pastureland and coffee trees, the largest areas in subsistence crops (i.e. rice and maze), herds (i.e. chicken, swine, and dairy and beef cattle), regional crops (i.e. rubber tree, Brazil nut, and guaraná), and use of fallow.

Number of years in the state and in Machadinho has a limited potential to capture integration into the regional and local culture. Unfortunately, variables such as state/geographic region in which heads of households were born or their previous state/geographic region of residence before migrating to Rondônia did not work and were discarded from the final model. The basic problem with these variables was lack of distribution of cases among all categories. The majority of cases fell in two or three states in the south-southeast of Brazil.

Results on number of years in the state and in Machadinho are difficult to interpret and variable outcomes are mixed. More than integration, results suggest that the longer farmers are in the area, the more likely they are to expand deforested areas. This is clearly the case for data on the number of years in Machadinho and expected as farmers need a minimum number of years to establish a farm and development needs a longer span of time to mature (Table 6).

Qualitative Approach – Mediating Factors

To overcome the constraints imposed by the limited number of variables on environmental attitudes and behaviors on the survey, I used qualitative interviews to go into more depth about issues that are relevant and to qualify results provided by the quantitative analysis presented above. In order to illustrate how culture and other factors mediate farmers' interactions with the environment and development of parcels, I examined more closely the case of two farmers living in neighboring parcels in Machadinho. For this purpose, I integrated data from the 1999 land-cover map, household survey, and in-depth interviews I conducted in 1986, 1999, and 2001 with those farmers.

The settlers on these two parcels had several things in common. First, they were migrants who came to the frontier in search of a piece of land in which they could develop agricultural activities and make a better living. Second, they were both part of the first group of settlers to receive a parcel in Machadinho in 1984-85. In 2001, they were small-scale farmers occupying their original single parcel of about 50 hectares. Third, both household heads were in their sixties and had a household size between four and five, which was between the average household size (4.7) for the total surveyed population. In both cases, there was only one available adult male laborer in the household. Fourth, after more than 15 years living in the area both settlers considered themselves adapted to the region and expected to live on and from the parcel until the end of their lives.

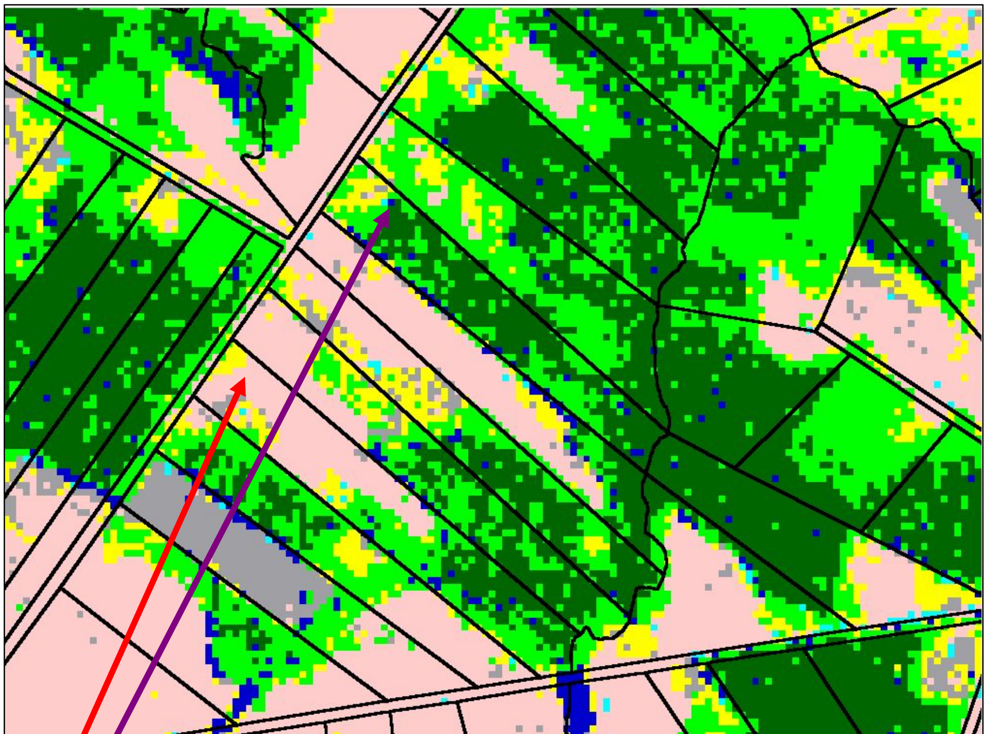
There were also some differences between these two farmers. In socioeconomic terms, Farmer A was married and made a living from the production of their parcel (mainly milk and coffee). Farmer B was divorced and his children spent just part of their time in the parcel. He earned a modest retirement pension that covered a large portion of his basic needs and was supplemented by his farm income.

However, the most remarkable differences between the two neighbors related to how they had developed their parcels and changed the landscape. Figure 3 provides an overview of the lad-cover for both parcels and basic information on them.

Farmer B had more than half of his parcel covered with primary forest, less than 2% in pasture, no herds, and around 6% in various crops including annual subsistence crops, fruit trees, and perennial crops such as coffee and cacao. One third of the parcel was a mix of secondary forest in various stages of re-growth, including a small area in fallow and areas previously cropped and currently semi-abandoned. A significant portion of the area in secondary forest had been enriched with various native species such as hardwood and fruit trees. There was also a small home garden with herbs and medicinal plants.

Farmer A had cut more than 80% of the primary forest, 39% percent of the parcel was in pasture, 10% was planted with coffee, and 28% was a mix of secondary forest and old coffee and cacao trees no longer in production. According to the settler, they planned to change this area that was currently out of production (28%) into pasture and almost double their milking herd.

These case examples demonstrate that culture and other factors play a crucial role in mediating settlers' relation to the environment and explain these distinct outcomes regarding primary forest conversion and agrosilvopastoral systems in place. Although a migrant from the northeast of Brazil, farmer B (significant area in primary forest) had lived in Brazilian Amazonia for more than forty years and was well acquainted with challenges of hostiles environments. He had worked most of his life cropping the land but also interacted extensively with rubber tappers. He claimed to have learned about the "mysteries of the forest" from rubber tappers and considered himself quite knowledgeable about uses of many native plants. He talked about the forest in a very personal and intimate way, suggesting almost a "symbiotic" interaction with the local environment. His house resembled more a cabin built by locals rather than a typical house of a settler, and his home garden included herbs and medicinal plants, several of them native to the region. When questioned about why he did not expand his agricultural area, he was very straightforward: "…without the interest of my son and daughters in this parcel, there is no reason to expand; but to make a living, we wouldn't need more than subsistence crops, some coffee, and extract some products from the forest… let the forest recover…."



Cases	Hhold Size	Parcel (ha)	Land Cover (%)					
			Forest	Sec For.	Pasture	Crops	Other	Total
A	5 (2)	58.1	17.1	28.4	38.8	9.6	6.2	100.0
B	4 (1)	46.1	54.5	33.2	1.4	5.7	5.3	100.0

Figure 6.2 Contrasting Land-Cover, Neighboring Parcels, Study Site 1999

Farmer A and his spouse are *gaúchos*, natives from the south of Brazil and came to the Amazonia just a few years before getting their parcel in Machadinho. They were raised in an area known for its natural open fields and extensive beef herds. They were very proud of their cultural traditions. Some of these traditions such as the *chimarrão* – hot herb tea shared among friends and drunk from the same gourd and silver tube – were still part of the daily family routine. *Gaúchos* are also known to be entrepreneurial and good managers, a reputation that this settler had among the small-scale farmers along the feeder road where he lived and in the community at large. When asked about the expansion of pasture he paused for a second and then provided a detailed explanation about his rationale and how it had evolved over time. In the end, he concluded by saying that "now having only the two of us in the parcel there is no way but moving into pasture in order to have it clean, organized, and well taken care of as I like to see my farm."

In summary, the two cases show that farmers with similar household size led to quite different outcomes. Also, it highlights that several factors – some quantifiable and others only qualitatively assessed – mediate and shape the ways in which human populations interact with the environment. The cases reported above focused essentially on the individual characteristics and responses. However, they are part of a broader context, which includes collective action and community behavior as well. The link between entrepreneurship and the "rancher" suggests a view of local development project more identified with traditional agricultural expansion rather than environmental management. This perception and social construction of a "successful farmer" is informed by policies and incentives operating in the region and the outcomes could be different if mechanisms such as a credit for carbon sequestration or more robust incentives promoting agroforestry systems were in place.

CONCLUSION

In this paper, I examined the importance of the "population factor" as a cause of deforestation in Machadinho D'Oeste, Brazilian Amazonia. Drawing from data sources such as land-cover maps generated from satellite imagery, socioeconomic household survey, and in-depth interviews and different methodological approaches, I showed that in the case of Machadinho D'Oeste, the population-environment equation is more complex than the pressure of human population size on natural resources. Qualifying population size from the point of view of available labor force opens the possibility for more creative ways of linking what individuals do with environmental stress or environmental conservation.

The mixed-method approach and, particularly, fuzzy set statistics (Grade of Membership, GoM) provided an analysis structure to integrate data from the several sources. The pool of available survey variables imposed some challenges for the analysis. Nevertheless some limitations, the research findings better identify, quantify, and qualify the relationships between land-cover change, population dynamics, and socioeconomic characteristics of the local population. The research findings reinforce the complex and synergetic dynamics operating at different levels – micro, meso, and macro – in various areas in the tropics as shown by review studies (Geist and Lambin 2001; 2002; Kaimowitz and Angelsen 1998). Moving one step further with the analysis presented in this paper would require collecting more refined data.

Studies on LUCC as the one presented in this paper offer venues to promote better understanding on society/population-environment interactions. If population pressure cannot be taken for granted the opposite is also true. We ought to examine in each case how historically grounded local social relations and specific conditions of natural resource systems jointly shape the ways in which society interacts with the environment. A full account of society/population-environment relationships, including quite varied linkages and quite complex underlying dynamics has to place the demographic dynamics *per se* of a given human population in the specific biophysical and historical context. This approach allows uncovering the population-environment interconnections in terms of their *conjoint constitution* and the *mediating factors* (Freudenburg et al 1995; Marquette and Bilsborrow 1994; 1997).

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